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FEASIBILITY STUDY, EXTENDING THE SWATH WIDTH OF TOPDRESSING AIRCRAFT TO REDUCE STRIPING OF FERTILISER MIXES

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Abstract

Fertiliser mixes of magnesium oxide coated urea and super phosphate require high application rates 250kg/ha - 500kg/ha. These rates are inclined to clog spreaders reducing their efficiency and compromising operational safety. As a result, the current spreader design is, not fitted for these rates. The swath width from a Cresco 08-600 without a spreader is only 12m wide, meaning many passes are required to cover a field. The mixture also tends to segregate which leads to striping.

A new method of spreading fertilizer, which provides a wider swath width and an even distribution, is required. This method must be able to meet the CAA requirements for topdressing safety, minimise segregation in fertiliser mixtures and preferably should be applicable to most bulk fertilizers in common use; the method must not add any significant weight to the aircraft that would decrease its operating capacity.

The feasibility of developing a means of initiating spreading of bulk fertilisers from topdressing aircraft hoppers from regions outside of the influence of the prop wash are investigated. If feasible, the system should be able to apply fertiliser across a 40m swath width at the target application rate, in a single pass. This would reduce flight time and improve the distribution pattern leading to reduced operating costs and higher crop yield.

This preliminary report suggests that it is mathematically possible to widen the swath width of the Cresco 08-600 to 40m at an application rate of 350kg/ha by means of a screw conveyor transporting and evenly releasing fertiliser along the length of the wing up until the dihedral is reached. The next stage in this project will be to design the screw conveyor system and test it on the ground to see its limitations and potential safety concerns.

Key words: Striping, Fertiliser mixes, Swath width, Auger, Pneumatic conveying

Introduction
Fertiliser spreading via topdressing aircraft is commonplace in New Zealand. Currently the fertiliser is released from a 2.1m^3 hopper out of the bottom of the Cresco 08-600 where it is forced into a spreader via ram air. This increases the swath from 12m without the spreader to 22m. Previous attempts to widen the swath width have been made by widening the spreader. However this has had little effect due to the prop wash confining the material (Jones, *et al.* 2008).

An increased swath width would be valuable to the industry, as it will increase both the application accuracy and efficiency while reducing operating costs.

Aim and Scope
The aim of this Feasibility study is to investigate the possibility of widening the swath width of the Cresco 06-800 topdressing aircraft by transporting the fertiliser outside of the prop wash prior to release. This will have to be done in a way that is reliable, safe, efficient accurate, cost effective and meets Civil Aviation Authority (CAA, 2007) requirements.

Two means of particle transportation, pneumatic and mechanical, are evaluated in this study.

Literature review

Current status
Grafton (2010) and Grafton, *et al.* (2011) found that all common fertiliser products apart from limestone were free flowing and therefore suitable for pneumatic and mechanical conveying.

Previous attempts
Rotary Aircraft Spreader
In the 1960's and 1970's Norman Akesson and Wesley Yates conducted research into the performance of aerial spreading and potential solutions to widen the swath width.

One of their first works was to evaluate the effectiveness of different sized fishtail spreaders experimentally and then determine the economic cost of aerial application of fertiliser (Akesson and Yates, 1964). Using 6 and 8 "foot" spreaders on a Boeing Stearman biplane aircraft they found that the swath width was not significantly widened with the larger spreader. Based on this information Akesson and Yates looked at developing a new aircraft that pneumatically conveyed fertiliser within the wing itself. However, it was only designed to apply at a rate of 100kg/ha.

Pneumatic Conveying
A summary of the advantages and disadvantages from Svensson (1990)

Main Advantages

- Typical pneumatic systems have few moving parts
- They perform well with hydroscopic materials like fertiliser.
- The fertiliser sustains less degradation.

