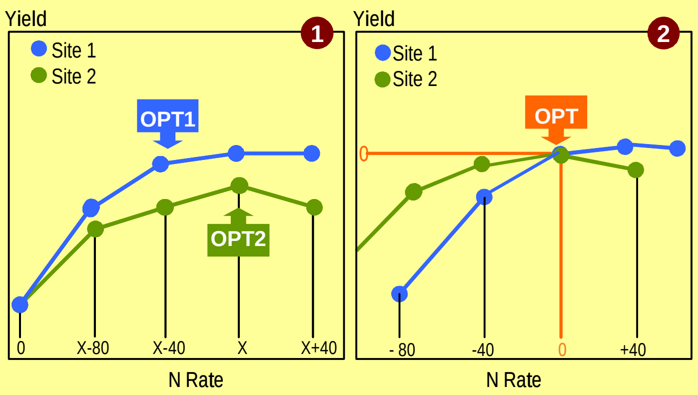
Optimum nitrogen rates for wheat

Impacts of wheat and nitrogen fertiliser prices

At current wheat prices, does an increase in nitrogen unit price require adjustment to the total nitrogen rate? Two methods can help answer this question.

A situation with wheat at 180 €/t and N at 0.70 €/kg, would only require a small increase in the fertiliser rate (+ 8 kg N/ha) compared with a scenario with wheat at 100 €/t and N at 0.50 €/kg.

Principle of centring crop response curves on the "optimum" nitrogen rate of each trial *(fig. 1)*



Post harvest, each yield response curve ① helps to identify which nitrogen rate resulted in a yield equivalent to at least 97% of the maximum yield of the trial. Each curve is then "moved" so that it is centred horizontally on that rate, called optimum rate, and vertically on the corresponding yield. The figure on the right②) represents the difference in yield when the nitrogen rate differs from the optimum rate

The increase in nitrogen unit price over the past few months poses the question of whether or not fertilisation should be adjusted.

Our aim was to answer this question globally, in relation to the whole wheat area in France. 558 "crop response to nitrogen curve" trials carried out between 1991 and 2002 helped build a set of data highlighting the impact of increasing nitrogen rates on yield and grain protein content. In order to analyse them simultaneously, nitrogen rate and yield must be expressed on scales which do not take account of local characteristics (soil nitrogen supply and yield potentials). By centring both scales on an optimum rate to maximise yield *(figure 1)*, it becomes possible to quantify the impact a lack or excess of nitrogen has on yield and protein content *(figure 3).* Quadratic and linear models were adjusted according to yield and protein content recorded after centring the data on those optimum rates. The adjusted models therefore characterise the average impact of nitrogen fertilisation at an overall national level, and account for respectively 77% and 69% of the total variability.

Using the average relation between nitrogen rate and yield *(figure 3a)* helps to calculate the sufficient nitrogen rate required to maximise the per hectare margin, using a hypothetical wheat-nitrogen prices pairing. We chose to compare the economic impact of this optimum rate with a reference scenario representative of the situation experienced before the increase in nitrogen fertiliser prices: 100 €/t for wheat and 0.50 €/kg for N. *Table 1a* shows adjustments that need to be made to nitrogen rates according to wheat and fertiliser price variations, compared with the reference scenario. The impact of those adjustments on protein content was evaluated using the relations shown in *figure 3b*. Results are presented in *table 1b*.

> 558 trials helped to illustrate the impact an increase in nitrogen rates has on yield and grain protein content.

A few points must be emphasised following this programme:

- the overall summary of hundreds of trials carried out over more than ten years does not allow going further than presenting average trends: figures in *table 1* must not therefore be interpreted as figures individually recorded in each particular case, and are only valid on the scale of the whole French wheat area.
- *a contrario,* the wide range of environments (soils and climates) exported by this set of multi-site and long-term reference data, gives weight to those trends.
- we did not include additional costs linked to nitrogen fertilisation adjustment, such as the number of applications (resulting in variations in spreading costs.).

Fertiliser production cost: strongly depends on gas production cost

Manufacturing nitrogen fertiliser first requires synthesising ammonia (NH3) which uses atmospheric nitrogen (N2) present in the air, and natural gas as a source of hydrogen.

Urea and ammonium nitrate are obtained by ammonia reacting with CO2 or nitric acid, whereas liquid nitrogen fertiliser is obtained by mixing the latter components with ammonium sulphate.

Whereas the price of ammonia accounts for 30% of the cost of producing calcium ammonium nitrate, the price of natural gas accounts for 50%, which means that 80% of the cost of this nitrogen fertiliser is more or less directly due to the price of gas, which can vary on a scale of 1 to 10 between supply sources (Norway, Russia, Algeria and the Netherlands).

