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Field Trials of an Improved Oil Palm Harvesting Tool

STANNERS G.*
Interface Services Pte. Ltd., No. 12, Sussex Garden, Singapore 2879.

AND
THOMAS GEORGE
Kulai Besar Estate, 81000 Kulai, Johor, Malaysia.

Tools are the limiting factor in productivity of oil palm harvesting. A dedicated designed Extendable and Telescopic tool, referred to as EX-T-EL, has successfully incorporated composite hybrid pultrusions, preprietary spacers, collars, couplings and bands into a complete tool which now is lighter, easier, stiffer, more convenient, and safer than conventional tools. Productivity more than doubled (ref page on "Cost Effective") as a result of improved efficiency and higher utilisation. Management should now re-evaluate the cost of harvest in terms of labour, accommodation, levies, TOOLS, lost fruit, lack of skills and shortage of labour, against these gains".

Harvesting of oil palm is a major cost of production and in prime focus for mechanisation. Mechanisation is the process of applying machines instead of using the efforts of human beings, and by suggestion, should substantially lower labour content. However, considering the nature of planting, *i.e.* poor access to field and fruit, and labour *i.e.* education and mobility, it is highly improbable harvesting will ever be fully mechanised.

The problem however, is not of mechanising harvesting, but of improving productivity of systems already in place.

Productivity is based on three factors:

- natural resources; *i.e.* plant and planting whose form, place and condition can be changed by the expenditure of,
- human energy, both physical and mental, with the aid of,
- tools.

Tools are the only one of the three factors which man can create without limit.

The "productivity" of a tool is the efficiency of human energy applied in connection with its use, and thus should be the focus of development.

A definition of tools as used today might be: "a steel blade secured by wire or twine to an aluminium pole approximately 32 mm to 44 mm in outside diameter (OD), with 1.5 to 2 mm wall thickness, in lengths of 5.5 to 6 m, in a variety of alloys, in smooth, ribbed or oval profiles. Reach can be extended and adjusted by either coupling or telescoping lengths together, and by dexterity on part of the harvester, secured by bamboo laths

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Editor's note:
The planting industry is in great need to improve output and worker productivity. Therefore, the introduction of an improved oil palm harvesting pole, is timely and look forward to the early availability of this tool commercially.

* G. Stanners, B. Mech. Eng. is the Managing, Director, of Interface Services Pte. Ltd.

and strips of bicycle inner tube or hose clamps". Hardly definitive or concerted, but harvesters are only being provided with poles (tubing), and not tools. Harvesters have done well with these and some ingenious adaptations evolved. However, harvesters are not engineers and have little access to information and materials, so it is no surprise there is no "standard tool" today. Each is unique to its harvester, and all have reached their limit of productivity. Improvements now can only come from a clean drawing board addressing all parameters of a harvesting tool collectively and incorporating them into a dedicated design.

A dedicated designed oil palm harvesting tool should probably address the following parameters:

i) Extendable
ii) Telescopic
iii) Light weight
iv) Lower torque moment about the base
v) Increased relative stiffness
vi) Fast and convenient adjustment of extensions and telescoping
vii) Higher reach
viii) Lightweight and detachable blade
ix) Improved durability
x) Cost effective ("productivity")
xi) Worker acceptance
xii) Safety

Aerospace industry's demand for materials with broader windows of performance than metals, opened a multitude of opportunities for composite hybrid pultrusions. Scrupulous engineering of composite structures can in addition provide combinations of properties to address multiple demands. The necessity to provide couplings and collars in a harvesting tool to overcome extensions and telescoping, allowed composites to be considered while overcoming design constraints intrinsic to composites. The opportunity to extract maximum in material properties could justify the higher material costs and the additional engineering.

A number of tools were designed, developed, and manufactured around the above parameters and offered for trial to Kulai Besar Estate, Asiatic Development Sdn. Bhd., Kulai, Johore. The tools offered were preproduction prototypes and the manufacturer worked four months "infield" to accommodate design constraints set by market acceptance, price, and technical changes before trials were conducted through July 1992.

Production tools will reflect technical improvements developed during trials.

The primary feature of the tools being EXTendable and TELescopic, they will be referred to in abbreviated form "ex-t-el".

Tools incorporating the wide range of aluminium tubings available and local adaptations for extension and telescoping will be referred to simply as "conventional".

