TO SPRAY OR TO SPREAD: QUANTIFYING UAN LEAF UPTAKE

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TAKE HOME MESSAGES

- Soil applied fertiliser was better than liquid urea or UAN applied with standard spray nozzles to the crops leaves.
- Both urea and UAN are equally as effective when applied to the soil.
- Growers should select the nitrogen product that most suits their farming system in terms of logistics and cost.

KEY WORDS

Leaf uptake, nitrogen, UAN, urea, volatilisation, wheat.

BACKGROUND

Fertiliser inputs represent a significant proportion of total variable costs in grain production. When rain forecasts fail to eventuate after in-season applications of fertiliser it is frustrating as losses can occur. This is because growers recognise the interaction between volatilisation, the effect this has on reducing the amount of nitrogen available to their crop, and the consequent 'waste of money'. A common question arising during the cropping season is: "How much nitrogen (N) is lost when fertiliser, particularly urea, is applied and follow-up rain does not occur immediately after application?" Proponents of fluid nitrogen products, such as UAN, have suggested that liquid applications can reduce the potential for volatilisation. The perception is that a large portion of the nitrogen, when applied as UAN, is taken up by the crops leaves and that there is a reduced need for follow-up rain.

Urea is prone to volatilisation because it is highly reactive with water. Before N from urea can become available for plant use, it must pass through a two stage reaction.

1. The first stage of the process is the conversion of urea [$(NH_2)_2CO$], with the addition of water, to ammonium (NH_4^+) as ammonium carbonate. This is called urea hydrolysis.
2. The second stage occurs when ammonium is in its plant available form. Depending on conditions, this ammonium can be converted to ammonia (NH_3) which is a heavier than air gas, or to plant available nitrate (NO_3^-).

The rate of the first stage of the reaction depends on the presence of the soil enzyme urease and is usually quite rapid. The outcome from the second reaction depends on a number of factors: the production of ammonia rather than ammonium or nitrate will be favoured with warmer temperatures, high soil pH (especially where carbonate is present), low moisture, low clay content and the presence of organic materials.

If the soil is dry, the second stage of the reaction will not progress, leaving the nitrogen in a gas form (ammonia) that is susceptible to volatilisation into the atmosphere.

The perception that UAN liquid fertiliser – a solution of urea (35%) and ammonium nitrate [NH_4NO_3] (45%) – can reduce volatilisation because of its ability to be taken up through the crops leaves, is only partially true.

When in the root-zone, both ammonium and nitrate are immediately available to the plant, but when applied to leaves, the urea is taken up 10 times more rapidly than the ionic N forms. Even so, only a relatively small amount is able to be taken up without causing leaf damage due to urea toxicity and salt damage. In addition, in some circumstances, not all of the liquid fertiliser will make contact with the crop leaves; some may pass through to the soil thus reducing the actual percentage of N immediately available to the crop to less than 50%. The density of the crop canopy also has a significant impact on the amount of nitrogen immediately available to a crop. In a dense canopy, some ammonia that is produced through the above soil reactions can be absorbed directly by the leaves.

AIM

To quantify nitrogen leaf uptake when applying UAN with and without follow-up rain; and to determine the effect of streaming versus standard nozzles on nitrogen leaf uptake.

METHOD

A replicated field trial was established at the BCG main research site at Watchupga East. The trial compared a range of fertiliser application methods and products to establish how well nitrogen was taken up by the wheat plants' leaves. Granular fertiliser treatments were applied using garden hand spreaders and liquid fertilisers applied using a hand-held 1.5m boom with either a streaming nozzle (TeeJet SJ-04-VP) or a standard nozzle (TeeJet AIXR110025). A modified hand-held boom with nozzles set to the crop inter-row and with modified nozzles (single stream) was used for the inter-row treatments.

