Knowledge grows

The Yara N-Sensor™

Complete Solution to Precision Farming

Introduction

The Yara N-Sensor offers farmers a solution to real-time variable rate nitrogen applications by adjusting rates according to crop growth whilst travelling across a field. As a result the N-Sensor is designed to deliver precise levels of input according to the crop's requirements helping to both reduce environmental effects whilst maximising potential profit.

A dedicated group of scientists at Yara's R&D base at Hanninghof carry out trial work annually to improve the calibrations that exist currently and increase the range of options for use. As such the N-Sensor truly is Backed by Science.

The result – improved gross margins and greater nitrogen efficiency.

The N-Sensor™

Its Development

The N-Sensor was first developed by Yara's Research & Development team at Hanninghof in Germany following over 10 years of intensive testing and trial work. It was introduced on farm in the 1990's offering a practical solution to farmers for variable rate nitrogen applications as a cab-mounted tool that can easily be transferred between machines on both tractors and self-propelled sprayers.

In 2005 the N-Sensor ALS (Active Light Source) was introduced as a solution to restricted working hours due to low light intensity. As the name suggests the ALS contains its own light source to continue operating irrespective of ambient light conditions.

Backed by Science

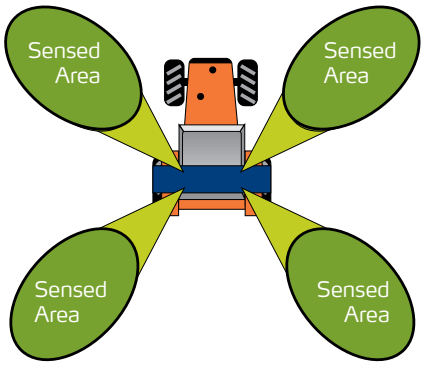
Trial work continues to be carried out annually at Hanninghof in order to progress the system further. Prior to the introduction of a calibration for a new crop, there are a large number of trials conducted to look at the nitrogen uptake of the crop in question and the effects of the interactions between different varieties and seed rates on the N-Sensor measurements at different stages of growth and the actual leaf nitrogen contents through laboratory analysis. Only once it is confirmed that there is a good correlation between the two will a new calibration for a crop be released.

Even for calibrations which are long established, work is carried out annually to fine tune them where necessary in order to continually improve accuracy.

How Does the N-Sensor Work?

The N-Sensor, situated on the cab roof, gains an oblique view of the crop on both sides of the tractor or sprayer measuring a total area of approximately a quarter of a bout width, away from the tramlines, at 24m tramline spacing (figure 1). The crops nitrogen demand is then determined by measuring the light reflectance. This occurs either through ambient light reflected off the crop to the sensing head in the case of the classic N-Sensor, or through the reflectance of its own light source in the case of the ALS, from a Xenon flash light.

Figure 1. Crop area 'Sensed'



The initial research work carried out during the development of the N-Sensor focussed on measuring the correct wavelengths on the reflectance curve (figure 2) to accurately determine crop nitrogen. This resulted in measuring two wavelengths, one in the visible red spectra of the curve relating to plant chlorophyll content (the colour of the crop) and one in the invisible near-infra red spectra relating to biomass. Using this information the N-Sensor can measure a crop to calculate the amount of nitrogen taken up by it and translate this data into an application rate. This sends a signal to the sprayer or spreader rate controller to adjust the rate of application accordingly. The whole process from measuring the crop through to adjusting the fertilizer occurs within a fraction of a second, realising the potential of 'real-time' agronomy (figure 3).

