Australian Government

National Landcare Program

A BUG'S LIFE

DEVELOPMENTAL MODELS FOR INSECTS – DECISION SUPPORT TOOLS

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Why do we need developmental models for broadacre farming ecosystems?

Understanding when a crop is threatened underpins management of pests to limit economic loss. Central to Integrated Pest Management (IPM) practised in broadacre farming in Australia is monitoring to determine insect populations prior to implementing controls when action thresholds are reached[1]. However, monitoring is often under-resourced, which leads to prophylactic insecticide applications. Diverse farm ecosystems will be enhanced by incorporating new technologies and pest developmental models into IPM.

Insect phenology

Most growers know about crop phenology. When a crop flowers in the optimal period, yields are maximised by minimising losses due to frost, heat, drought and insufficient radiation. Flowering time is determined by interactions between genetics and environment: for example, the development speed of the cultivar, the environment in which it is grown, and the time of sowing. The APSIM (Agricultural Production Systems sIMulator) growth model of crop development is an example of a decision support tool used to predict optimal sowing dates for a given cereal cultivar across Australia.

[1] An 'economic injury level' is where pest populations reach a level that causes crop damage that will result in economic loss above the cost of applying controls. This level is calculated based on C = cost of control/V = value of the commodity*I = injury (e.g., defoliation or damaged grain) based on a given density of insects*D = economic damage (e.g., tonnes lost or quality discount) caused by a given level of injury*K = proportion of reduction in injury resulting from a control measure (usually the proportion of the insect population that is killed, or "percent control").

An 'action threshold' is based on an economic injury level for a particular insect pest that incorporates population density to determine if a control tactic is justified. An action threshold is a dynamic, simplified economic injury level applied before that level is reached.

More generally, phenology refers to recurring seasonal, plant and animal life cycle stages, such as flowering, maturation of agricultural plants, emergence of insects, and migration of birds. Insects have four life stages: egg, larvae, pupae and adult. Determining when an insect emerges from one stage to the next is often linked to environmental conditions, time of the year and availability of resources. For example, moths emerge from pupae in spring when plants are flowering, hence adults lay eggs in flowers, then larvae develop when seeds are forming. 'Instar' is a larval development stage. Older larvae (late instars) move from seed-head to seed-head. Often these plant-insect interactions are tightly linked, hence the success of that insect population relies on their host flowering at a specific time. If flowering is earlier, before moths have emerged, then less seed predation occurs.

Since insects are cold-blooded animals, temperature plays a major role in their growth and development. Insects have an optimum temperature range in which they will develop; no development occurs when temperatures are below a lower level or above an upper level. These values are used to predict insect activity and appearance of crop damage during the growing season. Understanding when insects emerge at various stages of their lifecycle is required to successfully implement IPM. Part of this is understanding their speed of development.

Use of degree day models.

In plant growth, we refer to growing 'degree days', which is the accumulation of average daily temperatures that dictates development for Australian spring wheat and varies between cultivars. For example, barley is considered a shorter crop than wheat as it requires less degree days to reach maturity.

The same principle applies to insects where a degree day model is used as a proxy for estimating rates of insect development, using cumulative degree days to predict important events in the life of an insect. Developmental stages include egg laying, egg hatch, larvae instar development, pupation and moth emergence. These biological events are used inform monitoring and insecticide application.

'A degree day' occurs when the average temperature for a day is one degree over the minimum temperature required for development and below the maximum threshold temperature insect development can occur. Cumulative degree day totals usually begin in one of two ways. One is to start keeping track of degree days for a pest on a calendar date. While this is simple, there is the disadvantage of having to keep up with temperatures long before any insect development will occur. The second method, used for other pests, starts from a specific biological event called a 'biofix'. Often this biofix is the date of the first capture of an adult in a trap. Use of a biofix starting point means keeping up with degree days over a shorter period and often provides a more accurate predictor of insect development.

An example: Etiella or Lucerne Seed Web Moth (*Etiella behrii*)

Etiella can have up to three generations per year occurring from spring to autumn. Larvae from the previous autumn overwinter in the soil and adults emerge from September, hence moth flights are observed often at a time when lentils are flowering. Adult females are capable of laying approximately 200 eggs on the surface of leaves, stems and flowers. Eggs hatch from 1-14 days, depending on temperature. Larvae bore into seedpods where they feed and cause downgrading and/or loss of lentil seed.

A degree day model has been developed to predict the onset of moth flights in spring. This model has a start date of 21 June. The lower temperature for development is 10 ° C, with no upper temperature limit. To calculate degree days, subtract the lower temperature limit from the minimum and maximum temperatures recorded for that day, the results are added together and then divided by two. For example, if the minimum temperature was 11 °C and the maximum was 21 °C then the degree days for that day is six: that is, *((11-10)+(21-10)) ÷2*. Degree days are then added to together to calculate the cumulative degree days. Three hundred and fifty cumulative degree days equates to approximately 10% of the moths into peak flights. It is recommended monitoring commences 1-2 weeks before this, at around 300 cumulative degree days. As a guide, daily maximum temperatures of 25 °C would see cumulative degree-days increase from 300 to 351 in about 7 days.

An Etiella development model developed by SARDI (http://sagit.com.au/projects/improving-monitoring-management-etiella-lentils/) was ground truthed 2020. Insecticide was applied soon after 300 cumulative degree days when moths were active, but before eggs were laid at three South Australian sites. The calculated dates were 15, 17 and 21 September. Using female pheromones that attract male moths, monitoring supported degree day models projecting moth activity. Where insecticides were applied in a timely manner, one application resulted in no damage to the lentils.

Integrating modern technology

More accurate developmental models for insects are needed for pests that are migratory. Developmental models based on the first arrival of migratory adults (biofix) provide better estimates of when threats will occur. An influx of adults that infest crops is common in Australia, where native species are adapted to moving around the landscape in search of resources.

An example in faba bean crops is native budworm flights and timing insecticide applications once larvae have developed. DTN smart traps, set with specific female pheromone lures, take images every night of male moths caught. The traps use algorithms to count moth numbers and are connected to the internet to provide information to the user. These traps were used to provide real time data on native budworm flights and their threat to bean crops on Yorke Peninsula. A similar trapping network is provided by ADMA using trap view technology (https://www.youtube.com/watch?v=qa4_HtxemTY). Real time moth flight data was used to inform application of a non-disruptive biocide, Vivus, when first instar larvae were projected based on development models that resulted in no damage to beans. The grain quality was considered equal to conventional insecticides applied at the third instar, when caterpillars can easily be detected using sweep nets.

The use of digital technology, internet connectivity and decision support tools based on developmental models, underpinned by life history information of the pest, will ensure timely application of insecticide that will reduce prophylactic chemical use while eliminating economic threats.

Acknowledgements

Dr Michael Nash (https://www.researchgate.net/profile/Michael-Nash-2) is funded through the mixed species cover crop project supported by Ag ExcellenceAlliance through funding from the Australian Government's National Landcare Program, Grains Research and Development Corporation and the South Australian Department for Environment and Water.