Exploring the potential of UHP jet-stream technology

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SANTFA is continuing to explore the potential of Ultra-High-Pressure (UHP) water-jet cutters for agricultural applications.

In the past 12 months we have undertaken a preliminary examination of how the Aqua-Till application might perform as a liquid coulter in stubble retention systems, used the technology in trials exploring nutrient and fungicide injection into the soil and have begun investigating how it might be used as an inter-row weed slasher.

Liquid coulter

Preliminary fieldwork with the Aqua-Till concept has shown that the technology may work well as a 'liquid coulter', especially in soft soils with wet, ropey stubbles. This is potentially significant because it is in scenarios like this that the performance of current no-till and zero-till seeding equipment is still limited and timely seeding can be delayed. And in many situations removing stubble to improve seeder performance heightens the risk of erosion.

The Aqua-Till work has so far been demonstrated using a contraption comprising basically a UHP nozzle and PTO-driven UHP pump on a tractor-mounted tool bar.

This apparatus has enabled us to prove the concept, but without any meaningful ground engagement mechanism such as a parallelogram, it does not represent a prototype. We are designing a working prototype that will enable control of the ideal ground engagement mechanism, the rake-angle of the water jet and various other configuration options.

FIGURE 1: AN AQUA-TILL CONCEPT DESIGN USING A NOZZLE EMBEDDED AT A 150 FORWARD RAKE ANGLE IN A SKI WITH A KEEL-STYLED SEED DELIVERY MECHANISM. THIS CONCEPT MAY HAVE PROMISE FOR SEEDING INTO WET, SOFT SOILS WITH HEAVY STUBBLE COVER.

FIGURE 2: ON THIS AQUA-TILL PASS THE CUT WAS SO CLEAN THAT, AT FIRST GLANCE, IT SEEMED THE JET HAD DONE NOTHING. HOWEVER, CLOSER INSPECTION BY EYRE PENINSULA FARMERS MARK MODRA AND JORDY WILKSCH REVEALED THAT THE STUBBLE AND SOIL BELOW HAD BEEN CUT CLEANLY BY THE JET STREAM FROM THE AQUA-TILL NOZZLE. THERE WAS NO EVIDENCE OF HAIR-PINNING, EVEN THOUGH THERE WAS A THICK COVERING OF PLIABLE AND MOIST STUBBLE, AND THE SOIL WAS RELATIVELY SOFT.

Ground engagement is a key feature in the performance of Aqua-Till, with the distance between the nozzle and the stubble very important, since performance deteriorates significantly when the nozzle bounces away from the ground.

Our partners at Flowcorp, who understand the performance of UHP water-jet cutting through a variety of materials, have indicated that this technology performs much better when cutting through a relatively consistent material than when layers of material are separated by layers of air. This means cutting loose stubble comprising multiple pieces of straw with gaps between them will be much less effective than pressing the stubble into a single layer, which might be achieved by using a ski (Figure 1).

Good design has the potential to make Aqua-Till a practical option in at least some field situations, but there is also significant inherent room for gains from improvements in UHP technology.

FIGURE 3: SIDE-BANDING UAN INTO A CORN CROP USING THE AQUA-TILL INJECTOR PRODUCED A MEASURABLE REDUCTION IN NITROUS OXIDE EMISSIONS COMPARED TO LOSSES FROM SURFACE APPLICATION (WOLLONGBAR, NSW, DECEMBER 2012)

The UHP pump and nozzle system SANTFA is testing are fairly basic UHP technology and are likely to be superseded as time goes by. UHP water-jet cutters are one of the fastest-growing suites of industrial tools in the world and the UHP industry is developing new technology at a rapid rate. Just as spray performance has improved dramatically due to developments in spray nozzle design; so we can expect to see ongoing improvements in UHP nozzle performance as new venturi and induction-style cutting heads deliver efficiency gains and improved cutting capability.

For example, water by itself is not enough to cut hard materials like stone or steel, so when UHP technology is used to cut hard materials a venturi nozzle is used to draw an abrasive into the water-stream. Using a venturi to pull specialised fertiliser granules into an Aqua-Till stream could be an opportunity to significantly increase the ability of the Aqua-Till to cut through surface stubble and into the underlying soil while simultaneously applying nutrients without increasing power or water demands.

