Technical
Bioscience insider

Harvest more light

Plants suffer environmental and physiological stresses throughout their lives. Research has found that upregulating the production of chlorophyll at key times can boost productivity. *CPM* reports.

By Lucy de la Pasture

The one thing all cropping systems have in common is that they're harvesting light. Photosynthesis is the process of converting light energy to chemical energy which is stored in the bonds of plant sugars. This sugar becomes the building blocks for proteins, oils and carbohydrates that are harvested for food.

One of the key aims of plant breeders is to elevate photosynthesis to produce more productive plants, explains Dr Nigel Grech, director of Unium BioScience. The faster the solar factory functions then more simple sugars (CHO — carbon, hydrogen and oxygen) are produced to form the building blocks of yield.

What does the science say?

Researchers have found that a leaf with 70 million cells houses five billion of the solar powerhouse structures, the chloroplasts. Each one of these contains approx 600 million molecules of chlorophyll. Together these trillions of chlorophyll molecules, all of which are bound to proteins of the photosynthetic membranes, harvest the sunlight. In fact half of the proteins present in plant leaves are geared towards photosynthesis, points out Nigel.

Chlorophyll molecules transfer the absorbed light energy through neighbouring pigments to a "special pair" of chlorophylls in a reaction centre. Thisspecial pair of chlorophylls in photosystems I and II are the primary electron donors that drive the conversion of light into chemical energy, he explains.

"Light excites the chlorophyll, producing an energy cascade that enables the plant enzymatically to fix carbon and split water. Chlorophyll is a green coloured pigment so is in the middle of the visible spectra and absorbs light of every colour other than green. That makes it very efficient as it's able to harvest light in both the high energy blue spectrum and the longer-wave red spectrum.

"Structurally the chloroplasts which house chlorophyll are architectural masterpieces. Their structure is optimised to capture light and they're able to change their shape under different light conditions, a process which is possible because of the speed that proteins are turned over in plant leaves," he adds.

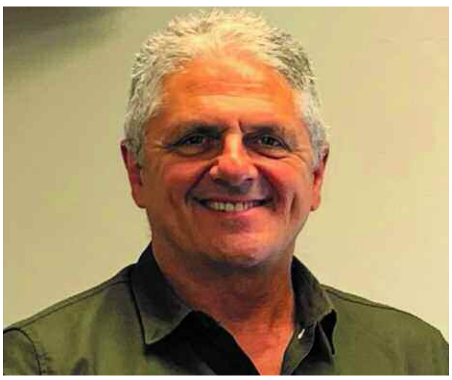
"Photosynthesis is limited by low and high light levels. Like a solar panel, the process goes less quickly on a cloudy day. In the Northern hemisphere light levels change with day length, which limits photosynthesis in winter.

"In summer high light intensity can also pause the process as photo-inhibition can occur, which is more common in arid climates. However, climate change is resulting in temperate plants experiencing more of the hot dry conditions conducive to light saturation inhibition of chlorophyll," he explains.

"Plants evolved to use much higher atmospheric rates of CO_2 than are present today. In Jurassic times CO_2 was present at around 1500ppm which is much greater than the current levels of 400ppm. That means the mechanism to upregulate photosynthesis is already present in plants, with the only limitation being the levels of CO_2 available. This is why elevated CO_2 levels can be successfully used in glasshouses to boost productivity.

"Interestingly, in temperate summers plants may have adequate light, water and nutrients but be limited by CO_2 levels, he adds.

Nigel believes this CO_2 limitation also affects the productivity of crops in



Klorofill contains pentanoate which is a precursor in the chlorophyll C5-synthesis pathway and contains a keto acid which elicits chlorophyll biosynthesis.

temperate regions during summer because plants have a higher capacity to fix CO_2 than is currently available in the atmosphere, limiting optimal sugar synthesis.

He points out that photosynthesis is also driven by temperature, with C4 plants (such as maize) better able to photosynthesize at higher temperatures than C3 plants (such as wheat).

"C3 plants aren't adapted to hot conditions and excess heat can induce stomatal closure and photosynthetic inhibition," he says.

From Science to Bioscience

So how can the process of photosynthesis be optimised? By upregulating chlorophyll biosynthesis, explains Nigel. Unium have found a plant-derived molecule that can do just this.

"Pentanoate is a unique biological chlorophyll booster. It's a precursor in the chlorophyll C5-synthesis pathway and contains a keto acid which elicits chlorophyll biosynthesis. Peer-reviewed research shows pentanoate is also able to reverse the suppression of this pathway when the plant is under stressful conditions. As a result, it can significantly increase the net photosynthetic rate and gas exchange capacity of plants when they're under stress."

Unium have taken this precursor and formulated it

Flowering is stressful and Klorofill helps plants emerge from such stress periods by supplying the building blocks for chlorophyll biosynthesis.

with trace elements that are essential in chlorophyll biosynthesis in their product Klorofill.