OBJECTIVE

Ex-t-el tools having been designed around the parameters described in the "introduction", it is the objective of this report to evaluate the level to which these design parameters were achieved in contrast to conventional tools.

PROCEDURE

Four harvesters were issued with ex-t-el tools in February 1992 and by July considered adept for the purpose of a comparative trial. Twelve harvesters were left with conventional tools.

Harvesting returns for ex-t-el were recorded for each harvester by bunch count and hours worked. At month end, ex-t-el returns were deducted from accumulated figures for the four fields and divided by respective mandays to reflect average daily bunch count on the two types of tools.

Plantings from 1965, 1967, 1968 and 1971 were used, ranging in height 10 m through 17 m over largely undulating to hilly terrain.

OBSERVATIONS

Extendable

Ex-t-el. Two 5.5 m lengths of 42 mm tube (or shorter lengths) can be coupled as extensions through the use of a preprietary fixture. The coupling consists of a half meter length of 35 mm outside diameter tubing, to which are permanently fixed a centre locating ring, and centring rings at both ends. Ends of the coupling are inserted into the 42 mm tubes and the tubings drawn together at the centre locating ring. The other part of the fixture consists of a preprietary fabric reinforced rubber collar and convenient screw driver operated stainless clamping bands which secure the tubes at the joint. The joint has structural integrity with the main tubings and being of close tolerance fit, provides a solid and repeatable connection.

Conventional. Conventional tubings are extended by inserting approximately a half meter length of heavier aluminium tube into the extension piece and jamming it in place half way with paper, wood, *etc.*, or even denting the outside of the extension. By necessity, the internal tube diameter is slightly smaller than the inside diameter of the tool so as not to jam. The joint is then secured by bamboo laths approximately 300 mm long and hand tied with strips of bicycle inner tube or hose clamps. Because of the loose fit of the internal tube, the joint itself is somewhat loose. Though extensions are changed only once every two or three days, poor dexterity on part of the harvester may require they be retied to correct looseness or slipping.

Telescoping

Ex-t-el. One 5.5 m length of 35 mm outside diameter tubing is telescoped into a 5.5 m length of 42 mm outside diameter and secured by a preprietary fixture. A feature of the intertelescoping aspect is the tubes are held concentric by plastic spacer rings at their ends, thus maintaining close tolerance fit without chance of jamming. In addition, composites do not plastically deform before yield, guaranteeing telescoping will not jam because of a dent or a bend. Clamping is secured by a preprietary fabric reinforced rubber collar which is held by convenient stainless bands operated with a screw driver. Clamping is convenient, secure, and repeatable.

Conventional. Two tubings of suitable diameter are intertelescoped and clamped with bamboo laths approximately 300 mm long, hand tied with bicycle inner tube or hose clamps. No provision is made for maintaining the tubes concentric and clearance between the tubes must be sufficient to ensure they do not jam when overlapping long lengths. As aluminium will deform plastically and retain a dent or bend, jamming of the telescopic action is frequent with the additional expense that two tubes are involved. Due to clearance in the tubes, looseness at the joint is always present, and where harvester dexterity is lacking, the joint may often have to be retied.

Lighter weight

Weight of a harvesting tool is the sum of its components including the blade. Blades in this report were the same for both tools weighing an average of 700 g and attached externally using rubber bands and wire weighing approximately 200 to 300 g.

Ex-t-el. An ex-t-el tool consisting of one length of 5.5 m x 35 mm diameter intertelescoping into 5.5 m x 42 mm with 2.75 m x 42 mm extension has a length of 14 m plus blade length. Net weight including blade, binding, extension, collars and end plugs is 7.0 kg *(Figure 1a)*.

Conventional. A conventional tool consisting of 6 m x 32 mm (1.25") diameter intertelescoping with 6 m x 38 mm (1.5") diameter with an extension of 1.75 m x 38 mm has a length of 14 m plus blade length. Net weight including blade, binding, bamboo laths, rubber bands, and hose clamps is "average" 8.2 kg *(Figure 1b)*.