All plots received identical agronomic management; the only difference was in the treatments applied. Trial assessments included: a measure of greenness (NDVI refer to pp. 229) prior to treatment applications; total nitrogen percentage and dry matter of biomass cuts (from one meter of crop row four and 10 days after the application and at anthesis); and yield and quality parameters. Treatments that had the potential for liquid fertiliser to end up on the leaves (standard nozzle and streaming nozzle treatments) were washed prior to the nitrogen percentage analysis to prevent invalidating the results. The washing ensured no liquid fertiliser remained on the outside of the leaves. No measurements of ground cover were taken in the trial.

Location:	Watchupga East	
Replicates:	Four	
Sowing date:	15 May	
Target plant density:	150 plants/m^2	
Crop type:	Correll wheat	
Fertiliser:	MAP + Zn (55kg/ha)	
Herbicides:	15 May	TriflurX® (2L/ha) + Weedmaster® Duo (2L/ha) + Avadex® Xtra (2L/ha)
	9 July	Velocity® (670ml/ha) + Lontrel™ Advanced (50ml/ha) + Hasten™ (1%)
Insecticides:	23 September	Fastac® Duo (200ml/ha)
Seeding equipment:	BCG cone seeder (knife points, press wheels, 30cm row spacing)	

Table 1. Trial treatment products and application methods, dates, rates and growth stages.

Treatment	Follow-up rain		No follow-up rain	
	Timing	Rate (kg/ha)	Timing	Rate (kg/ha)
Control	GS31 (16-Aug)	0	GS32 (29-Aug)	0
Liquid urea standard nozzles		18		18
UAN inter-row only				
UAN standard nozzles				
UAN streaming nozzles				
Urea top-dressed				

RESULTS AND INTERPRETATION

The measure of green cover (NDVI), a surrogate for crop biomass, conducted prior to the UAN or urea applications returned no significant differences between treatments. From this, it can be concluded that all treatments were starting from a similar point and that any differences observed from this point forward were the result of treatment effects. It should be noted that the trial was very nitrogen stressed. While no data was collected to determine the actual ground cover, the average NDVI readings measured prior to treatment applications were 0.13. A wheat variety trial assessed for NDVI at the same site on a similar day recorded a trial average NDVI reading of 0.55. This trial had received an additional 106 kg N/ha which indicates the level of N stress in the UAN trial.

To assess the impact of rainfall on crop N uptake, the trial included treatments exposed to follow-up rain and no follow-up rain. The fickle nature of rainfall in the Mallee meant that finding appropriate application times was challenging. Further to this, the fact that the variates require different quantities of rainfall made it necessary to apply the treatments at different times and crop growth stages.

Prevailing rainfall conditions for the 10 days after application (DAA) were relatively consistent with the trial design (Table 2). That said, the follow-up rain treatments received many small rainfall events to total 11.9mm. While this should be enough to ensure the N is washed into the soil, the trial failed to receive the desired large single rainfall event. Although the maximum daily temperatures over the 10 days were low (<18.5° C), the potential for loss through volatilisation was still quite high. In similar work conducted on a Kalkee clay loam, urea was completely hydrolysed by Day 7 at 25°C, by Day 10 at 15°C, and by Day 15 at 5°C. (*Suter et al, 2011*). On the lighter soils at Watchupga East, the urea could be expected to be lost even more rapidly.

The 'no follow-up rain' treatments received only very small quantities of rain which should not have affected the results. Of greater interest were the higher temperatures recorded over the period, with three of the ten days reaching in excess of 25° C. These temperatures are at a level at which it could be expected that the nitrogen reactions would progress at a significant rate. In the 10 days after application there was an 8.9° C difference between the average daily maximum temperatures recorded for the follow-up rain and no follow-up rain variates. This is a significant difference and has the potential to influence volatilisation rates between the two variates.

Table 2. Maximum daily temperature and rainfall received in the ten days following application of the follow-up rain and no follow-up rain variates.

