POTASH NEWS

December 2021

Potassium and nitrogen interactions in crops

Nitrogen has hit the headlines in the last few months, not just within agriculture, but across the mainstream media on the back of factory closures. Within agriculture the focus has clearly been on the steep price rises and the resulting impact on the economic optimum rates. These calculations are wholly justified, but as is often the case, are very singular focussed.

The technical paper on the PDA website titled 'Potassium and nitrogen interactions in crops' www.pda.org.uk/technical-potash-notes/potassium-and-nitrogen-interactions-in-crops/ by A E Johnston and G F J Milford, Rothamsted Research presents evidence from field experiments in the UK which shows that the plant-available potassium (exchangeable K) status of a soil has a considerable influence on the uptake of nitrogen (N) by crops. Yield response to applied fertiliser N is decreased when the exchangeable K content of a soil is below a critical target level.

This response by a crop to one nutrient being dependent on an adequate supply of another nutrient is known as an interaction between the two nutrients. Where such interactions occur there is no point in saving on one fertiliser input if this affects an important aspect of crop growth which limits the effect of another fertiliser input. And if N is used inefficiently not only is this a financial cost to the grower but there is also the risk that any excess unused fertiliser N lost from the soil can have undesired adverse effects on the environment.

The interactions between N and K on crop growth and yield that are seen at the agronomic level can be explained by their effects and interactions on the growth processes within the plant at the tissue and individual cell levels. Knowing how these interactions within the plant control its growth makes it easier to understand why it is important to have sufficient exchangeable K in the soil.

Maintaining an adequate level of soil potassium over the long term is important because on potassium deficient soils it is difficult to distribute fresh potash fertiliser sufficiently evenly throughout the rooting zone in the season it is applied for the roots to access enough potassium to produce optimum yields.

Crop processes underlying nitrogen and potassium interactions.

The primary processes involved in growth and dry matter production, such as photosynthesis and protein synthesis, upon which final yield depends, occur within individual cells and tissues. Although individual cells are extremely complex and often highly specialised to perform different functions, they can be visualised simply as an expandable cell wall enclosing a central space, the vacuole, containing an aqueous solution. Because it is largely composed of water, the vacuole has an important role in the water economy of the plant and it acts as a 'general storage compartment' for nutrient ions, like potassium, phosphate and magnesium, and other solutes like sugars.

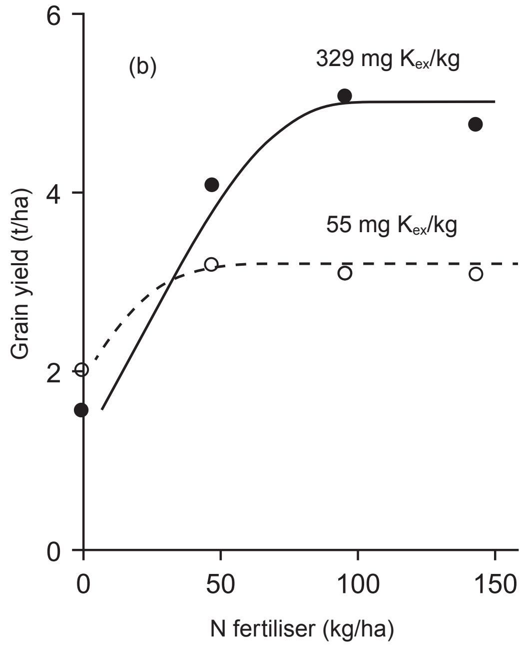
The vacuole of a mature cell comprises more than 80-90% of the total cell volume and contains most of the plant's water. The volume of water contained within cells increases considerably as cells expand (for example, a two-fold increase in cell length, approximately results in an eight-fold increase in cell volume and quantity of vacuolar water). This has implications for the K requirement of the plant because the forces (or turgor pressures) required to power cell expansion are ultimately generated by the concentrations of osmotic solutes within the vacuole, and potassium is the major osmotic solute.

One major determinant of growth and a prerequisite for large yields in most arable crops is the rapid expansion of the leaf canopy in spring which allows it to fully capture the sunlight energy required to convert carbon dioxide (CO_2) first to sugars (soluble carbohydrates, e.g. $C_6H_{12}O_6$) and then into dry matter. Nitrogen is a major driver of leaf canopy expansion, which it does by increasing cell division and cell expansion. This large, nitrogen-induced increase in cell number and volume, and the consequent changes in cell water, requires a corresponding increase in the uptake of potassium to maintain the osmotic concentrations of leaf tissues (which otherwise will become diluted) at an effective level to maintain turgor. Much of the total N and K required by crops is therefore taken up to sustain development and expansion of the leaf canopy during the early months of growth.

The interaction between N and K is well illustrated by an example from the Hoosfield Barley experiment started in 1852 at Rothamsted. Over the years, large differences in soil exchangeable K have developed between plots to which fertiliser K was or was not given. When four amounts of N were tested on both high and low K soils there was a considerable difference in the response of spring barley to the applied N (Figure 1). The small yields may partly be explained by the fact that barley was grown every year but, even so, the principle of N x K interaction is clearly demonstrated. The average yields between 2000 and 2005 show that there was no justification for applying more than 50 kg N/ha to the barley grown on the soil with only 55 mg/kg exchangeable K, but yield was further increased by an application of N of up to 96 kg/ha when the soils contained adequate amounts of exchangeable soil K.

This interaction is not just seen in arable crops. An N × K interaction was also shown in an experiment on grass at Rothamsted in 1965-68. Nitrogen was tested at 40 and 80 kg N/ha applied for each cut of grass, usually four harvests per year. Grass yields were greatly increased by adequate exchangeable soil K (Figure 2) whilst the uplift in yield from the higher

Figure 1: Response of spring barley to N fertiliser on soils with different levels of exchangeable soil K (Kex), Hoosfield, Rothamsted.