Figure 2. Typical reflectance curve for vegitation

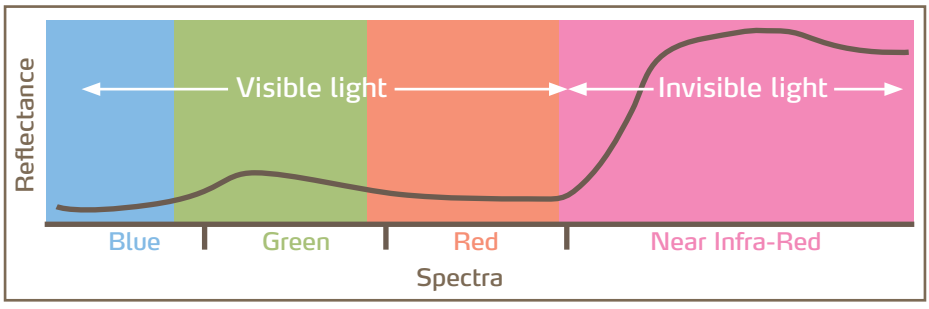
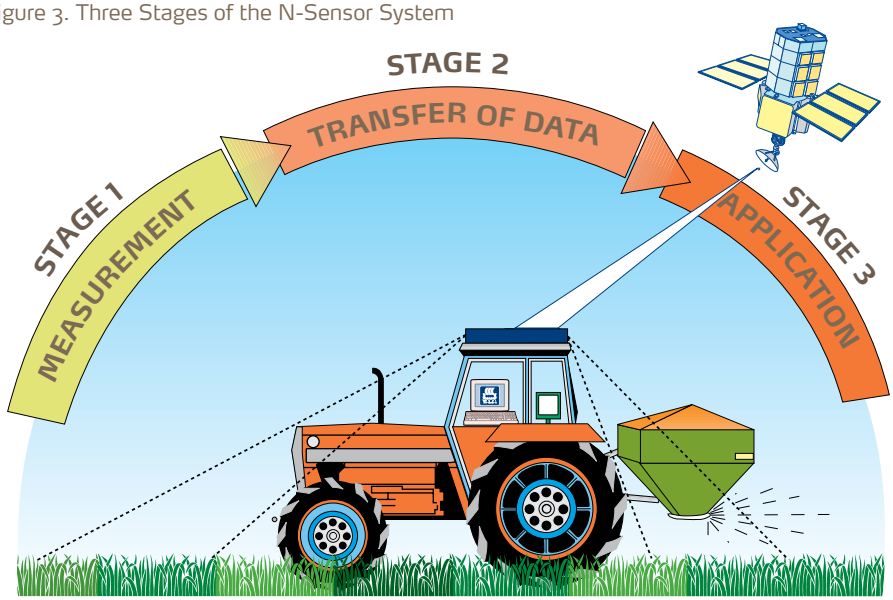


Figure 3. Three Stages of the N-Sensor System



As the reflectance for the classic N-Sensor is governed by light intensity, an additional sensor is located on top measuring light intensity to compensate for changes during operation. This sensor is not required for the ALS as it only measures the reflectance from its own light source directed at the crop.

Modes of Operation

New calibrations have been introduced to the system since its original launch to allow more accurate nitrogen applications and to improve ease of operations.

N Application

This calibration is the original which requires a reference scan to be conducted from an average area of the field, and entered before beginning the fertilizer operation.

Target Rate

Target rate was introduced to speed up the calibration process and allows a rolling calibration during operation, whereby the reference value is calculated from the moment the sensor begins taking measurements in the field. Usually a run of two tramlines will be enough to gain an appropriate average for the field.

Both modes of operation allow reference or target nitrogen rates to be assigned as well as fixing minimum and maximum rates to restrict the range of adjustments possible. The reference or target rate is the average rate to be applied to the field at the time of operation, which should be calculated prior to entering the field. The N-Sensor will then vary around this average depending on the measurements from the crop; applying more fertilizer where the crop nitrogen is lower than the average and vice versa.

Absolute-N

The Absolute-N calibration was introduced on farm in 2010 for oilseed rape. In this mode, rather than calculating the amount of nitrogen to apply before getting to the field, the N-Sensor makes the recommendation at the point of application. The N-Sensor measures the nitrogen picked up by the crop and from the entered growth stage, knows the amount of nitrogen that is required by the crop at that timing and therefore applies the difference. It is based on a two split program and has, in trials carried out over three years prior to its release, been shown to improve nitrogen use efficiency compared with standard farm practice through maintaining yield whilst decreasing the amount of nitrogen applied (figure 4).

- Increased yield (+3.9%)
- Increased revenues (+£76.8/ha)
- Improved N balance (-20 kgN/ha)

Other parameters are required during the setup to help calculate the appropriate rate of nitrogen to apply, including dead biomass and mineralisation potential.