Follow-up rain			No follow-up rain		
Date	Max daily temp.	Rainfall (mm)	Date	Max daily temp.	Rainfall (mm)
16 Aug	18.5	1	29 Aug	22.0	0.2
17 Aug	14	2.1	30 Aug	21	0.3
18 Aug	18	0.4	31 Aug	24.5	0
19 Aug	12.5	5.3	1 Sep	27.5	0
20 Aug	13	0.9	2 Sep	26.5	0
21 Aug	14.5	0	3 Sep	27	0
22 Aug	14.5	0.6	4 Sep	30.0	0
23 Aug	16.5	1.3	5 Sep	22.5	0
24 Aug	15.5	0.3	6 Sep	17.0	1.6
25 Aug	17	0	7 Sep	19.5	0
Mean	**15.4**	**–**	**Mean**	**24.3**	**–**
Total	**–**	**11.9**	**Total**	**–**	**2.1**

Source: SILO patch point dataset (Birchip Marlbed)

The rainfall received was sufficient to allow a rigorous assessment of the need for follow-up rainfall after N applications. The average total plant N from one metre of crop row did not show any differences between treatments at 10DAA (N.B. dry matter data was not available for the 4DAA follow-up rainfall variates). However, at anthesis, both the UAN streaming nozzles and urea top-dressed treatments had a higher total plant N at anthesis than the UAN standard nozzle and liquid urea treatments (Table 3).

Table 3. Average total plant N from one meter of crop row 4 and 10 days after application and at anthesis.

Treatment	Total plant N 4 DAA (no follow-up rain only)* (kg N/ha)	Total plant N 10 DAA (kg N/ha)	Total plant N at anthesis (kg N/ha)
UAN streaming nozzles	23.2	30.5	30.5[a]
Urea top-dressed	19.3	26	29.9[a]
UAN inter-row only	19.3	25.4	26.6[ab]
UAN standard nozzles	22.1	25.4	24.0[b]
Liquid urea	20.1	31.4	17.3[c]
Sig. diff.			**P=0.021**
LSD (P=0.05)	**NS**	**NS**	**8.4**
CV%			**31.7**

* Dry matter data was not available for the 4DAA follow-up rainfall variates. Data relates to the 'no follow-up rainfall' only.

The UAN streaming nozzles treatment had more N uptake with no rain than with rain (Figure 1). It is possible the rain may have washed some of the ionic N from the leaves, but the effect was not seen when the UAN was applied with standard nozzles. No clear reasons can be ascribed to this interaction.

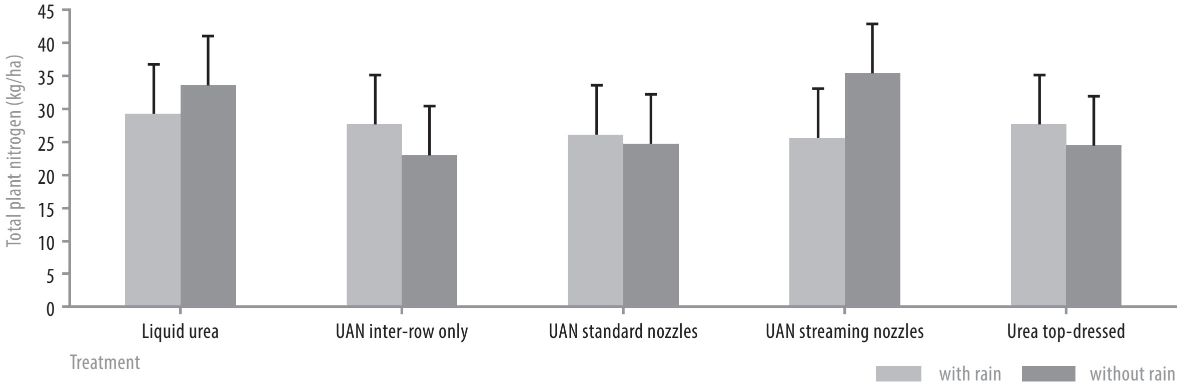

Figure 1. Total plant nitrogen by treatment and rainfall 10DAA (P=0.049, LSD=7.5kg N/ha, CV=18.6%)

Rainfall following N application produced a higher yield than no rain. At maturity, there were no treatment or treatment by rainfall interactions for grain yield in this trial.