Approximately 650 growers and industry people have seen the Aqua-Till contraption and the results it is producing over the past 12 months, and there is an understandably wide spread of opinions about the potential and practicality of this radical concept.

This spread of opinion includes strong positive views, with more than one grower making seemingly genuine offers to buy a full liquid coulter system to deploy in front of their knife-point seeders in situations where they want full stubble retention to blanket weeds and protect against erosion.

However, commercial deployment is still some time off. We have only just achieved 'proof of concept' and more development is required. Ideally we need to develop prototype Aqua-Till designs for knife point and disc seeding systems, an exercise that is likely to involve development and refinement of concepts such as the stubble ski and keel concept.

In due course, Aqua-Till needs a manufacturing partner to come on board to develop the prototypes into a range of products farmers can access and have supported with parts and warranties.

Aqua-Banding

UHP technology is also being used in research comparing nitrogen losses from UAN applied as a surface spray and injected into the soil.

In this two-year trial, currently in its second season, an Aqua-Band application of the jet-stream technology is being used to inject UAN beside the seed row in winter wheat in SA and summer corn in northern NSW (Figure 3).

With the dry finish in SA last year the researcher found no meaningful difference in nitrogen-use efficiency between surface-applied and Aqua-Banded UAN injection. However, preliminary data from the NSW trial site, which was drenched with rain during the growing season, suggests UAN injected into the soil lost measurably less nitrogen as nitrous oxide than UAN applied as a surface spray (Figure 4).

Nitrous oxide is a powerful greenhouse gas and a major source of nitrogen loss from agricultural soils.

The results from this nitrogen side-row injection trial will be published only after the second year's results have been fully analysed. However, the sugar industry is already seeking funds to test the Aqua-Banding technology in northern cane fields; an action based on the first year's results from the NSW corn trial and the observations of local researchers involved in that work.

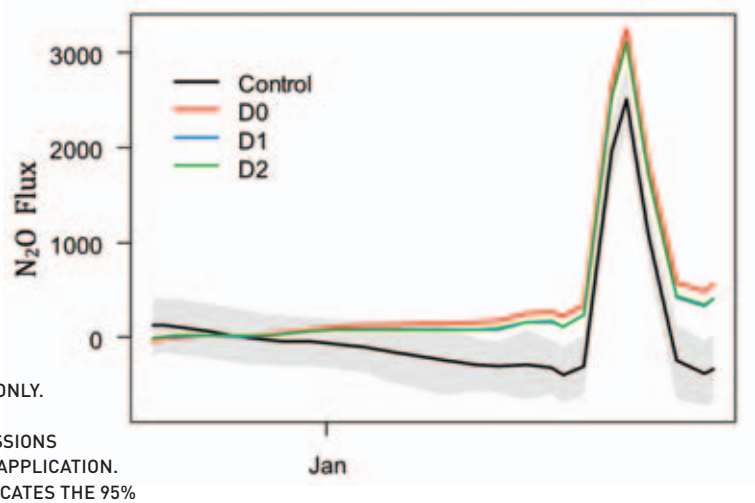


FIGURE 4:
PRELIMINARY DATA ONLY.
TREND ANALYSIS OF
NITROUS OXIDE EMISSIONS
CONTROL = NO UAN APPLICATION.
THE GREY AREA INDICATES THE 95%
CONFIDENCE LIMITS FOR THE CONTROL.
D0 = SURFACE-APPLIED UAN
D1 = UAN INJECTION AT 25,000 PSI
D2 = UAN INJECTION AT 50,000 PSI

At Karoonda, in a separate trial supported by SAGIT, SANTFA compared the efficacy of a fungicide injected into the soil to control rhizoctonia with the same chemical applied as a seed dressing. Injection of the fungicide produced no yield benefit and marginally reduced efficacy of the chemical on the disease, although the result was not biometrically significant (Figure 5).

The robustness of the UHP delivery system has been pleasantly surprising, with the pump, pump seals and nozzles working well in field conditions and the apparatus handling a variety of fluids including water, UAN and fungicides with few problems.

There is potential to use the core UHP technology in multiple roles across the growing season, and in addition to the Aqua-Till application and Aqua-Band nitrogen injection, SANTFA is keen to address the potential of the technology in an Aqua-Slash application for inter-row weed control.