Figure 4. Comparison between standard farm practice and Absolute-N

		2006	2006	2007	Average
Yield (t/ha)	uniform	3.37	4.59	3.82	**3.93**
	N-Sensor	3.55	4.87	3.82	**4.08**
N fertilizer rate (kg N/ha)	uniform	178	156	170	**168**
	N-Sensor	150	182	91	**141**
Revenues (£/ha), N cost considered *	uniform	£66	£1,129	£900	**£1,224**
	N-Sensor	£844	£1,182	£979	**£1,301**
N balance (kg /ha)	uniform	67	5	44	**39**
	N-Sensor	33	21	-35	**19**

(Oilseeds at £350/t and Nitrogen at £0.90/kg. Jan 2011)

Biomass Cut-Off

For all three modes a biomass cut-off value is required during the setup which will vary according to the growth stage of the crop. This instructs the N-Sensor to cut back to the minimum application rate when the biomass measurement falls below the entered value. This ensures nitrogen is not wasted on areas of the field which are not likely to yield, due to grazing damage, waterlogging etc. Rather than applying very high rates of nitrogen due to the low readings, it is assumed that the crop is uneconomical to treat and therefore cuts right back.

Earlier in the season this value needs to be low as the crops are still able to compensate for poor growth compared to later in the season.

Potato Haulm Killing

An additional module for the N-Sensor has been developed and was released in 2007 by Plant Research International, Wgeningen in the Netherlands for site specific dosing of potato desiccants. By measuring the reflectance of a potato canopy it is possible to pick up differences in colour significantly in advance of the naked eye, therefore applying higher dose rates to the 'greener' canopies to improve the uniformity of action and help reduce overall herbicide use.

This module is available through the Yara N-Sensor under licence from Plant Research International.

N-Sensor Terminal

The N-Sensor package offers a considerable benefit to farmers interested in all aspects of precision farming as a result of the Windows based terminal that is supplied. Not only is the touch screen computer very easy to operate and clear to view, allowing maps of the fields to be viewed during application; it also has the potential to offer a lot more than just variable rate nitrogen applications, including:

- Variable rate drilling
- Auto steer
- Guidance
- Auto section cut-off for sprayers

An Agronomy Tool

Although the Yara N-Sensor operates as a standalone system, in that GPS is not essential, this is usually supplied as part of the package to enable customers to create biomass and nitrogen application maps for each field scanned. These maps can be useful as a general agronomy tool highlighting areas of low biomass which enable the users to go back and gather more information as to the cause of the problems. They can also be matched up with yield maps to help identify reasons for high or low yielding areas and can also be useful for traceability records for Crop Assurance Schemes.

The field information is stored on a USB pen and can easily be transferred to a PC in the farm office, where the maps can be produced. Recent developments allows users with a windows terminal and wireless technology to send the data back to the farm office via the internet, it also allows networking for remote data transfer.

N-Sensor maps are produced using Internet based software called 'Sensor Office'. Sensor Office is part of Yara's precision farming Internet site, which allows users to produce crop biomass maps as well as N application maps. This software also enables transfer of data into formats which can be used in other mapping packages.

Further information on Sensor Office can be found via the Yara website at www.yara.com, or direct from www.sensoroffice.com

Figure 5. N-Sensor Biomass Map
Showing tramlines which were missed during the first application and therefore received no nitrogen
Showing tramlines which were missed

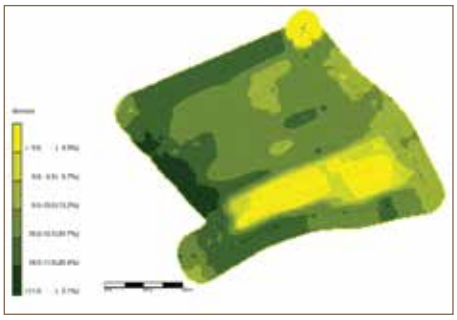
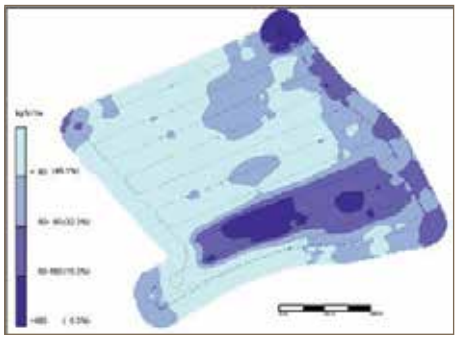


Figure 6. N-Sensor Application Map
Showing higher nitrogen for the tramlines which missed during the first application