In this trial, protein was influenced by follow-up rainfall and the varying treatments (Table 4). That said, the protein results were very low (<9.9%) with all treatments achieving an AGP specification. None of the increases in protein resulted in an increase in grain quality specification; all were below the 10.5% threshold required to reach a higher grade.

The low protein results for all treatments are indicative of insufficient nitrogen being available to the crop. This was evident during the growing season with all treatments showing visible signs of nitrogen stress. While this situation is not ideal, it should have enabled treatment differences to be expressed and highlight any volatilisation that may have occurred.

Table 4. Average yield (t/ha) and protein (%) for the nitrogen treatments and rainfall variates.

Treatment	Yield (t/ha)		Protein (%)	
	Follow-up rain	No follow-up rain	Follow-up rain	No follow-up rain
UAN inter-row only	1.75	1.54	9.6[ab]	9.3[abc]
Urea top-dressed	1.69	1.69	8.5[d]	9.9[a]
UAN streaming nozzles	1.76	1.5	8.7[cd]	9.1[bcd]
UAN standard nozzles	1.6	1.51	8.6[d]	8.8[cd]
Liquid Urea	1.59	1.26	8.9[cd]	8.9[cd]
Mean	**1.68**	**1.5**	**8.9**	**9.2**
Sig. diff.				
Treatment	NS		P=0.011	
Rainfall	P=0.005		P=0.016	
Treatment x rainfall	NS		P=0.006	
LSD (P=0.05)				
Treatment	-		0.4	
Rainfall	0.12		0.3	
Treatment x rainfall	-		0.6	
CV%	11.7		4.6	

Total average grain N was calculated by multiplying the yield with the protein percentage and applying a multiplier (protein (%)/7) based on the N portion of protein (Figure 2). The UAN inter-row only and top-dressed urea treatments achieved significantly higher total average grain N compared with the UAN standard nozzle and liquid urea treatments.

Irrespective of follow-up rainfall, in this experiment, applying N to the soil achieved the greatest plant uptake. The liquid urea applications to the leaves of the crop (standard nozzles) did not result in as high N uptake as the soil applied (UAN inter-row, streaming and urea top-dressed) treatments.

There are two potential reasons to account for the improved N uptake from soil applied treatments over the liquid leaf applied treatments. The first is the fact that the crop was N stressed at the time of application and had a smaller leaf area, thus reducing the opportunity for N uptake. There is also a possibility that due to the low leaf area, most of the foliar applications landed on the soil. The very small, dilute and widely dispersed urea particles may have reacted more quickly than the larger particles in the granular or stream applications and were lost. Secondly, it is possible that rainfall received soon after application under both variates was enough to wash the N off the leaves of the crop, reducing the opportunity for leaf uptake. From these results it is difficult to quantify exactly why the leaf applied applications did not result in grain N accumulation.

With the UAN inter-row, urea top-dressed and UAN streaming nozzle treatments all achieving comparable total grain N results, it appears there is no penalty or benefit from using UAN over urea or vice versa, provided it is applied to the soil. It is also apparent from the results that the liquid urea did not perform as well as UAN and its granular counterpart.

