Some advances in mechanization options for Conservation Agriculture systems: reflections from the V World Congress of Conservation Agriculture, Brisbane, Australia, September 2011

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Summary

The 5th World Congress on Conservation Agriculture was held in Brisbane, Australia in September 2011. During the Congress, and especially during the field day, equipment for CA at several levels of sophistication was discussed and demonstrated. This account reflects on some of the technology on view.

No till planters for two-wheeled tractors are becoming increasingly demanded in Asian and African CA systems. The ACIAR Rogro and strip-tillage machines were on view. CA planters suitable for smaller farms include the Turbo Happy Seeder and chain-driven residue management system planters. For smaller farms yet there is the novel Yunfan jab planter from China which may be set to challenge the Brazilian domination of the market.

Narrow tine openers for no-till planters have been the norm in Australia. But times are changing with both double and single disc openers increasingly being incorporated in commercial no-till machines. Controlled traffic farming (CTF) is a natural partner for CA as it eliminates wheeling compaction in the cropped area. Aspects of precision farming are also relevant to CA systems as they can ensure more precise application of inputs and amelioration of problem areas. Crop mapping with tractor-mounted red and near infrared light reflectance, motorcycle-mounted soil parameter sensors and helicopter-mounted cameras are all playing a part in improving the efficacy and efficiency of CA.

Introduction

To be clear at the outset and to ensure that we all know what we are discussing, I will give a reminder of what CA is all about. Plough-and hoe-based agriculture often results in soil degradation through wind and water erosion, structural collapse, the production of impermeable layers (plough pans) and organic matter depletion. Conservation agriculture (CA) has been proposed to reverse this degradation in an effort to move towards sustainable cropping systems. CA is a crop production system based on minimum soil disturbance, surface crop residue retention and species diversification through crop rotations and associations[1]. To this list it may now be time to add a fourth principle, that of controlled traffic farming (CTF) which eliminates compaction from the cropped area.

To achieve the implementation of CA, specialist equipment is being produced, whereas it is true that a pointed stick is all that has been needed by ancient cultures to sow seeds in CA systems, today there is a range of options for planting through soil surface residues and these include machines designed for manual, draught animal, two-wheel and four-wheel tractor power sources. This paper reflects on aspects of these options that were raised during the Congress. My own contribution (in collaboration with several co-authors) discussed the establishment of the CA equipment manufacturing capability in sub-Saharan Africa[2].

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[1] www.fao.org/ag/ca

[2] the paper is available at: www.engineering4development.co.uk/publications

Two-wheel tractor options

The increasing focus on two-wheeled tractors (2WTs) as a power source for CA operations is evidence that there is a growing demand to apply CA on small and medium sized farms, especially in Asia and, increasingly, in sub-Saharan Africa. The following are some of the options on display or discussed during the Congress.

ACIAR-Rogro tined seed drill

Jeff Esdaile (Esdaile, 2011) has developed a tined no-till seeder for attachment to 2WTs in collaboration with the Australian Centre for International Agricultural Research (ACIAR). The machine is a three-row tined planter with adjustable row spacing (Figures 1 and 2). Its metering units, for both seed and fertilizer, are of roller design – either fluted or with seed cells – and are manufactured in China (Figures 3 and 4). Seed and fertilizer are delivered down the same tube and this has raised comments about the possibility of seedling damage and poor fertilizer placement.

Jeff is working on alternative soil engaging components, in addition to the standard chisel tine that has been fitted to date (Figure 5). These include double offset and single disc openers adjustable for offset and tilt (Figure 6).

Fig. 1. ACIAR-Rogro tined seed drill

Fig. 2. ACIAR-Rogro seeding in wheat residue

Fig. 3. Seed (cells) and fertilizer (fluted) metering

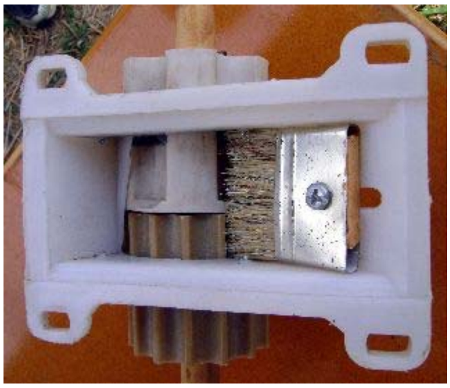


Fig. 4. Fluted metering roller


Fig. 5. Chisel tine


Fig. 6. Range of disc openers


Fig. 7. Rear foot stand for better penetration

To add weight to the rear of the seeder, a foot stand has been added to the press wheel shaft so that the operator can stand on the seeder and improve tine penetration and seed covering (Figure 7).