"Chlorophyll pigment contains a magnesium atom in the centre of its structure, which means maintaining a supply of bioavailable magnesium is crucial to support its manufacture in leaves. Like all proteins, chlorophyll is continually turned over in the leaves — being made (anabolism) and being broken down (catabolism) — and Klorofill supplies the ingredients that help the plant make it," explains Nigel.

As well as magnesium, Klorofill supplies trace elements, including manganese and iron — which are needed as cofactors to enzymes in the respiration biochemical pathways. Organic sulphur is also supplied because it helps to stabilise proteins in the form of disulfide bridges.

"Klorofill ensures there are minimal limitations to chlorophyll biosynthesis and is useful early on and throughout the growing season when chlorophyll is being 'turned over' in the leaves."

As well as upregulating the production of chloropyll, one of the roles of Klorofill is to help plants when they're emerging from a period of stress.

"For example, if a crop is growing in a soil that's high in calcium then magnesium will have low availability. Magnesium is more soluble than calcium so if it's dry and then rains, calcium is released and outcompetes the magnesium in the soil solution to cause a transient deficiency in Mg. Klorofill is useful when plants are emerging from a dry period to make sure sufficient resources are available to start making chlorophyll again (this pathway is downregulated when the plant is under stress)."

High temperatures can also cause photosynthesis to slow down. "When under heat stress, C3 plants close their stomata and then the formation of chlorophyll suffers. So Klorofill has a good fit whenever there are periods where strong chlorophyll biosynthesis is needed to either maintain levels, during and when exiting stressful conditions," he says.

Proving the concept

Early proof of concept work was carried out by CMI and the work has continued in Agrovista

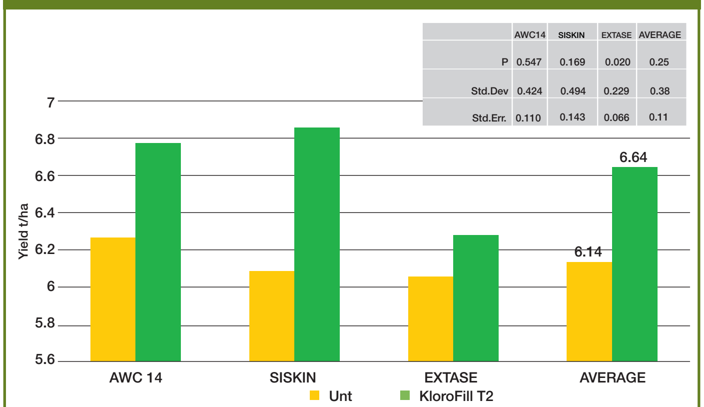
Mark Hemmant says targeting plants when they're under physiological stresses, such as flowering or rapid growth, gives reliable results.

trials. Mark Hemmant, technical manager at the agronomy company, says Klorofill has reliably produced more productive plants that are using nutrients more efficiently.

Agrovista assessments have shown increases in leaf chlorophyll levels and a visible improvement in green leaf area after Klorofill treatment. Trials have looked at its application in spring cereals, winter wheat and oilseed rape and Mark's now comfortable that adding Klorofill to tank-mixes not only boosts yields, but also doesn't disrupt fungicide performance in any way.

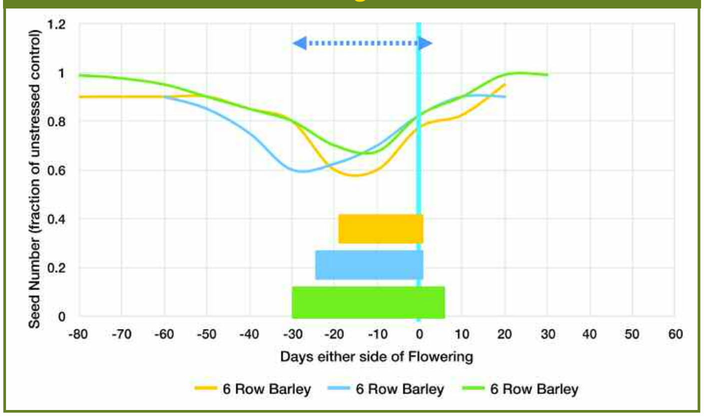
"Abiotic stress is difficult to predict in crops, so we've been targeting times when plants are under physiological stresses, such as flowering or rapid growth periods, to be sure of getting reliable benefits,"

Effect of Klorofill at T2



Source: F1 Seeds, 2020

Stress relative to flowering



Source: Unium, 2021

John Murrie says he consistently see flag leaves are darker green and bigger where Klorofill has been applied.

explains Mark.

"In spring barley we recommend targeting Klorofill at the tillering stage to GS30, which produced the largest yield increases in trials. Tillering is the period when the barley crop sets its yield and maintaining tillers means maximising the number of ears.

