# Sustainable N use helping Integrated Pest Management, not hindering: Aphids as indicators.

*Report by:*
*Dr Michael Nash on behalf of the South Australian No-Till Farmers Association*


## Key Points

Understanding likely Aphid population responses to management, climate, crop type and increased diversity within a crop field, it may be possible to select agronomic practices that limit threats.

The impact of Aphids is greatest when the virus is transmitted early in the season, especially when plants are stressed.

Applying excess Urea in marginal moisture conditions has two outcomes:

- Increased plant stress levels

- Higher N concentrations in the plant leaf.

The combined effect of these two factors can lead to rapid build-up in Aphids population under marginal moisture conditions.

## Background

Nitrogen has been proposed as the biggest limiting factor for cereal yield in Australia, once moisture is considered (Meier et.al 2021). Insects are explored as a bio-indicator of Nitrogen availability in Australian cropping systems in this article. In 2020 Russian Wheat Aphid was observed damaging cereal crops throughout South Australia during July, despite cereal seed being treated with insecticides. Foliar insecticides were needed to limit damage to plants that were often stressed due to dry winter conditions.

> *"The supply of available nitrogen is a limiting factor of all life."*
>
> T.C.R. White

One possible reason given for these outbreaks was Aphid populations were migrating in to crops, however this theory was not supported by growers' observations. Again, in 2021 Russian Wheat Aphid is being observed on emerging crops across Victoria and NSW where conditions are dry, despite early warnings and the application of seed treatments. Similar dry conditions were experienced when Russian Wheat Aphid was first detected in 2016 in Australia, populations seem to be greatest where plants are moisture-stressed and are often found along with Oat and Corn Aphids. We propose Aphid outbreaks are an indicator of not only plant stress, but also an imbalance of Nitrogen.

## Understanding the Threat of Aphids

Aphids can cause considerable reductions in yields, both acting as a vector for viruses which, when transmitted early in a crop's life can cause the greatest damage and to a lesser extent direct feeding damage when crops are producing seed (Table 1).

Aphids feed on the plants phloem that can trigger plant stress responses, which may include signalling to natural enemies. To balance their diet when feeding on a diet high in sugars, Aphids secret honey dew leading to secondary fungal infections.

Table 1. Threats posed to grain growers by commonly encountered Aphids (Valenzuela & Hoffmann 2015) with estimated yield reduction presented. Oat and Corn Aphid impacts are not separated as both species are often found together, likewise Pulse Aphids are not separated. Note this is not a complete list of all aphids encountered.

| Aphid | Crops impacted | Virus Transmission | Direct damage | Insecticide Resistance |
|---|---|---|---|---|
| Russian Wheat Aphid | Cereals | No | Wheat 25% | No |
| Oat Aphid | | (BYDV) 39 % | 26 % | No |
| Corn Aphid | | | | No |
| Cabbage Aphid | Canola | Poor (TYV & MVs) | 34% | No |
| Turnip Aphid | | No data | No | No |
| Green Peach Aphid | Canola | (TYV) 34% | No | Multiple MoAs |
| | Pulses | Lentils 85% (MVs) Lupins (CMV) 16% Peas (PSbMV) 14% | Lupins 13% | |
| Cow Pea Aphid | Pulses | | | No |
| Blue Green Aphid | | | | No |
| Foxglove Aphid | Faba Beans | (SCRLV) 43% | No | No |

BYDV, barely yellow dwarf virus; TYV, turnip yellows virus; MVs, alfalfa, bean yellow, cauliflower and turnip mosaic virus; CMV, cucumber mosaic virus; Lupins, lupins narrow-leafed and yellow lupins; PSbMV, pea seed-borne mosaic virus; SCRLV, subterranean clover read leaf virus.