The Turbo Happy Seeder

John Blackwell was on hand to demonstrate the Turbo Happy Seeder – THS (Sidhu *et al*., 2011). This machine (also developed with assistance from ACIAR) has undergone an evolutionary design process since the first model was produced in 2002 which blew the residue over the seeder in the style of a forage harvester. The machine has been designed specifically to deal with heavy rice residue (up to 10 ton/ha) and to direct seed wheat into this immediately after the rice harvest. Burning the straw is the other option and this produces both atmospheric pollution and loss of soil organic matter. The Turbo Happy Seeder has a set of straw management flails (Figure 8) immediately in front of the chisel tine openers (Figure 9). These clear the straw (Figure 10) and allow direct seeding to take place before the residue falls back to cover the soil. Even straw distribution is essential and for this and combines need to be fitted with straw spreaders.


Fig. 8. Rotary flails


Fig. 9. Furrow opener


Fig. 10. THS in work

There are four commercial manufacturers of the machine and about 250 seeders are in use on-farm in the Punjab of India. A useful development from a CA perspective is that short duration mung bean (*Phaseolus aureus*) can be sown into the wheat stubble before the following rice season.

Strip tillage

Strip tillage with 2WTs is accomplished by modifying the rotary cultivator which is usually supplied as standard kit with 2WTs (Esdaile, 2011). Blades are placed in front of the seed and fertilizer delivery tines according to the row-width required (Figures 11 and 12). Haque *et al*. (2011) describe the modifications required to use 2WTs for zero tillage, shallow full-width tillage, strip tillage and bed planting. The machine, known as the Versatile Multi-crop Planter (VMP) can meter seed and fertilizer through four delivery systems and is attached to the 2WT by side arms and connecting rods to the main handles (Figure 13).

Fig. 11. VMP rotary blade shaft

Fig. 12 VMP rotary blades

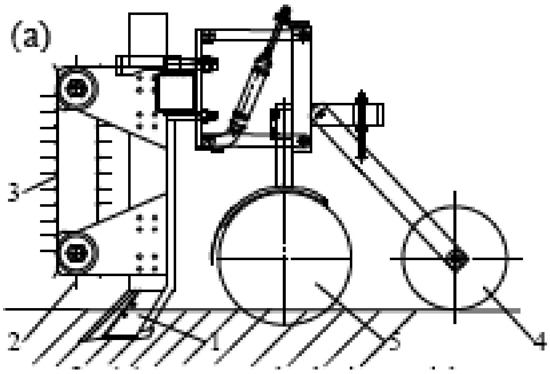
Fig 13. VMP seed and fertilizer delivery

The result of the strip tillage system is that the soil is only cultivated along the sowing lines. And while this cannot be described as minimum soil disturbance, it does mean that the inter-row space is left untilled (Figure 14).

Fig 14. Lentils established with the VMP in strip-tillage mode. Source: M.E. Haque, VMP publicity leaflet

Residue management with 2WTs

Adoption of CA in some situations in China is still hampered by residue management problems. Li *et al*. (2011) report that no-till wheat after maize is complicated by heavy stover cover and have suggested that the use of a strip-till seeder is too power-intensive and damaging to the soil. Instead they propose a chain-driven residue management arrangement. This comprises a shaft with rigid tines which is rotated by a chain drive in front of the tine opener and double disc seed and fertilizer delivery assembly (Figures 15 and 16).



Figs 15 and 16. The chain-powered residue manager which clears residue in front of the double disc opener of the no-till seeder. Source: Li *et al.*, 2011. (1: tine opener; 2: Rigid fingers; 3: Chain; 4: press wheel; 5: Double disc opener)

Tine and disc openers

According to Jack Desbiolles (Desbiolles, 2011) one of the 'pillars' of Australian no-till farming has been the use of the narrow tine opener and press wheel system. And although this was borne out during the field demonstrations, there is also a move towards disc openers to reduce soil disturbance during the seeding process. In a survey of 200 no-till farmers in Australia, the stated pros and cons of disc openers noted in Table 1 were reported.