FIGURE 5: INJECTING FUNGICIDE IN FRONT OF DISC-SEEDED WHEAT AT KAROONDA DID NOT IMPROVE RHIZOCTONIA CONTROL COMPARED TO FUNGICIDE APPLIED AS A SEED DRESSING. HOWEVER, THE AQUA-BAND DELIVERY MECHANISM CAN BE SIGNIFICANTLY IMPROVED THROUGH USE OF A GROUND ENGAGEMENT TOOL SUCH AS A PARALLELOGRAM, BENEFITS MAY BE GAINED FROM THIS TYPE OF APPLICATION METHOD IN THE FUTURE.

Aqua-Slash weed control

The number of herbicide-resistant weed populations is exploding exponentially and alternatives to chemical control need to be found and incorporated into integrated weed management strategies.

Last year, using the UHP contraption developed for the Aqua-Till trials, a preliminary assessment was made of the effect UHP water-jets could have on weedy biomass. This work showed the nozzle can effectively slash through weedy biomass (Figure 6). The challenge now is how to build this ability into an effective farm tool.

SANTFA, which has an on-going emphasis on alternative weed control strategies, has been successful in attracting a 'Caring for Our Country' Community Grant to build a single-row weed slasher using UHP technology. It has been termed Aqua-Slash.

The aim is to have the nozzle pointing forward and down at an angle of approximately 30° to the soil surface and oscillating rapidly back and forth across the inter-row so the jet stream from it clears the full width between the crop rows.

Once the technology is established the machine will be used to test the practicality and efficacy of different inter-row swathing patterns and could provide the basis for a prototype in the future.

SANTFA is also planning to test smaller nozzle orifices down to 6/1000" (0.152mm) because slashing biomass is much easier than cutting soils with a water-only jet-stream. Reducing the size of the nozzle orifice has the potential for major reductions in water use, since halving the radius of the nozzle orifice effectively reduces the water rate by 75%, provided the pressure is unchanged (Table 1).

Orifice size (inch)	Water rate (L/min) at 55,000 psi
10/1000	1.84
8/1000	1.19
6/1000	0.67
4/1000	0.29

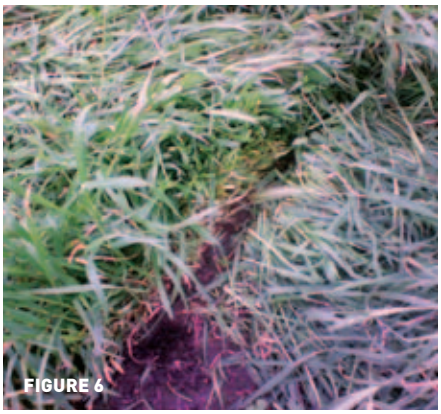
TABLE 1: THE RADIUS OF THE ORIFICE HAS A MAJOR EFFECT ON WATER RATES.

It is always most efficient to cut at the highest pressure possible, and in terms of water rates and power requirements relative to cutting performance, a high-pressure, small-orifice configuration provides a better cutting outcome than using a large orifice at a lower pressure.

For example, an inter-row weed slasher using two 6/1000" nozzles per row would use about 30% less water than one with one 10/1000" nozzle per row.

The efficacy and coverage achievable with such machines have yet to measured, but it is reasonable to assume that coverage with two nozzles will be better than the coverage with one nozzle.

Previous investigations of inter-row weed slashing using mechanical blades identified two major issues: difficulty achieving high enough blade speeds to achieve a quality cut and poor performance on small and



WEEDY BIOMASS SLASHED WITH 10/1000" (0.254 MM) NOZZLE AT 50,000 PSI (3,447 BAR).

sprawling weeds that easily escaped under the horizontal-only action of mechanical blades. Speed is not an issue with an Aqua-Slash water-jet and it is hoped that angling the jet-stream nozzles 30° downward onto the soil surface will improve performance on sprawling or emerging weeds.

It seems likely the Aqua-Slash device will be able to be positioned in the inter-row using Eco-Dan or Robo-crop local positioning technologies that have been successfully deployed to position spray nozzles applying knock-down herbicides between rows of crop.

SANTFA is open to approaches from industry co-operators interested in being part of this exciting work and invite agricultural manufactures interested in working with Flowcorp UHP pumps to develop agricultural prototypes to contact SANTFA R&D Manager Greg Butler.

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