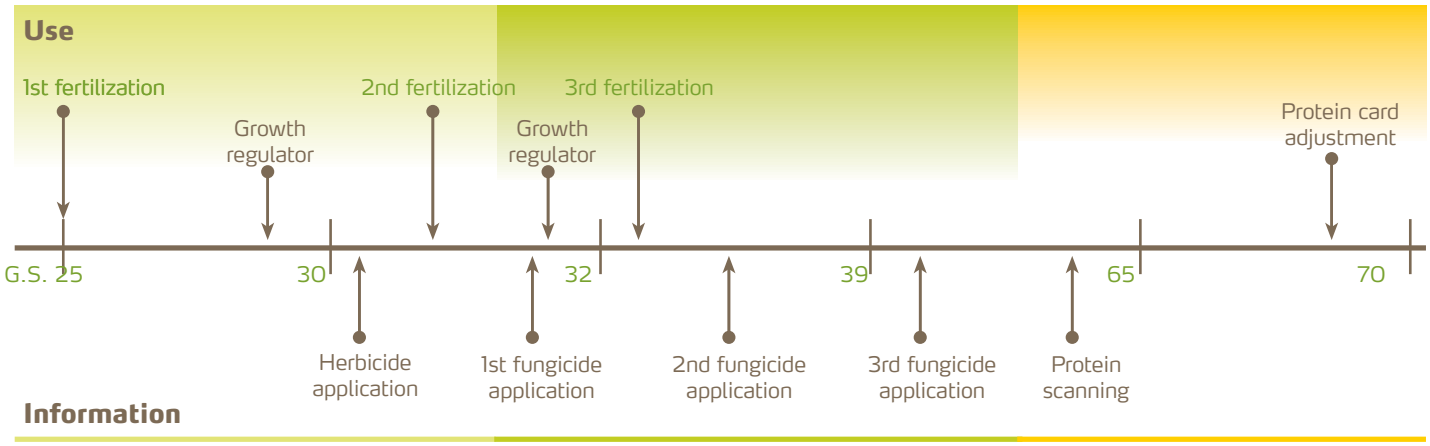
Crops Included

N-Sensor can measure the light reflectance of any crop but the system requires software to translate that reflectance information into an application rate.
Currently, software has been developed for:

- Winter Wheat
- Winter Barley
- Spring Wheat
- Spring Barley
- Winter Oilseed Rape
- Potatoes
- Maize
- Sugar Cane
- The N-Sensor has also been used on some field vegetable crops in the UK.

Ongoing research by Yara is focusing on use in terms of timings and other agronomic practises. Software has also been developed for the protein application in cereals.

Figure 7. A sample plan for wheat



Field Management Tool

The Yara N-Sensor is a management tool that can be used for fertilizer application, as well as data capture right the way through the growing season (figure 7). If linked up to DGPS, maps can be produced whenever the tractor or sprayer passes over the crop, without actually applying fertilizer. These are extremely useful in aiding the operator to identify potential problems within a field and are effective management tools when making agronomic decisions.

Importance of Fertilizer Quality

Accuracy of fertilizer application is essential to gain the full benefit of N-Sensor. When using N-Sensor for nitrogen application it is important to use a quality fertilizer like YaraBela Extran, Yara's 33.5% ammonium nitrate, to ensure an even and accurate spread across the entire bout width. This ensures the crop receives the optimum amount of nitrogen recommended by the system for that specific part of the field.

Spreaders and sprayers applying the fertilizer must also be correctly calibrated and well maintained to ensure they achieve their optimum spread/spray patterns.

Optimising Canopy Management

The Yara N-Sensor was originally developed for variable rate nitrogen applications, but to maximise its potential during the season, further developments have been sought for use in optimising canopy management. This can be achieved through variably applying other inputs, such as fungicides and plant growth regulators (PGR) to result in:

- A uniform active ingredient concentration on leaves
- Improved utilisation of the applied inputs

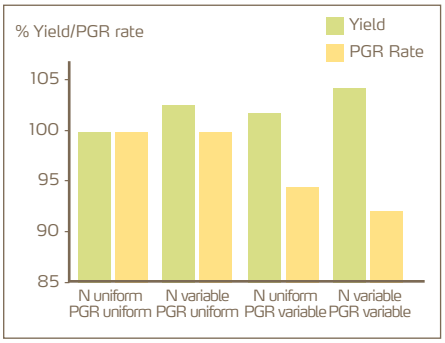
Traditionally, applications have been made based on soil area, but by altering rates according to the crop density it is possible to make more efficient use of what is applied. Crop density variations greatly influence the amount of active ingredient each leaf receives, and as a result will vary the effect it will have on the crop as well. By basing application rates on crop densities it allows a more uniform application of active ingredient across the whole field.