Table 1. Pros and cons of discs compared with tines for opening the soil in no-till seeders

Reasons for favouring disc openers	
1	Ability to plant through (soil-improving) heavy residue
2	Reduced soil disturbance
3	High speed capability
4	Ability to handle stones and create minimal soil surface roughness
5	Ability to plant through viny weed residue
6	Narrower crop row spacings are possible
7	Improved seeding depth uniformity and accuracy
8	Lower draught requirement
9	More even crop establishment in marginal moisture conditions
10	Lower weed germination
11	Reduced seed inputs
Limitations of disc openers	
1	Poor handling of sticky soils
2	Inadequate incorporation of soil applied herbicides
3	Poor penetration
4	High maintenance costs (especially bearings)
5	Residue pinning
6	High wear in stony soils
7	Poor furrow closure in wet clays
8	Poor disc drive in soft soils
9	Furrow smearing and compaction in wet clay
10	High draught in compacted soils

Many of the negative aspects can be avoided by planting when soil conditions are more nearly optimal, so that wet clays are left to dry out before planting. Keeping discs sharp (to cut residues and eliminate hair-pinning) is a logical requirement. And, perhaps most importantly, avoiding compaction by controlled traffic farming is clearly indicated as a future necessity.

The move towards disc openers will continue apace in Australian agriculture and interesting indications of a move in that direction were on display. The Stubble Star double notched disc opener was being demonstrated and is about to be manufactured commercially (Figure 17). The discs are angled at 7° to each other and have an undercut angle of 3.5° to improve soil conditions in the base of the furrow.

Fig. 17. Stubble Star double disc opener

Another approach is an adjustable single-disc opener like the Daybreak[3] arrangement shown in Figure 18.

Fig. 18. 'Daybreak' single disc opener technology

A novel manual seeder for no-till planting

Made by the Yunfan Company in China[4], a new 'jab' planter is now available for smallholder farmers. The machine is operated in the manner of a light hoe and the impact of the beak hitting the soil moves a pendulum which actuates the delivery mechanisms for seed and fertilizer (Figures 19 and 20). The seed hopper is the hollow handle of the planter, and fertilizer is carried in the operator's back pack. Seed cells are interchangeable according to the crop being sown and the fertilizer rate is metered by an adjustable slide.

Fig 19. Yunfan jab planter. General view showing the handle / seed hopper, fertilizer bag and delivery tube

[3] www.daybreak.com.au
[4] www.qybzg.com

Fig. 20. Yunfan jab planter seed and fertilizer beaks and actuating pendulum

Controlled traffic farming

CTF confines farm traffic wheels to permanent tracks (Figure 21) and requires the use of implements fully matched to the wheel-track spacings (Yule and Chapman, 2011). The result is dramatically reduced soil compaction with concomitant improvements in physical properties and soil fauna (especially earthworm numbers and size). There is also evidence that GHG emissions (especially nitrous oxide) are reduced from permanent beds was compared to random wheelings (Tullberg *et al*., 2011).

Fig. 21.the permanent wheel tracks required for CTF create better cropping conditions in the permanent beds. Machinery widths have to match the (usually 3 m) bed widths and it is best to start with the combine header as this is the biggest, heaviest and most expensive machine. Source: Don Yule

Crops grow better as their root systems encounter fewer impediments and are healthier with fewer diseases reported. Consequently yields can improve by up to 20% compared with conventional systems. CTF neatly complements CA as direct planters can work easily in the un-compacted inter-track cropped land.

CTF benefits from accurate guidance systems so that vehicles can return to precisely the same wheel track positions. The application of Real Time Kinetic (RTK[5]) geographic positioning systems (GPS) has allowed precision control of traffic position to within 20 mm. Figure 22 gives an impression of how Global Navigation Satellite Systems can be used in a CTF application.

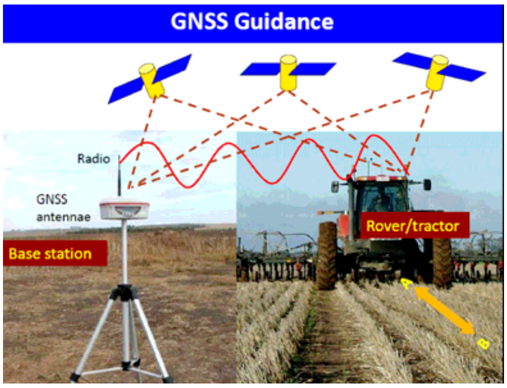


Fig. 22. Global Navigation Satellite GPS is used for precise vehicle location in CTF. Source: Don Yule

[5] http://en.wikipedia.org/wiki/Real_Time_Kinematic

CTF combined with geo-referenced satellite imagery analysis can pin point problems such as poor drainage, inadequate fertilization of weed infestation problems. These can then be addressed precisely resulting in better targeting of inputs and more even production over the whole growing area.