## Pest Population Increases Intrinsic Growth Rates

Australian pest species generally have the potential to increase their numbers rapidly, commonly observed as a "boom" in numbers. The time taken for a population to double its size can be measured as its intrinsic growth rate. Pests with fast intrinsic growth rates often deplete unreliable resources and move on. The potential to form outbreaks depends on temperature and host resources, as illustrated by Oat and Corn Aphids. Unlike Europe, Australian Oat Aphids do not have overwintering sexual forms: they reproduce without sex which requires less energy, hence resources, which is considered an adaption to agricultural environments. Oat Aphids switch from wingless adults to migratory winged Aphids based on several factors based on available resources. Aphids also reproduce more in the wingless form: offspring per female (fecundity) reported for winged Oat Aphids (25.1 ± 2.1) is lower than for wingless adults (62 ± 1.4). Reproductive rates may vary between species and may be lowered when development occurs during drier conditions: Corn Aphid has a much lower fecundity than Oat Aphid (26 ± 4), which decreases on moisture-stressed hosts. By understanding likely Aphid population responses to climate, crop type and increased diversity within a crop field, it may be possible to select agronomic practices that limit intrinsic growth rates for Aphid populations. For example, Nitrogen usage that does not result in excess sap nitrates would limit Aphid food resources. Thus, by limiting Aphid population growth they will take longer to reach levels that cause direct damage, giving natural enemies time to provide some control.

Current pest management paradigms focus on decision support tools where climate, hence likelihood of a green bridge, is used to project populations. For example, the RWA CLIMEX model projects favourable summer conditions across Victoria and NSW, suggesting high RWA pressure in 2021. However, for populations to build up these favourable conditions need to be sustained for at least two months. These models fail to account for other factors that limit populations, let alone an individual pest's "struggle for existence" (see below). The outbreak of Russian Wheat Aphid winter in 2020 across the Mid North of South Australia is an example of individuals thriving, as populations increased at a greater rate than predicted based on current understanding: that is, numbers doubled in less than 30 days.

## Nitrogen (N) Availability

Of the elements essential to organic life abundant in the biosphere 99.95% of Nitrogen is mostly unavailable, as it exists as an inert gas. Of this 0.05% nearly


half is in an inorganic form with 95% of that organic form tied up in dead material. Nitrogen is the second most needed element after Carbon. In contrast Carbon is readily available and is found in excess to Nitrogen in all living tissues. In the basic compounds needed make proteins, such as amino acids, the Carbon to Nitrogen ratio (C:N) is greater than 1 (i.e. 1.1 - 1.7:1). At the other extreme secondary woody plant tissues can have a C:N ratio of 1000:1. Only plants can incorporate inorganic Nitrogen into organic forms that animals can use. To further compound this hunger for Nitrogen, animals use structural materials based on proteins, not carbohydrates like plants. For herbivores the lack of available N in their diet is their greatest problem. At best they can feed directly on plant reproductive tissues that contain the highest Nitrogen content: that is seeds at around 9 – 12 % Nitrogen. Those that feed on growing plant tissues would get around 5% Nitrogen of total dry weight.

## Struggle for Existence

White (1993) argues that despite the limitations imposed by a lack of Nitrogen, individuals that remain have an attribute that is good enough to survive and reproduce. Secondly, most individuals die because they fail to gain access to enough of a limited resource to survive and grow. This “struggle for existence” does not have to be due to active causes (weather or predators) or where individuals are outcompeted. By not observing pests threatening crops in that absence of controls (insecticides), Australian growers regularly experience individuals’ struggle for existence.

Pests have evolved to reproduce during adequate plant Nitrogen levels. For example, Native Budworm moths migrate from inland pastoral zones to cropping areas in early spring when pulse crops are flowering. Hatching larvae have access to seeds, thus this migratory, native species synchrony with resources across the Australian landscape has been favoured by the growing of pulses. Pests can modify their food resource to increase Nitrogen availability. For example, Green Peach Aphid transmit viruses in their favour as it increases the proportion senescing leaves for their nymphs to feed on.

Has management made it easier for pests to survive and reproduce?

## Aphids are Bio-indicators of N Overuse under Moisture Limited Conditions

Nitrogen deposition increased Aphid per capita population growth, plant foliar Nitrogen concentrations, and plant biomass when tested. Despite the increased number of Aphids this was matched by an increase in plant carrying capacity, leading to no overall change despite more Aphids surviving. However, can plants compensate for the increase in Aphid feeding due to the increased application of Urea under marginal conditions, especially where plant growth is restricted by limited moisture? Under field conditions in West Australia research indicated Potassium deficiency caused significant:

(1) Increase in concentrations of Nitrogen in youngest mature leaves, and
(2) Increase in Green Peach Aphid density in Canola leading to lower yields.

Sadras et. al. (2021) found where Oat Aphids could move throughout a wheat plant, high nitrogen enhanced their reproduction, but the number varied tenfold with plant growing conditions and correlated negatively with molar concentration of sugars in stem.