In 2002 work was carried out by a precision farming company in Germany on varying the rates of plant growth regulators using N-Sensor application maps. On farm experiments were then set up in 2003 and continued in 2004 on over 1300ha. In total the trials have so far been conducted on 3000ha, with the following results. There was an overall yield increase from 0.1-0.3t/ha, a reduction in the rate of growth regulator used of 10-30% and visible reductions in lodged grain each year. Figure 8 shows the variations in yield and growth regulator inputs from the different treatments on trials from 2002 to 2004. These trials looked at both variable nitrogen inputs as well as variable growth regulators, an in all trials the combination of varying both inputs came out on top. The financial benefit of varying both nitrogen and growth regulator averaged £26.80 and ranged from just over £4 to just over £44/ha compared to constant applications of both.

Work has also been carried out by Plant Research International to develop a strategy to use sensing techniques to support decisions on herbicide treatments and doses. In 1999 they started research to develop a system for potato haulm killing herbicides. Trials in 2006 looked at varying herbicide rates using an injection sprayer. The results proved effective under difficult conditions, leading to an average reduction in herbicide use compared to standard practise of 46%.

To continue the development of N-Sensor further, Yara are always looking for new partners to develop applications for. If you wish to get in contact, email info@yara.com.

Figure 8. Comparison of uniform and variable rate PGR and Nitrogen applications



Benefits of the Yara N-Sensor™

Improved Yield - Improved Gross Margin

The single biggest benefit from using the N-Sensor is also the hardest to measure on farm, however Yara have conducted a large number of trials over the years looking at the yields of uniform compared to variably applied nitrogen in the UK and throughout Europe.

Figure 9 shows the yield response of 186 trials conducted on cereals comparing the use of the N-Sensor to uniform application. 82% of the trials showed advantage of using the N-Sensor. The average yield increase compared to uniform application was 3.2% with a maximum of over 12% on some trials.

The focus of the trial programme was not only to assess the impact of N-Sensor on yield but also to discover in what conditions it could be expected to get the best yield responses. Analysis has shown that where fields contain higher levels of variability due to changing soil type, manure application or topography, the benefit obtained from variable Nitrogen application using the N-Sensor was at its greatest.

Figure 9. Yield advantage with N-Sensor - 1999-2005 186 trials (172 Winter Wheat, 14 Winter Barley)

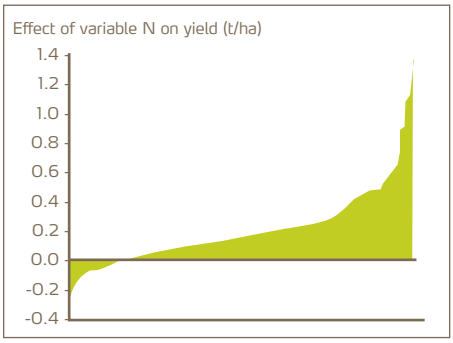
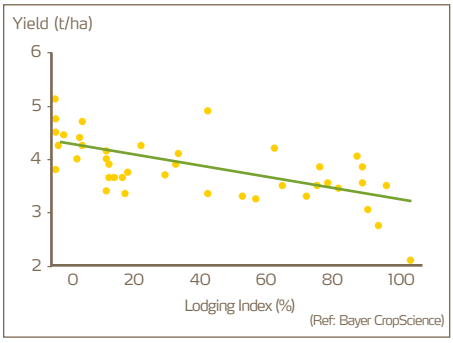


Figure 10. Impact of lodging on OSR



Reduced Lodging

One of the most common benefits seen by customers is the reduction in lodging from using the N-Sensor. By reducing the area of over application of nitrogen the N-Sensor helps to reduce the amount of crop lodging, which can have dramatic effects on its profitability through reduced yield and quality and increased harvest time and drying costs.
Lodging in oilseeds in particular as a result of too dense a canopy, can have a severe impact on yield, with losses of up to 30% possible (Figure 10).