It should be noted that conventional tools ranged in weight from 7.5 to 9 kg, but as weight decreased, stiffness suffered and vice versa. *Around 8.2 kg, the combination of weight and stiffness*

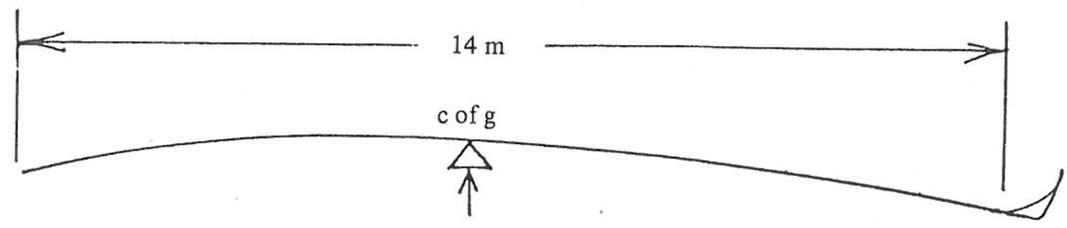


Figure 1a: An ex-t-el tool weighs 7.0 kg.

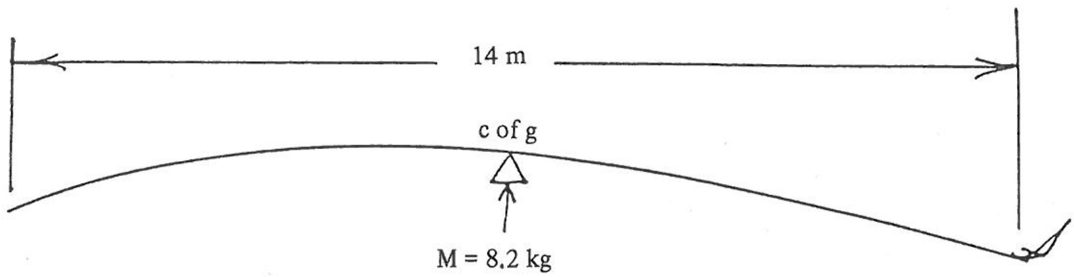


Figure 1b: A conventional tool weighs 8.2 kg.

may be said to have been universally acceptable.

Lower torque about the base

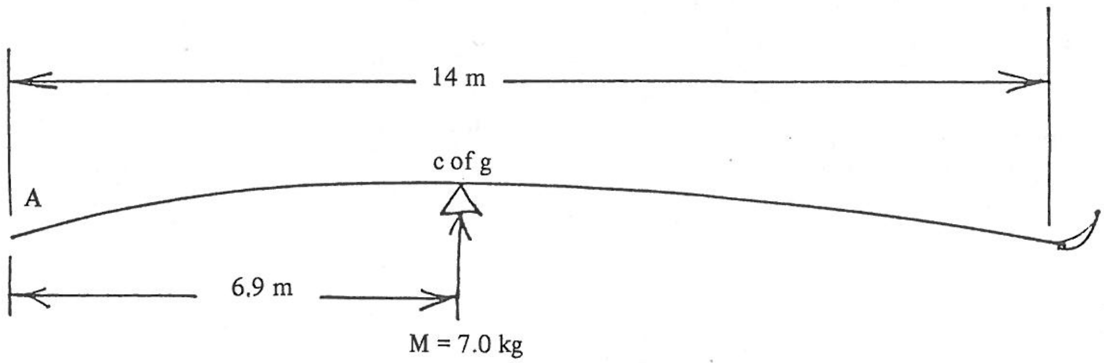
Torque about the base is the product of the mass of the tool (multiplied by a gravitational constant) and the distance the centre of gravity is from the base of the tool *(Figures 2a & b).*

Comparing torque about the base is a relative measure of the effort required to raise and manipulate a tool at the vertical.

Conventional tools require approximately (595 N-m/473 N-m) x 100% = 125%, or 25 per cent more effort than ex-t-el.