The increased reports of Aphid outbreaks despite the adoption of prophylactic application of seed treatments targeting Aphids

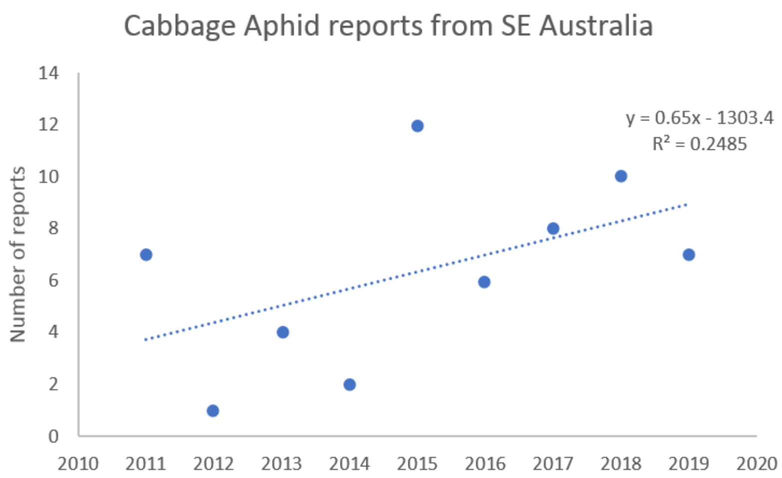


Figure 1. Year on year reports to GRDC pest reporting services of Cabbage Aphid incidences in Canola that may reflect the over-use of Nitrogen.

would suggest Nitrogen overuse and plant health need to be considered.

Insecticide resistance is often given as a major reason for limited crop protection, however only one species of Aphid threatening broadacre crops has developed resistance to commonly used insecticides: Green Peach Aphid. Climate change is another major factor implicated for the increase in some threats to crops from some pests, however often it is the grower's response to climate change in the form of Conservation Agriculture that retains more moisture in the system that has seen a shift in pest communities toward more resident pests that have relatively lower intrinsic growth rates. Loss of biological control, through the overuse of disruptive pesticides and a loss of habitat, is another factor considered to cause an increase in pest threats. This may well be true given the increased expenditure on crop protection products in Australia, despite continued investment in Integrated Pest Management by industry.

An alternative hypothesis presented here is that an oversupply of Nitrogen to crops, especially under marginal moisture conditions, is a major contributing factor to increased threats posed by Aphids in particular, and other crop threats more generally. Hence, recent observations of Aphid populations thriving is in fact their release from "the struggle for existence" due to an abundance of Nitrogen.

## Solutions: Understanding Nitrogen Use

Long term research conducted on Yorke Peninsula indicates an overuse of urea in conservation agriculture systems where a high proportion of pulses are grown in the rotation. This is leading to acidification and stratification in soils with an associated rundown of Carbon. Recent research supports the common interpretation that high Nitrogen favours insect fitness, but needs expanding to account for the association between low Nitrogen and high concentration of labile carbohydrates in plant. This equilibrium can cause osmotic stress in aphids and lower their intrinsic growth rate. The role carbohydrates and Nitrogen interact in a plant's resistance to aphids needs further research if damage thresholds are to become more reliable. Further understanding of agricultural ecosystems to improve Nitrogen utilisation is needed, not just applying more that disrupts the system's biology and leads to greater rates of pest increase and hence greater risks to yield.

## Take Home Messages

Modern farming practices are making it easier for aphids to survive and reproduce due to increases in Nitrogen and changes to plant C: N ratios.

Improving crop Nitrogen utilisation will help Integrated Pest Management, leading to less reliance on disruptive pesticides.

### References

Meier, E.A., Hunt, J.R., Hochman, Z., 2021. Evaluation of nitrogen bank, a soil nitrogen management strategy for sustainably closing wheat yield gaps. Field Crops Research 261, 108017. doi:10.1016/j.fcr.2020.108017

Sadras, V., Vázquez, C., Garzo, E., Moreno, A., Medina, S., Taylor, J., Fereres, A., 2021. The role of plant labile carbohydrates and nitrogen on wheat-aphid relations. Scientific Reports 11. doi:10.1038/s41598-021-91424-8

Valenzuela, I., and Hoffmann, A.A. (2015), Economic loss of grains by Aphids. Austral Entomology, 54: 292-305. https://doi.org/10.1111/aen.12122

White T.C.R. (1993), The Inadequate Environment: Nitrogen and the Abundance of Animals. Springer-Verlag, Berlin pp. 425.