"Flowering is a physiologically stressful period in OSR and the effect of Klorofill has been seen in trials. Our recommendation is to target OSR at mid-flowering, when a sclerotinia fungicide spray is also likely to be applied.

"We're applying Klorofill when we know the crop needs it. OSR yield is all about setting the right number of seeds and the Healthy Area Duration (HAD) — keeping the canopy green for longer to help fill them."

A series of trials by Envirofield have shown that the T2 timing is the key growth stage to apply Klorofill to winter wheat, with the highest risk period for physiological stress occurring in advance of flowering. In 15 winter wheat trials an average yield response of 7% has been seen, with a 100% chance of a return on investment (ROI). An average yield response of 17% has been achieved in OSR (4 trials) and the average ROI over all trials is £81/ha.

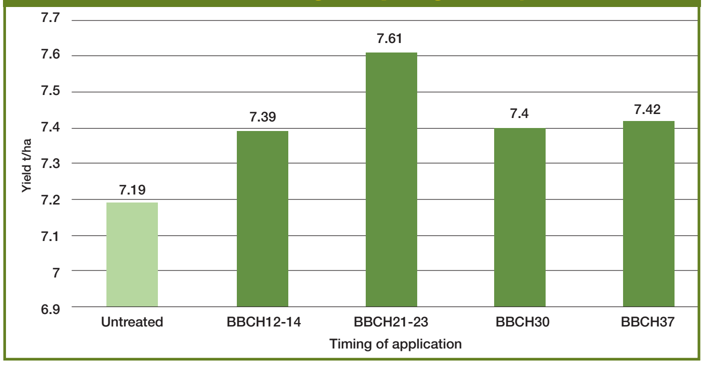
Unium director, John Haywood says that in every situation where Klorofill was applied, the levels of chlorophyll increased, together with an increase in yield.

"Other data points indicated that where chlorophyll was increased by over 20%, there was a corresponding yield increase of just 5%. Once the point of chlorophyll saturation (optimum) for the plant is reached then the yield will max out because something else has become yield-limiting," he explains.

Pioneers in the field

John Murrie farms 160ha of mostly arable land in central Scotland, between Dundee and Aberdeen. Spring barley for distilling is his major crop, with winter wheat, potatoes and vining peas filling the rest of his rotation.

Effect of Klorofill timing in spring barley



Source: Agrovista, 2018

Cover crops have always had a place on the farm and use of these has taken a step forward in recent years, due in part to the information gleaned from his other role as a technical manager for Agrovista.

"Improving soil health is central to my farming operation and I have arrived at my own version of regenerative agriculture — this year we've taken the significant step of moving to a minimal tillage system," he says.

"The drought in 2018 brought home to me how important a factor stress can be. The quality and size of barley grains was good, but we had high nitrogen and low yields. It really focused my mind on doing everything I can to increase the resilience of my soils."

So where does bioscience fit in to his farming system? John says it helps him produce a healthier crop and get more out of the soil, which is very light and gravelly.

"The majority of the crops suffer a stress period at some point in the spring. We've found Klorofill is one of the products that can help keep the crop going and recover when these happen."

Trials have shown that T2 is the best timing to apply Klorofill to winter wheat and feed barley, with yield increases of 0.4-0.5t/ha achieved in trials.

"We consistently see flag leaves are darker green and bigger where Klorofill has been applied. Leaves stay greener for longer and this increases grain fill and ultimately yield. We've also tissue-tested leaves and found when Klorofill was applied at GS30 all nutrients were elevated, except P and K."

Nitrogen content of the grain is his main consideration in the spring barley and John had concerns that Klorofill could cause an increase if it were used at the same timing as in wheat and feed barley (GS39). He's found that the product is better placed at GS30, another period of physiological stress as the spring barley crop begins stem extension and rapid growth.

"Keeping stress out of the equation is particularly important in spring barley because of ramularia, which lives in the plant happily until a stress period causes it to become pathogenic and release toxins. So we apply folpet to help control ramularia and Klorofill to relieve any plant stress," he says. ■

Bioscience insider

As the chemistry toolbox continues to shrink, a mesmerising array of new bio-solutions are coming to market, offering a range of benefits and complementary additions. Evaluating just how effective they are, and where they're best placed can be tricky, however.

This series of articles opens a window on the science behind these innovations. *CPM* has teamed up with Unium BioScience to explore the background, unravel the physiological processes and provide analysis on the results of trials. Above all, these articles give the grower an inside view on some of the exciting opportunities biosolutions offer in the field.

Klorofill contains pentanoate — an organic keto acid-based compound that is a unique biological precursor to chlorophyll synthesis. Pentanoate reverses the chlorophyll suppression that a plant may experience during rapid growth or periods of stress e.g. at flag leaf stage. By increasing chlorophyll production, Klorofill maximises green leaf area and plant biomass, boosting crop growth and therefore yield.

Learn more by joining the Unium technical group https://www.uniumbioscience.comunium-technical-group