Draught animal powered CTF

During discussion of CTF it was observed that the concept is not confined to engine-powered mechanized farming systems. In the 1980s the International Centre for Research in the Semi-Arid Tropics (ICRISAT) developed the idea of a draught animal powered broad bed maker for the construction of permanent raised beds. Following the initial rather violent soil movement, subsequent cropping can be with no-till as part of a CA system (Figure 23).

Fig. 23. Constructing permanent raised beds in Mexico using draught animal power. Jean Nolle *Tropiculteur*, and a broad-bed maker.

Precision farming

The benefits of CA seem to clear enough to Australian farmers, but further advantages can be achieved by the application of precision farming options. Here are some that were on display at the VWCCA.

Weed control

Summer fallow weed control is a critical feature of CA. But blanket coverage of summer fallow with herbicides is expensive and wasteful. Not to mention environmentally irresponsible. Instead selective spot spraying is possible with the use of tools such as the WeedSeeker[6]. This is, of course, beneficial both to the environment and to the enterprise financial bottom line through lower agri-chemical input costs.

Fig. 24. 'WeedSeeker' emitter / receptor mounted forward of the spray nozzle

The WeedSeeker technology employs sensors and spray nozzles at a 380 mm spacing (Figure 24). The sensors work on the principle of reflecting red and near infrared light (from a light-emitting diode – LED) off a weed 600 mm beneath. When a green plant is identified (through an on-board analysis of the reflected light) the spray nozzle is activated above the offending weed.

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[6] www.cropoptics.com.au

WeedSeeker technology is attractive because of the reduced applications of herbicides, but it also allows applications of specific, and usually more expensive, herbicides to problem weeds showing signs of resistance to conventional herbicides such as glyphosate.

Crop mapping

Several technologies were on display which can be used for field mapping of growing crops. This allows geo-referenced applications of fertilizers, pest or weed control chemicals exclusively on particular, mapped, problem areas. Savings in input costs are attractive and crop yields are more uniform.

GreenSeeker[4] optical sensor technology is especially useful for assessing crop N requirements, and for applying the right amount where it is needed. Normalized Difference Vegetation Index (NDVI) readings are taken over the cropped area to be assessed. This is done by LED emissions of red and near infrared light as in the case of the WeedSeeker.

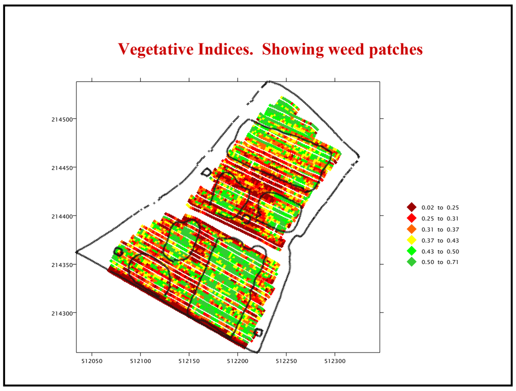

Fig. 25. Vegetative Index (NDVI) mapping. In this case to detect patches of weed infestation in a mature cereal crop. Source: Silsoe Research Institute, UK

Optical sensing of the crop condition is done by electronic NDVI interpretation. In real time this can lead to the delivery of the required liquid N or crop-care chemical dose. It can also be used to produce maps of the cropped area (Figure 25).

Other crop and field mapping options were demonstrated. One possibility is to mount sensor booms on a motorcycle and then to record the geo-referenced electrical conductivity of the soil (Figure 26). This allows assessments of moisture content, texture and pH. A rather more dramatic option is the use of radio-controlled aircraft (fixed wing and helicopters) with on-board cameras and geo-positioning (Figure 27). Maps produced by these methods can be ground-truthed and used for a wide range of crop care management applications.

◄Fig.26. Electrical conductivity and GPS mounted on a motor cycle

►Fig. 27. Helicopter with on-board camera for field mapping and problem identification

Conclusion

Mechanization is a major input to CA and good workable equipment must be on the market for wider adoption (than the current 120 million ha). Especially important is sub-Saharan Africa where increases in food production are urgently required given the unsustainable increases in population coupled with flat-line growth in cereal production. For small and medium scale farmers there are advances in manual, draught animal powered and tractor powered options (especially with 2WTs). However the eclectic mix of CA technologies discussed and displayed at the Congress gives a good idea of the direction in which we should be heading if we are to achieve the sustainable production intensification that is needed at the moment and which will become essential in the near future.

References

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