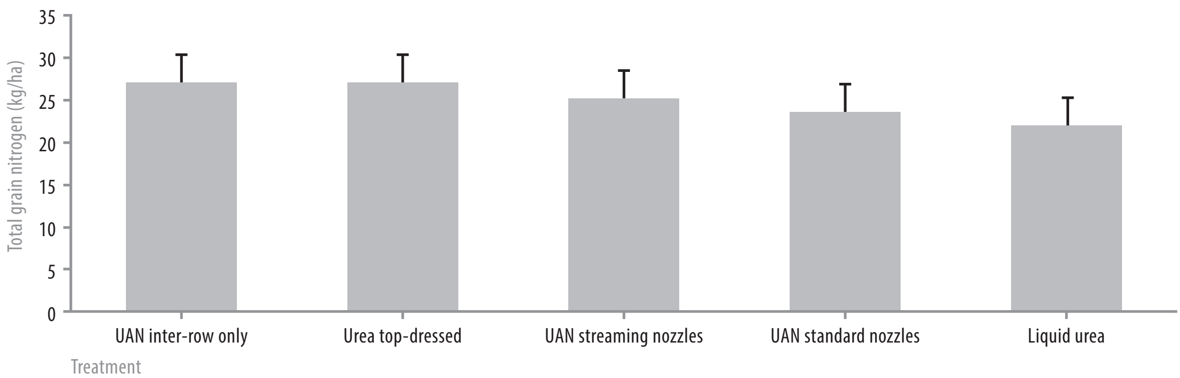

Figure 2. Average total grain N (kg/ha) by treatment (P=0.011, LSD=3.29 and CV12.8%).

Nitrogen fertiliser efficiency measurements (the proportion of the extra N applied that ends up in the grain and is removed at harvest above the control of the applied 18kg/ha) were also considered as part of this investigation (Table 5). The 47% efficiency achieved by the UAN inter-row only treatment seems relatively inefficient but typically only 50% of nitrogen applied is taken up by the crop (*Anderson and Garlinge, 2000*). The other 50% may be lost as ammonia gas to the atmosphere, remain in the crop residue or is still in the soil. The UAN standard nozzles and liquid urea had very poor efficiency.

Table 5: Total average grain N, accumulated grain N above the control and N fertiliser efficiency by treatment.

Treatment	Total grain N (kg/ha)	Accumulated grain N above the control* (kg/ha)	N fertiliser efficiency (%)
UAN inter-row only	27.3	8.5	47
Urea top-dressed	27.2	8.4	47
UAN streaming nozzles	25.3	6.5	36
UAN standard nozzles	23.7	4.9	27
Liquid urea	22	3.3	18

* Control mean grain N=18.76kg/ha

The results indicate that applying fertiliser to the soil gives the greatest N use efficiency and that there is no penalty or benefit from using UAN over urea or vice versa. The N stress experienced by the crop in this trial may have disadvantaged the leaf applied N treatments.

COMMERCIAL PRACTICE

The results from this trial do not support the notion that fluid fertiliser products minimise volatilisation when there is no follow-up rain. The soil applied urea was equally efficient as the UAN and better than the other modes of delivery. Given these results, growers can confidently use either urea product knowing that they are equally as effective when applied to the soil. Decisions about what urea product to use should be based on logistics, equipment, labour availability and cost, rather than on how efficiently the N is likely to be taken up by the crop. More work may be required to further assess the efficiency of foliar uptake of UAN and liquid urea in a non-stressed situation.

REFERENCES

H.C. Suter, P. Pengthamkeerati, C. Walker and D. Chen (2011). Influence of temperature and soil type on inhibition of urea hydrolysis by N-(n-butyl) thiophosphoric triamide in wheat and pasture soils in south-eastern Australia. Soil Research CSIRO Publishing

W.K Anderson and J.R. Garlinge (2000). The Wheat Book Principles and Practice Agriculture Western Australia.

V. Fernandez, T Sotiropoulis and P Brown (2013). Foliar Fertilization, Scientific Principle and Field Practices. International Fertilizer Industry Association (http://www.fertilizer.org/HomePage/LIBRARY/Our-selection2/Fertilizer-use.html/Foliar-Fertilization-Scientific-Principles-and-Field-Practices.html)

ACKNOWLEDGMENTS

This trial was partially funded by the International Plant Nutrition Institute (IPNI) and partially through BCG members through their membership.