Main Disadvantages

- The material properties will cause variations in performance.
- There is a large risk of clogging.
- The system if tilted by 10° will favour that side by 3-5%

Screw Conveying

A screw conveyor uses a long rotating shaft with a helical blade to move materials. Most screw conveyor designs; are based around an rpm and a volumetric efficiency, called the degree of filling. Typical volumetric efficiencies and maximum rpm vary from source to source depending on the application. For example Nicolai, *et al.* (2004) tested a 250mm screw conveyor between 300rpm and 1100rpm and found that the volumetric efficiency for conveying dry corn was close to 50% at 300rpm while peak flow occurred at 823±39rpm. However according to Fjordvejs (2002) who manufacture Screw conveyors, the maximum rpm for a 250mm diameter screw conveyor at 50% filling is 190rpm.

Design

Jones, *et al*. (2008), found the prop wash is a confining factor that limits the effectiveness of enlarging the spreader, therefore a means of transporting fertiliser outside of this zone to meet a swath width of 40m, should be developed.

Pneumatic Conveying

Concept

Pneumatic conveying of particles is the process by which bulk material is transported along a pipe while suspended in a stream of gas to later be dispensed at another location.

It is proposed that such a system could be used to transport fertiliser outside of the prop wash to be released from one or multiple points along the wing using a ram air scoop for the air supply. According to (Mills, 2016) for pneumatic systems with multiple exit points, the pressure at each point must be the same for the flow to be equal therefore because the pressure will decrease along the length of the pipe, the pipe must be stepped up in diameter to maintain constant pressure.

Screw Conveying

Concept

A screw conveyor uses a rotating helical screw to move material along a pipe. It is proposed that, this system could be used to transport fertiliser mechanically down a pipe to either; be released continuously along its entire length or in multiple discrete locations along the wing.

A screw conveyor offers a high degree of control and the potential to apply evenly across the whole system that could achieve a very low coefficient of variation.

The behaviour of a screw conveyor is much easier to model than pneumatic conveying therefore, it should not be difficult to develop software that marries into the current variable rate technology.

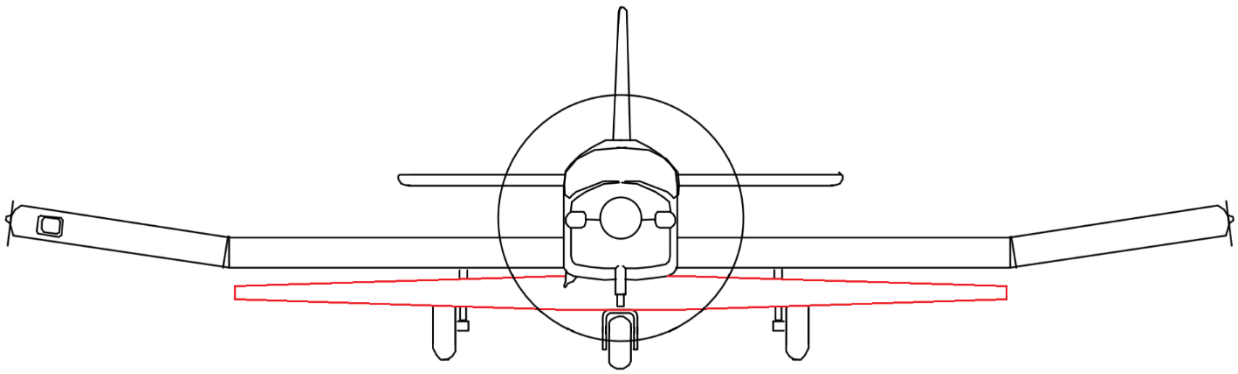

Figure 1 Possible tapered conveyor

Conclusions and Recommendations

Overall, this study found that it could be feasible to transport material outside of the Cresco's prop wash and that it, should be feasible to release the fertiliser in a way that widens the swath width while maintaining a low CV.

It is recommended that the Screw conveyor option is investigated further. Mathematically it is more reliable, will be able to meet the CAA discharge requirements CAA (2007) and offers more application rate control.

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