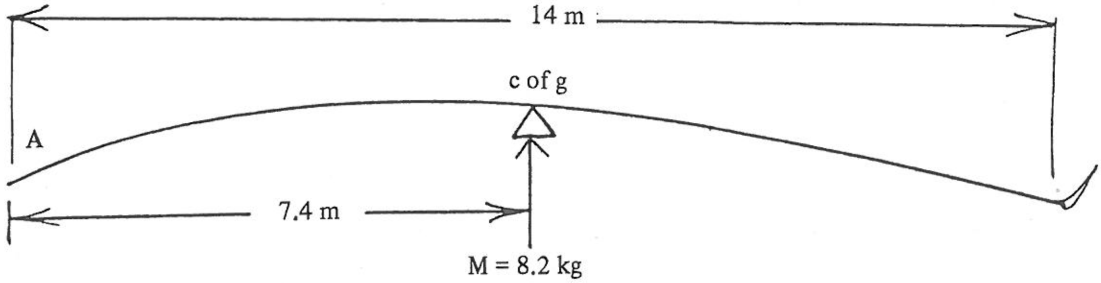
Increased relative stiffness

Relative stiffness is the measure of deflection a body produces under its own weight. In the case of harvesting tools it is of interest to know what the relative deflection is at the base when the tool is being raised and manipulated, and at the top when the blade is cutting fruit. However, as both are interdepen-



Torque about A = 7 kg x 9.8 newtons/kg x 6.9 meters
= 473 newton-meters

Figure 2a: An ex-t-el requires less effort to be raised and manipulated.



Torque about A = 8.2 kg x 9.8 newtons/kg x 7.4 meters
= 595 newton-meters

Figure 2b: Conventional tool requires more effort to be raised and manipulated.

dant, it will suffice to examine their combined deflection at the middle. This can be measured by locating the centre of gravity, raising the tool to the point both ends are just free of the ground, and measuring the displacement *(Figures 3a & b).*

Conventional. It should be readily observed that ex-t-el is approximately twice as stiff as a conventional tool under the influence of its own weight. Conversely if a conventional tool is assembled to be the same weight as ex-t-el, stiffness is lost to such a degree the tool is useless. When displacement (or stiffness) is made the same as ex-t-el, total weight becomes unmanageable. This is a visual example of the superior properties of composite hybrids in strength to weight ratio.

Fast and convenient adjustment of extensions and telescoping

Ex-t-el. Removal of extensions is a matter of using a screw driver to slacken stainless bands securing the joint, and removing the rubber collar and inner coupling. The open end of the tool should then be covered by a rubber plug to prevent the ingress of dirt. Addition of extensions is the reverse. Time is a matter of a minute for either operation and is required on average once in two or three days depending on the field, lengths required, and lengths available.

Adjustment of telescoping requires a screw driver to slacken a convenient stainless band, adjust the length, and retighten the band. Less than a minute is required, and adjustments were made

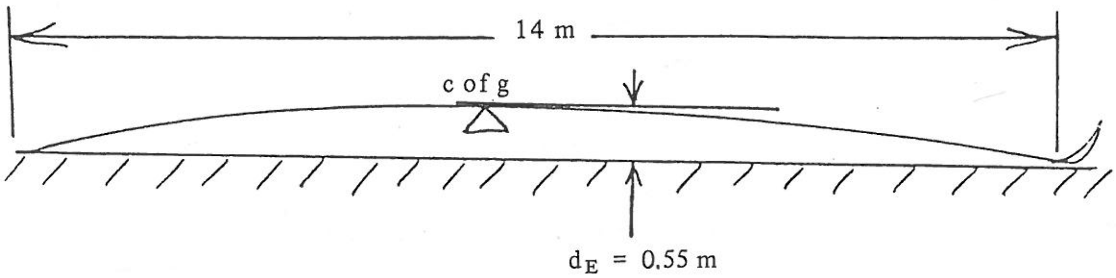


Figure 3a: An ex-t-el is stiffer than a conventional tool.

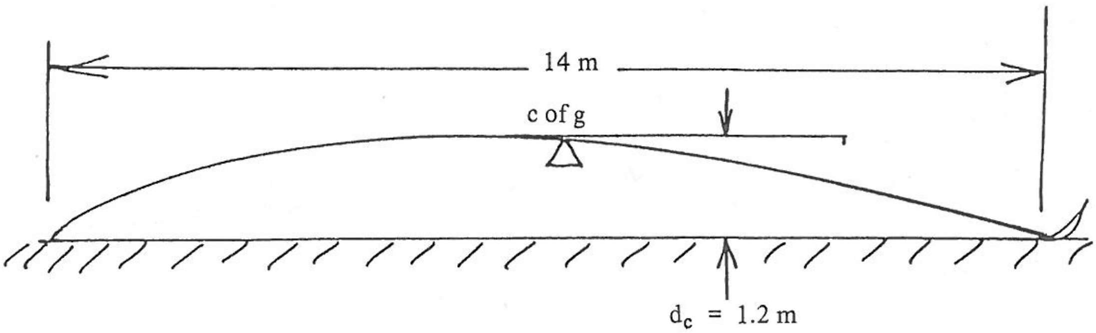


Figure 3b: A conventional tool is less stiff.

approximately ten times per day during trials.