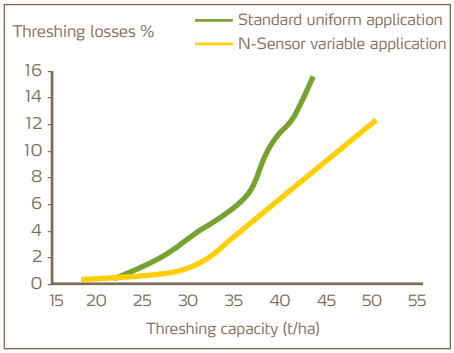
The photo below was taken from a trial in Germany in 2002. The overall difference in N rates between the two fields was less than 20kg/ha, but variably applying it with the N-Sensor avoided the severe lodging the field on the left suffered from receiving a uniform application.

Improved Combine Performance

Greater crop evenness achieved by using the N-Sensor also results in more even ripening enabling quicker harvesting and reduced drying costs.

Independent trials from 2002 to 2004 confirmed the improvements in combine output that came from the more even crop produced by the N-Sensor applications. Output increased by 10 to 26% across the trials with an average of 18.5% reducing harvest days required, and possibilities of reducing combine capacity requirements (figure 11).

Figure 11. Improved combine performance



Even Grain Quality

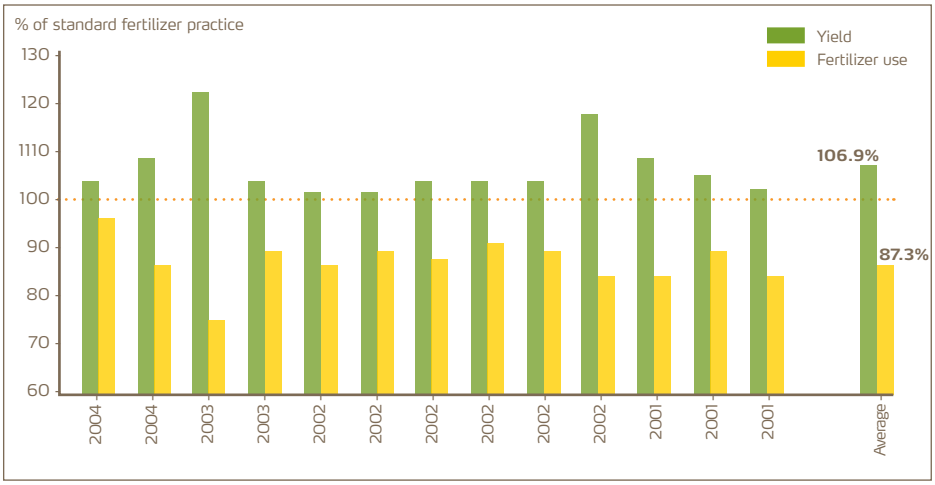
By applying the crop's optimum nitrogen requirement in all areas of the field, the N-Sensor has the effect of helping to reduce the variability in yield and grain quality over the field. A trial carried out in 2002 looking into the application of late nitrogen in winter wheat showed that the variability in protein quality was reduced by over 60% where N-Sensor was used, compared to uniform application.

Increased Nitrogen Use Efficiency

Application of the correct amount of nitrogen to all parts of the field also has a positive environmental benefit by improving nitrogen use efficiency. Over application is significantly reduced and as a result less nitrogen is left in the soil post harvest, which helps to minimise leaching potential. Where N-Sensor was used there was a large reduction in excess nitrogen application compared to Farmers Practice.

Figure 12 shows the results of a 4 year trial comparing the use of the N-Sensor with standard practice where yield was increased by 6.9% whilst fertilizer use was reduced by 12.7%, leading to significant improvements in nitrogen use efficiency.

Figure 12. Comparison of N-Sensor use against standard farm practice (Yara, 2001-2004)



Comparisons with Other Systems

Scans at a higher resolution than satellites, whilst scanning a greater area than other tractor mounted sensors in the market

N-Sensors scan the crop on either side of the tractor or sprayer, measuring up to 38% of the working area, (depending on the bout width and mounting height).

This helps to ensure that the impacts of field boundaries, grass margins and in-field trees are not affecting the readings and therefore the nitrogen applications.