The ammonia world market, ruled by a small number of players, is also subject to strong pressure in the USA and even in Europe

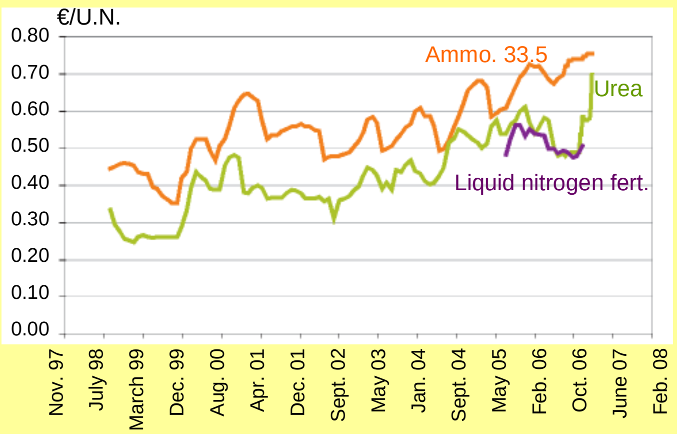
Gas prices being in line with oil prices, nitrogen fertiliser prices are partly subject to hydrocarbon price fluctuations.

In addition, strong world demand for nitrogen fertiliser weighs heavily on prices observed in Western Europe.

Straight nitrogen fertilisers used in France (all crop types) are essentially in the form of calcium ammonium nitrate (51%), liquid nitrogen (31%) and urea (13%). Those forms of nitrogen can experience very sudden price variations, like the latest one due to fluctuations linked to imports on the domestic market (figure 2). After following a peak and trough pattern, nitrogen unit price has now seen a 40% increase over the last four years.

Source: Unifa, 2006

Average nitrogen unit prices between Sept. 1998 and Feb. 2007 ***(fig. 2, data recreated based on data from various sources).***



However, this approach has limitations on two counts:

- "average curves" used to quantify the impact of input and product prices do not allow analysis of the variability in reactions to nitrogen between sites and years.

- our analysis work comes post trials: centring the crop response curves on the "reference" point (97% of the trial's maximum yield) is equivalent to assuming we are able to forecast the rate which maximises the yield for each of the site-year pairs studied. This approach does not reflect the reality of fertiliser rate management based on decision-making rules (balance method, regional grids...) using hypotheses regarding plant population's need for nitrogen, soil nitrogen supply and fertiliser efficiency.

Another way of dealing with the issue

Compared with our reference scenario (100 €/ t for wheat and 0.50 €/ kg for N), only a small increase in fertiliser rate (+ 8 kg N/ha) is required to maximise the economic margin when wheat is at 180 €/t and nitrogen at 0.70 €/kg.

To avoid limiting the data gathered from a large number of trials to a mere average curve, we are proposing a different approach, comprising three stages:

- modelling the crop response to nitrogen based on the relations between nitrogen rate –nitrogen uptake, and nitrogen uptake – yield, which take account of the main characteristics of the site (including soil nitrogen residue at the end of winter).
- using 115 experiments carried out in central France over a period of ten years to evaluate the parameters of the model.
- using the model to forecast the impact the fertiliser rate will have on yield and protein content depending on local characteristics (a thousand crop response curves are created using the parameter measurements previously recorded).

Those curves are then used to calculate a nitrogen rate which maximises the gross margin, depending both on local characteristics and on wheat and fertiliser prices.

The price of nitrogen fertiliser has increased by almost 40% over the last four years.

Impact of an excess or lack of nitrogen on the yield and protein content of wheat (558 trials) *(fig. 3)*