Conventional. Addition or removal of extensions is a matter of tying or untying bicycle inner tube strips, or hose clamps, holding the bamboo slats, and adding or removing the extension. Either operation requires about 3 minutes once every two or three days.

Adjustment of telescoping is a matter of untying the bicycle inner tube strips or hose clamps, selecting the length required and retying or tightening. Time required is about 3 minutes for either operation depending on harvester dexterity and is required about fifteen times per day.

Hand tying with bicycle inner tube strips requires dexterity and may occasionally require retying if done incorrectly. Hand tying is an irritating task on top of harvesting.

Hose clamps are more convenient, but not being designed for repeated use, are not long lasting, and do not secure tightly enough without over-stressing the clamp.

It should be noted here that approximately 50 per cent more adjustments were required on conventional tools. Ex-t-el having greater relative stiffness and lower torque about the base could be lowered further than conventional tools to reach low fruit, and thus did not require as many adjustments, leaving more time and energy for harvesting.

Higher reach

Reach is the height at which a worker can harvest productively. In theory the tools can reach higher, but the limit is with harvester skill relevant to specific tools. Therefore total length is of secondary importance.

Ex-t-el. The designed reach of ex-t-el is 16 m plus ½ m for the blade and 1 m for the harvester, giving a total of 17.5 m. At this reach, the tool is composed of one 5.5 m length of 35 mm OD telescoping into a 5.5 m length of 42 mm OD, with a 5.5 m length of 42 mm OD extension, and is manageable and productive with average skills.

Conventional. There have been harvesters able to reach 17.5 m but it is generally accepted only few are able: productivity is low, and tool breakage is high.

Light weight and detachable blade

A lightweight blade will increase relative stiffness of the overall tool and reduce torque about the base. It should be detachable for worker convenience and safety.

Conventional blades available on the market are generally hand forged from high carbon steel and quench tempered. Each is unique to the blacksmith who forged it making it impossible to provide a universal mounting. Blade weights range from 650 to 1 000 g and additional materials to attach the blade can add another 150 to 350 g.

Three methods of custom fitting exist. The most popular is external mounting against the side of the pole on a rubber padding, or such like, and binding tightly with twine. This method requires about 15 minutes but must be retied every three days or so, due to damage by frond thorns, and is also heavy.

Another method consists of providing a rubber padding or such like surface on the outside of the pole on which to rest the blade tang, then intricately binding the tang and pole with bailing wire. This is a lighter version and longer lasting, and also requires approximately 15 minutes to complete properly.

A third method involves inserting the blade tang into the open end of the aluminium tube and jamming it with tapered wood wedges, then folding over the tube lip to retain the wood. This method when properly done is the most satisfactory in that it is by far the lightest and offers best access to the fruit stock. Drawbacks are it requires the better part of a morning to complete, and if the blade breaks or slips, about 300 mm of tubing must be scrapped.

All three methods were in use on conventional tools but only side mounting was possible on the ex-t-el prototypes provided.

Improved durability

Durability may be defined as resistance to damage caused by the input of forces confronted in the role as a harvesting tool.

Ex-t-el. Composites do not deform plastically before yielding, and therefore will not retain a bend or a dent, making the telescopic action of the ex-t-el virtually' indestructible.

Collars and couplings were not damaged during trials and appear to be trouble free.

Composites are vulnerable to "point" impingement loads" and exhibit failure in the form of longitudinal splitting.

More failures were exhibited in the 35 mm tubing than the 42 mm which is not surprising in that it is at the higher end in a drop, and received more strikes from fronds and bunches than the lower 42 mm tubing.

The manufacturer will be offering a repair scheme for both sizes in production tools.

Conventional. Aluminium will deform plastically before yielding and so will retain dents and bends. The higher the hardness and alloying, the lesser extent to which this is true, but conversely the less frequently the tubing can be restraightened before breaking! The problems are intrinsic to aluminium, and jamming of telescopic action is common and costly as, it always involves two tubes and much of the harvester's time to attempt a salvage.