Gains an oblique view of the crop

The N-Sensor scans the crop at an angle, rather than looking vertically onto the crop to help eliminate the issues caused by small crops and weeds. Any sensor used for measuring crop nitrogen is unable to distinguish between crop and weeds when growing together in a field, however by not looking vertically at the crop, the N-Sensor will not measure weeds which are present below the canopy surface, unlike any sensor aimed to look directly into the crop.

This angle also helps to increase the accuracy of measurement when the crops are small, as the ground cover of a backward crop early in the season may be difficult to detect by looking straight down at it.

N-Sensor has the ability to compensate for different light conditions and cloud cover

Systems relying on satellites are very dependent on clear skies at the time the satellite is overhead in order to obtain the field images. One of the advantages of using N-Sensor is its ability to adjust to different light conditions, enabling it to continue working even during dull or cloudy conditions, which can be important when using liquid fertilizer. The N-Sensor ALS takes this one step further; by using its own light source it can operate irrespective of ambient light conditions.

N-Sensor is a 'real-time' system

N-Sensor is a 'real time' sensing device as it has the ability to scan the crop, convert the readings taken into an application rate and adjust the spreader or sprayer as the tractor passes over the crop. This means there is no time delay between any of the steps at a crucial time in the crops development. The system includes not only the sensor, but also the terminal, installation and one year's agronomic advice.

The operator can watch the computer working installing an element of reassurance that it's working correctly

The onboard computer is clear and easy to use, and during application clearly displays the changing nitrogen rates that are being applied. In certain areas of the field this allows the operator to see how the N-Sensor is altering the rates whilst being able to visibly see differences in the crop.

Operates using a windows based terminal

The old terminals that have in the past been used with the N-Sensor are now being replaced. The newer terminals are windows based and are therefore a lot easier to use and a lot clearer. As well as controlling the spreader or sprayer, they also have the ability to control drills for variable rate seed application and carry out other tasks such as parallel tracking and auto steer.

Measures different wavelengths that are more closely correlate to N uptake than NDVI used by all others

The majority of other sensing systems on the market measure the normalised difference vegetation index (NDVI) to calculate biomass and work out the nitrogen content from this. N-Sensor measures different wavelengths to the others in order to more accurately calculate the nitrogen in the crop. This is a fundamental difference between the systems, especially at high biomass levels as the NDVI reading becomes saturated and loses its accuracy (figure 13 & 14). Trials conducted annually by Yara at the research centre in Hanninghof help to show the correlation between the N-Sensor reading and the measured nitrogen uptake from destructive laboratory leaf analysis.

The wavelengths measured by the N-Sensor have helped increase the R^2 value from 76% by measuring the NDVI, to 93%.

Figure 13. Typical N Uptake graph for sensors using NVDI - Note the strong saturation effect at high N uptakes

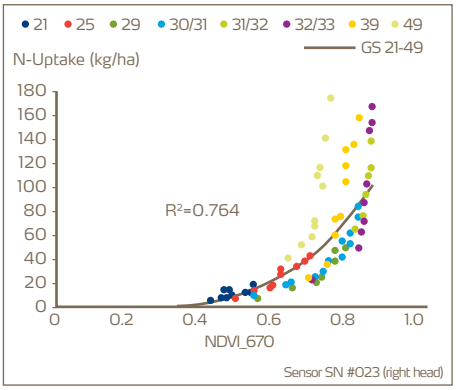
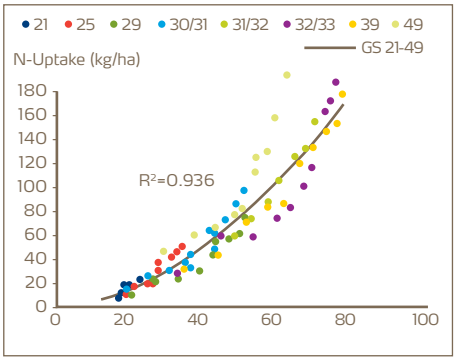