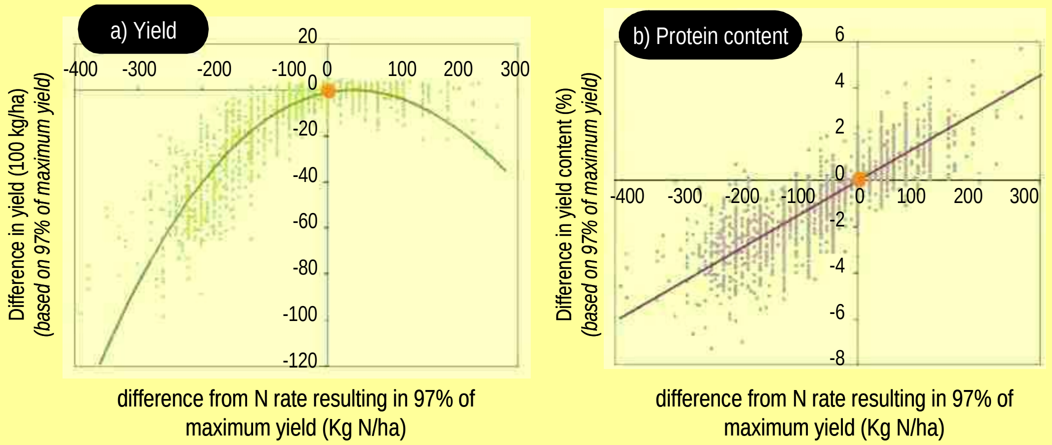
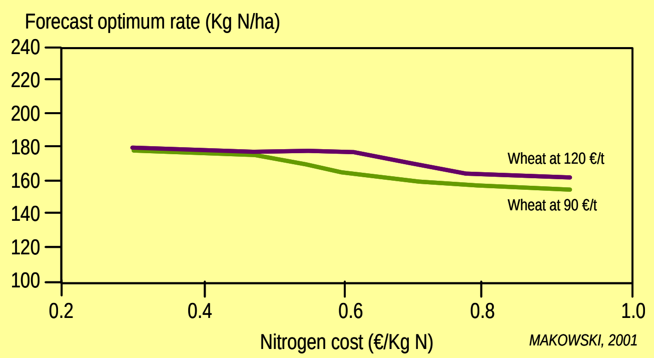


Figure a) shows the relation between a lack or excess of nitrogen (compared with the rate resulting in a yield equivalent to 97% of the maximum yield obtained for each trial) and the difference in yield and protein content. The reference scenario (100 €/t for wheat and 0.50 €/kg for N) used to quantify the impact of nitrogen and wheat prices (table 1) is represented by the orange circle

This approach has the advantage of helping to quickly develop models which simulate wheat and barley yield as well as protein content, using a "nitrogen trials" type database. Those models help to determine recommended fertiliser rates to maximise farmers' revenue, taking account of the economic situation and soil nitrogen supply levels, which the balance method does not do. This approach also helps to analyse the variability of crop response to nitrogen between sites and years.

Five nitrogen prices and two wheat prices were used successively to calculate fertiliser rates maximising revenue. The results help to see the sensitivity of the optimum rate to those economic factors *(figure 4)*.

Impact of wheat and fertiliser prices on the nitrogen rate maximising revenue per hectare *(fig. 4)*



Increasing nitrogen fertiliser prices are resulting in a reduction of the recommended rate of 15 to 20 kg N/ha

With this method, the impact of an increase in wheat prices between 90 and 120 €/t results in increasing the nitrogen rate by 10 kg/ha, which is consistent with the 8 kg N/ha calculated using the previous method with similar prices. The anteriority of this study explains the absence of tests based on a higher wheat price in line with current prices. However, trend convergence allows us to think that a price of 180 €/t increases the recommended optimum rate by around 20 kg N/ha compared with the lower level of remuneration.

> Taking account of the variability of the response to fertiliser rate limits the sensitivity of optimum rates to the price impact.

Logically, an increase in fertiliser cost results in a reduction in the optimum fertiliser rate. Using this new approach, a rise in nitrogen prices from 0.46 to 0.91 € /kg leads to a reduction in the optimum rate of between 15 and 20 kg N/ha, compared with 25-30 kg N/ha with our first calculation method.

This lesser flexibility of the optimum rate depending on fertiliser cost seems due to the fact that the variability is explicitly taken into account in the decision-making process (since here each parameter of the functions describing the response to nitrogen is weighted by variability, which is not the case in the first approach based on the average response for the 558 experiments).

Finally, we need to point out that the remuneration for protein content was not taken into account to calculate the optimum nitrogen rates in *figure 4*. However, protein content-based remuneration leads to modifying optimum fertiliser rates if the main objective is to maximise the economic margin. This effect has been demonstrated in previous studies on durum wheat (+ 40 to + 50 kg N/ha) and malting barley (0 to - 30 kg N/ha). In the case of soft wheat, a "protein premium" of + 3 to +7 €/t modifies the total optimum rate by + 10 to + 35 kg N/ha. Any pricing policy based on protein content will have a significant impact on the way fertiliser rates are managed, and is likely to modify the adjustments previously mentioned.

Any remuneration policy based on protein content will have a significant impact on the way fertiliser rates are managed.