On a comparison basis, the telescopic action of ex-t-el is infinitely more durable than conventional tools.

On overall durability, ex-t-el is only marginally better than conventional tools. It appears the inputs which cause failure are mostly frond strikes, bunch strikes, and free drops to the ground with a misfortunate contact with a rock. Such inputs are substantially higher than the design strengths and no tool will survive. Where ex-t-el appears to excel is where the inputs of such strikes are minor, the tubing does not sustain damage in the form of denting or bending and can continue harvesting without interruption. Aluminium on the other hand must be straightened and harvesting time is lost.

Cost effective (Productivity)

Cost effectiveness is measured in terms of bunches harvested per manday as a ratio of cost of manpower and tools. No difference in manhours per manday was noticed in trials between ex-t-el and conventional tools.

- It is a complete tool without further input from the harvester.
- It is convenient and fast to extend or adjust, making work easier and more productive.
- It having close tolerance fittings is more solid and responsive over the full length, providing more accurate and productive harvesting.
- It being lighter, stiffer, and having a lower torque moment about the base, is less tiring, more accurate and responsive, contributing to higher productivity for the same effort.

Year of planting	*Height (m)*	*Bunches/day conventional*	*Bunches/day ex-t-el*	*Productivity % age incr.*
1965	15.5–17	35.12	76.0	116
1967	12–14	46.88	115.3	146
1968	14.5–15.5	55.47	101.38	82
1971	10–12	54.59	129.1	136
			Average percentage increase =	120%

Ex-t-el oil palm harvesting tools more than doubled harvesting productivity. With labour input equal for both tools, estates can now calculate the dollar value of these gains as a ratio of tool cost. Some may also include financial gains from harvesting previously unreachable fruit, reducing labour shortage, and making up for lack of skilled workers.

Worker acceptance

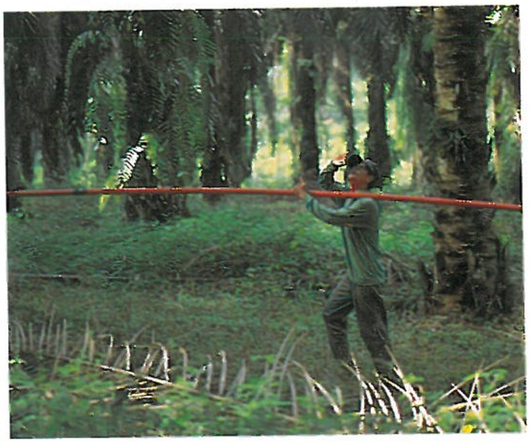
Worker attitude is the single largest factor in acceptance of new tools, followed by management's method of approaching the problem. Tools which have desirable features are just that much more acceptable. Features of ex-t-el which are improvements over conventional are:

- The texture of the pultrusion is less tiring to the hands than aluminium and does not heat up over the day.
- The durability of composite materials eliminates continual inspection for minor damage and potential failure. There is no more straightening of bent tubing or jamming of the telescoping action to absorb valuable harvesting time.
- It improves workers' earnings.

Safety

Harvesting oil palm is a dangerous job and injuries are common. Minor injuries come from the harvester being struck by fronds or fruit bunches.

Safety in composite hybrids



Productivity in harvester's hands

Tall palm easily accessible

Productivity

Serious injuries come from heavy strikes by fronds, bunches, and broken tools. Visibility of the tool in the fronds is important and the ex-t-el being bright orange is highly visible over its entire length.

In transporting on the ground it is highly visible reducing chance of contact with the razor sharp blade.

Management welcomes the visibility for easy tracing and monitoring of harvesters.

Additional safety is found in breakage. Composite pultrusions do not separate explosively like highly alloyed aluminium with risk of spearing the harvester.

CONCLUSION

Ex-t-el oil palm harvesting tools more than doubled productivity over conventional tools. This was achieved by higher utilisation of ex-t-el through reduction in worker fatigue, greater accuracy in tool manipulation, and less down time for adjustment and correction to damaged tubing and fixtures.

Ex-t-el tools are readily accepted by harvesters on the basis of ergonomics, improved earnings and safety.

Given the additional ability to reach previously unharvestable fruit, and to offset the shortage of labour and suitable skills, industry should test the potential of this improved oil palm harvesting tool.