Figure 14. N Uptake graph for the N-Sensor



N-Sensor™

- Increases yield - 3.5% on average
- Increases Gross Margin and Profitability
- Reduces lodging
- Improves Nitrogen Use Efficiency
- The most accurate measure of crop nitrogen available, not reading NDVI
- Backed by science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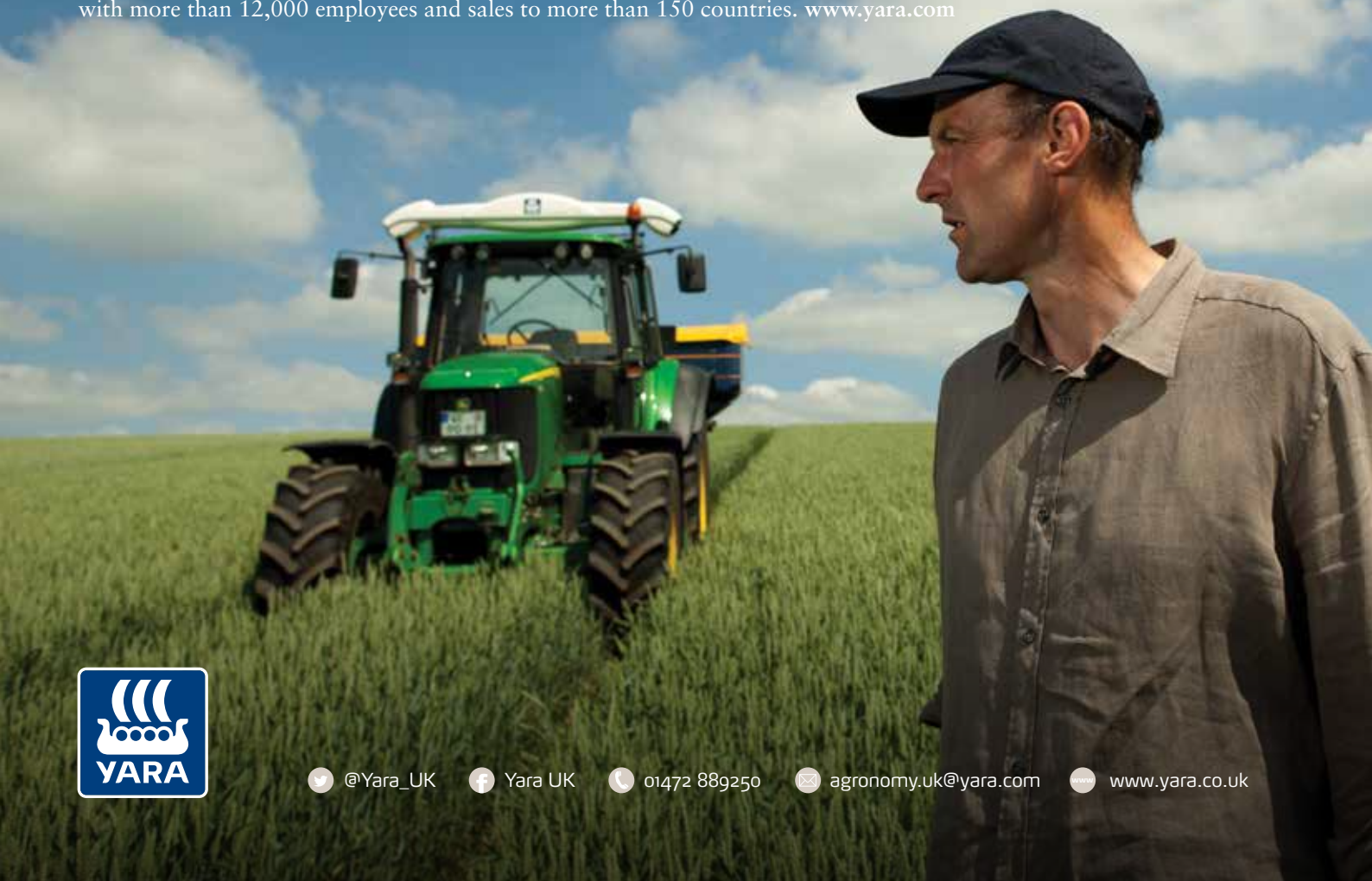
About Yara

Yara's knowledge, products and solutions grow farmers and industrial customers' businesses profitably and responsibly, while nurturing and protecting the earth's resources, food and environment.

Our fertilizers, crop nutrition programs and technologies increase yields, improve produce quality, and reduce environmental impact from agricultural practices. Our industrial and environmental solutions reduce emissions and improve air quality from industry and transportation, and serve as key ingredients in the production of a wide range of goods.

Founded in 1905 to solve emerging famine in Europe, Yara today has a global presence with more than 12,000 employees and sales to more than 150 countries. **www.yara.com**



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