Average impact of wheat price and nitrogen cost on the optimum nitrogen rate as determined post harvest, and effect on grain protein content *(tab. 1)*

(This impact is calculated by comparison with the reference scenario - 100 €/t for wheat and 0.50 €/kg for N - which is represented by the blue rectangle)

	OPTIMUM RATE (kg N/ha)											
	Wheat price (€/tonne)											
N cost (€/kg N)	90	100	110	120	130	140	150	60	170	180	190	200
0,30	12	15	17	19	20	21	23	23	24	25	26	26
0,35	8	11	14	16	17	19	20	21	22	23	24	24
0,40	4	7	10	12	14	16	17	19	20	21	22	23
0,45	0	4	7	9	11	13	15	16	18	19	20	21
0,50	-4	0	3	6	9	11	12	14	15	17	18	19
0,55	-8	-4	0	3	6	8	10	12	13	15	16	17
0,60	-12	-7	-3	0	3	5	7	9	11	12	14	15
0,65	-16	-11	-7	-3	0	3	5	7	9	10	12	13
0,70	-20	-15	-10	-6	-3	0	2	5	7	8	10	11
0,75	-24	-18	-13	-9	-6	-3	0	2	4	6	8	9
0,80	-28	-22	-17	-12	-9	-5	-2	0	2	4	6	7
0,85	-32	-26	-20	-15	-11	-8	-5	-2	0	2	4	6
0,90	-36	-29	-23	-18	-14	-11	-7	-5	-2	0	2	4
0,95	-40	-33	-27	-21	-17	-13	-10	-7	-4	-2	0	2
1,00	-44	-36	-30	-24	-20	-16	-12	-9	-7	-4	-2	0
	PROTEINS (%)											
	Wheat price (€/tonne)											
N cost (€/kg N)	90	100	110	120	130	140	150	160	170	180	190	200
0,30	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,4
0,35	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,3	0,4	0,4
0,40	0,1	0,1	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,3
0,45	0,0	0,1	0,1	0,1	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,3
0,50	-0,1	0,0	0,1	0,1	0,1	0,2	0,2	0,2	0,2	0,3	0,3	0,3
0,55	-0,1	-0,1	0,0	0,0	0,1	0,1	0,2	0,2	0,2	0,2	0,2	0,3
0,60	-0,2	-0,1	-0,1	0,0	0,0	0,1	0,1	0,1	0,2	0,2	0,2	0,2
0,65	-0,2	-0,2	-0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,2	0,2	0,2
0,70	-0,3	-0,2	-0,2	-0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,2
0,75	-0,4	-0,3	-0,2	-0,1	-0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,1
0,80	-0,4	-0,3	-0,3	-0,2	-0,1	-0,1	0,0	0,0	0,0	0,1	0,1	0,1
0,85	-0,5	-0,4	-0,3	-0,2	-0,2	-0,1	-0,1	0,0	0,0	0,0	0,1	0,1
0,90	-0,6	-0,4	-0,4	-0,3	-0,2	-0,2	-0,1	-0,1	0,0	0,0	0,0	0,1
0,95	-0,6	-0,5	-0,4	-0,3	-0,3	-0,2	-0,1	-0,1	-0,1	0,0	0,0	0,0
1,00	-0,7	-0,6	-0,5	-0,4	-0,3	-0,2	-0,2	-0,1	-0,1	-0,1	0,0	0,0

When wheat is at 100 €/t, an increase in the price of nitrogen fertiliser from 0.50 to 0.70 €/kg can justify a decrease in nitrogen fertilisation of 15 kg/ha resulting in a 0.2% decrease in protein content. In the updated situation (wheat at 180 €/t and N at 0.70 €/kg), a slight increase in fertiliser rate (+ 8 kg N/ha) is required, without having a significant impact on protein content.

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Tactical fertilisation choices

With wheat at 180 €/t (regardless of special remuneration for protein content), if the nitrogen unit price doubled from 0.50 to 1.00 € (we are currently half-way there), the total nitrogen rate would need to be adjusted by - 20 kg/ha. This would result in an average reduction in protein content of 0.4%. With wheat at 260 €/t, the same nitrogen price increase would justify decreasing the rate by 15 kg N/ha.

The impact of a rise in wheat prices between 90 and 120 €/t leads to increasing the fertiliser rate by between 8 to 10 kg N/ha.

But advice is given pre harvest and must take account of vagaries (climatic, biological…) as well as of a degree of uncertainty linked to technical reference data used to develop decision -making rules (variability of need per ton, of soil supply and of fertiliser efficiency...). Therefore, the impact of nitrogen costs doubling is nearer -10 to -15 kg N/ha off the total rate. This decrease would of course be accompanied by a decrease in protein content likely to result in economic penalties, depending on the remuneration policy applying to the crop.

Taking account of the economic situation is therefore not easy as part of the tactical choices that have to be made regarding fertilisation. Given current wheat prices, the increase in fertiliser prices we have experienced does not warrant a complete rethink of total nitrogen rate recommendations.

The impact of doubled nitrogen prices (from 0.50 to 1.00 €/kg N) would be a reduction of the total nitrogen rate by -10 to -15 kg /ha