N rate was also much greater with adequate levels of exchangeable soil K.

Another N × K interaction was shown by Rothamsted experiments on winter wheat on a sandy clay loam soil at Saxmundham in 1983 and 1984. There were plots with two levels of exchangeable K, but

Figure 2: Interaction between nitrogen and potassium on the yield of grass. (Park Grass experiment, Rothamsted 1965-1968).

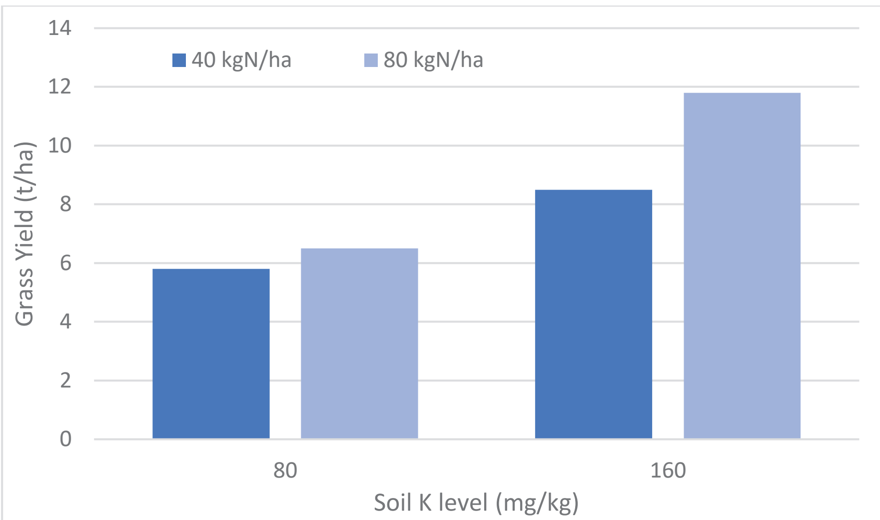
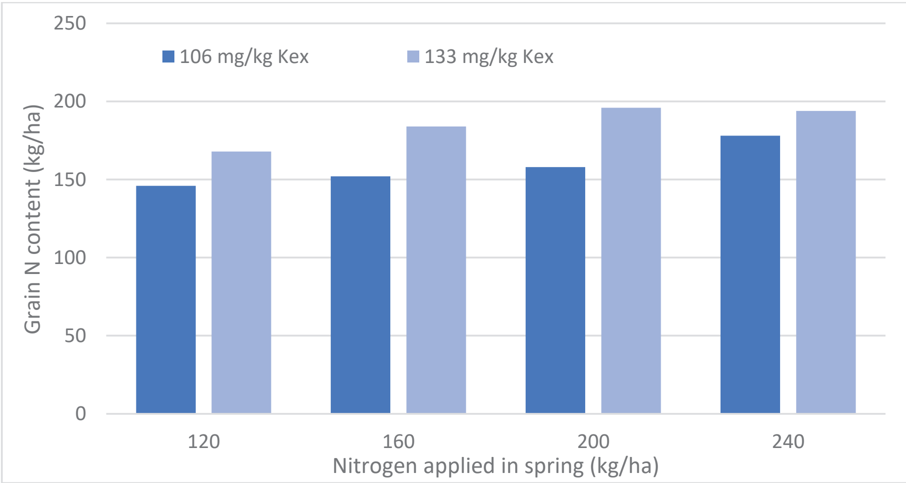


Figure 3: Effect of soil potassium and applied nitrogen on the nitrogen uptake in winter wheat grain grown on a silty clay loam at Saxmundham, 1983 and 1984.



the same amount of plant-available phosphate, and four rates of N fertiliser were tested (40 kg N/ha at sowing followed by 120, 160, 200 and 240 kg N/ha in spring). The increase in the average grain yield for the two years with increasing amounts of applied N was not large but, was larger for each rate of applied N on the soils with more exchangeable K. The grain N contents were also larger (figure 3). More importantly, only 160 kg N/ha was required to obtain maximum yield on the soil with more exchangeable K compared to 240 kg/ha on the soil with less exchangeable K.

Similar effects in farm practice could offer the opportunity for considerable savings in the cost of N fertiliser. The larger grain protein contents show that crops grown on soils with more exchangeable K took up more of the applied N. As the applied N increased from 120 to 200 kg/ha, the increase in yield ranged from 12-20% and the increase in N content from 15-24% due to the soil containing more exchangeable K.

Applying N to meet increasing demand by a rapidly growing crop invariably results in a very obvious visual response, which is usually associated with an increase in yield. This frequently observed association between N supply and yield is expected almost as a matter of course. What is less obvious and rarely realised, however, is that the increased supply of N also greatly increases the amount of water in the crop. For example, the shoots of a cereal crop well supplied with N can contain between 10-15 t/ha more water than those of a crop where N is limited. The difference in water content between sugar beet crops well- and poorly-supplied with N is even greater. A crop well supplied with N can contain 30-35 t/ha more water than one given less N. The increased water content in crops well supplied with N is the direct result of the stimulation of cell division and cell expansion. The increased water content leads to an increased demand for larger amounts of osmotic solutes, principally as potassium, to maintain turgor. Thus, applying more N to increase yield requires more plant-available K in the soil and without this K, the response to N will be limited.

PDA Leaflets

An updated copy of the OSR leaflet has been included with this newsletter. An online version can also be found on the website at www.pda.org.uk/pda_leaflets/13-oilseed-rape-and-potash/