REFINING nitrogen management

Used in "dynamic" nitrogen management tools, the CHN model continuously estimates a crop's nitrogen nutrition level and the quantity of available nitrogen in the soil.

The CHN model simulates in real time and forecasts crop growth and the factors that limit it. Its performance has been validated for wheat and maize. Nitrogen management tools incorporating the CHN model are now being developed for those species.

Arvalis has been working on the development of a dynamic model for several years now. Its name is CHN[1], and it simulates carbon, water and nitrogen flow within a cropping system.

It is connected to Arvalis's soil, weather, fertiliser and varietal databases and uses them to calculate the various flows daily through each 1 cm layer of soil. CHN is currently capable of simulating bread wheat, durum wheat and maize growth based on the crop's level of nitrogen or water deficiency-induced stress. Work is being carried out to set the model's parameters for winter and spring barley.

Validation of the CHN cropping model for bread wheat, durum wheat and maize has been ongoing since 2013. This is based on a strong set of data collected from Arvalis trials carried out for those arable species in sufficient numbers to enable a statistically robust validation of the model. For maize, for example, the database contains data from 29 years of trials spread over 18 areas in France, including 683 different trial schemes and a wide range of agricultural, soil and meteorological contexts, with a total of just over 11,000 measurements taken from plants and as many again from the soil. The databases for the other species were built following the same method, from a selection of trials carefully spread out throughout the main production areas.

« **Using CHN to manage** nitrogen inputs led to a 14% increase in efficacy »

Continuous nitrogen management

Nowadays, the guiding principles of nitrogen fertilisation are essentially based on calculating a provisional rate, which is then adjusted during the season using a management tool. In order to overcome their limitations, "dynamic" management tools need to be developed and monitor the plants' nitrogen nutrition level in real time, to trigger inputs according to predetermined "ideal" nitrogen nutrition index (NNI) curves. It is with that purpose in mind that Arvalis is assessing the CHN model to dynamically assess nitrogen.

A trial network was introduced for the 2016–2017 season, in order to establish decision-making rules focussing on utilising CHN outputs to dynamically manage nitrogen fertilisation in bread wheat (12 trials) and durum wheat (8 trials, 5 of which are being carried out by partners from the Durum Wheat Technical Committee for Central France: AgroPithiviers, Axereal, Bonneval Beauce et Perche, and the Champagne Berichonne Region CETA).

In those experiments, the CHN model has been used to simulate the nitrogen nutrition index (NNI), in order to utilise it following the principles set out in Clémence Ravier's thesis (see the article "Fertilisation azotée du blé : raisonner sans objectif de rendement ", Perspectives Agricoles nº 445, June 2017 – *in French*). The quantity of nitrogen absorbed is also simulated and used to calculate the input rate in real time for each soil and weather permutation, taking the biomass level into account.

Throughout the first year of the experiment, regular visits were set up in advance at the "ear at 1 cm", "two tillers detectable", "flag leaf fully unfolded" and "flowering" stages to adjust the nitrogen application split. Nitrogen must then be managed in such a way as to avoid a significant deficiency (NNI below the minimum NNI curve) which couldn't be corrected and would irremediably restrict crop growth. Applications can be triggered at each visit in order to reach optimal NNI again. (In the future, it will be possible to introduce a visit optimisation module to target the weather windows that maximise nitrogen fertiliser utilisation and are characterised by the apparent utilisation ratio.)
CHN also monitors the mineral nitrogen available throughout the rooting depth, to differentiate real nitrogen deficiencies that require an application from nitrogen deficiencies induced by water deficiency-related stress, that do not justify triggering an application.
The various decision-making rules tested include taking into account the target protein content, which is 11.5% for bread wheat and 14% for durum wheat. The varietal effect on protein content has been integrated into this approach.

In the short term, CHN is going to help utilise in real time the leaf area index (LAI) measurements and chlorophyll content figures supplied, for example, by field sensors or cameras fitted to drones.

Promising initial assessment

In order to assess this approach and its performance, the yields, protein contents and apparent utilisation ratios obtained for each set of decision-making rules that were being tested must be compared to a nitrogen response curve. Optimum permutations are then determined by statistical adjustment of the response curves. This article only gives the wheat results, but the same work has been carried out for maize.

The CHN model forecasts maize biomass at flowering time more successfully when it is "corrected" by leaf index measurements before flowering.

« **11,000 measurements taken from plants and soil have helped to develop the maize version of the CHN model** »

Data assimilation improves CHN forecasts

Another challenge in managing nitrogen with CHN is the real time utilisation of increasingly numerous and varied sources of data. Experience has shown several times that coupling a cropping model with field measurements repeated over time significantly improves forecast relevance.
We have assessed the positive impact on the performance of maize biomass forecasts at flowering time produced by the CHN model when it has "assimilated" leaf area index (LAI) measurements. CHN was "fed" LAI measurements prior to the flowering stage from 80 experimental treatments taken from the maize database. This showed an improvement in biomass forecasts at flowering time in 70% of the simulated scenarios.
Those initial results on LAI assimilation are promising. However, the assimilation of the nitrogen absorbed by the plant will be much more complex. This is because this variable is not measured, but deduced by converting the chlorophyll content using an absorbed nitrogen model. Residual nitrogen in the soil will also have to be taken into account in the adjustments made for the plant.
In the short term, CHN could assimilate data derived from proxydetection (photographs) or teledetection (multispectral images from satellites, planes or drones for example).
However, this will require an IT system capable of managing data exchange and ownership.

On average, real time nitrogen fertilisation management and NNI monitoring via CHN has led to a lower rate recommended compared with the optimum nitrogen response curve (-33 kg N/ha), due to more efficient mineral nitrogen inputs (+14%), Those initial results are promising, despite 2017 being characterised by particularly high levels of residual nitrogen at the end of winter and drought conditions at the stem elongation stage.

Initial results indicate that the minimum NNI curve needs to be reviewed at the start of the cycle, as some of the trials having suffered severe deficiencies at the tillering stage presented a substantially reduced number of ears, which led to significant yield losses.

but resulted in a significant yield loss of around 0.2t/ha compared with maximum yield. On average, a management approach based on a protein content objective helped to reach the targets set: 11.7% for bread wheat and 14.2% for durum wheat.

(1) The CHN model was described in the article "Aide à la décision : vers une déclinaison au quotidien du modèle CHN" published in Perspectives Agricoles n° 446, in July 2017 (in French).

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