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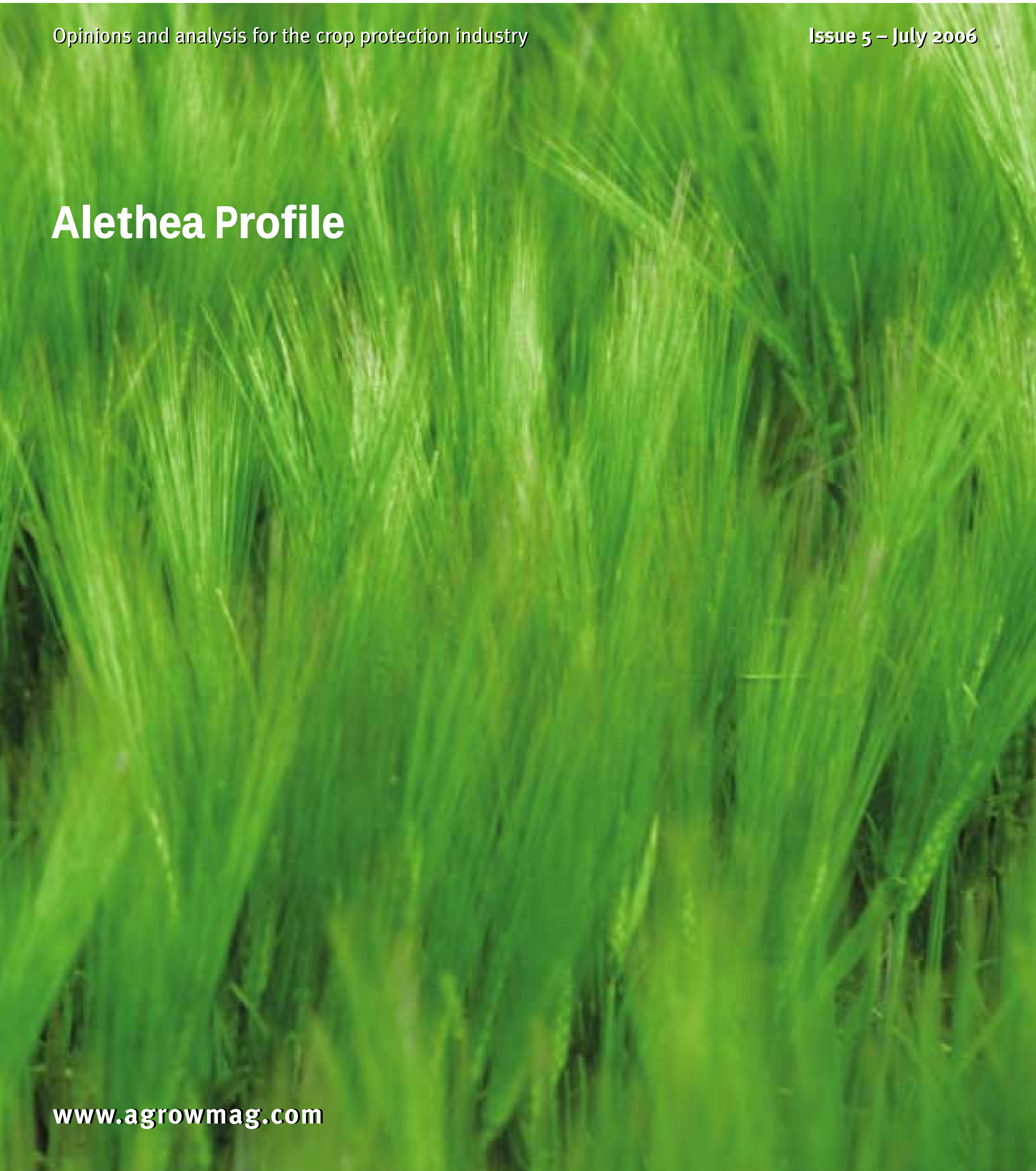

Opinions and analysis for the crop protection industry

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Alethea Profile

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A novel way to combat stress

The global pesticide industry is based on eradicating biotic stress in crops. But now, a new class of product has been developed that helps plants grow during conditions of abiotic stress, explains David Marks

Alethea, a patent-pending, novel anti-stress chemistry is at the forefront of a new generation of plant activators. In good experimental practice (GEP) trials it increased growth of stressed plants by as much as 140%, and in field trials (normal conditions) it has produced consistent yield increases of 60% while, at the same time, improving plant quality.

To understand how Alethea works, we need to look, in the first instance, at how stress affects plants and how they respond to it. There are two types of plant stress – biotic and abiotic. Biotic stress is stress caused by biological organisms (insects, fungi, bacteria, nematodes and weed competition). Abiotic stress is created by environmental conditions and encompasses intense light, ozone, herbicide damage, temperature stress (heat, cold, and freezing), water stress (drought and salinity), flooding and damage from heavy metals.

How much yield is lost to abiotic stress is difficult to quantify, as the type, level and frequency of stress encountered by crops is multiple, complex and shows variance from year to year. Stress does not need to be acute to cause yield loss – minor levels of stress throughout a growing season decrease the productivity of the plant by diverting metabolic energy to stress tolerance. These yield losses can be very significant and are demonstrated in Table 1, whose data is from a study comparing yield variation in US crops, and quantifying the typical level of loss due to biotic stress (addressed by agrochemicals) and abiotic stress.

It is clear from Table 1, therefore, that products which help plants combat abiotic stress represent a major opportunity for increasing yield. Furthermore, increased ozone levels and global warming are likely to result in increased levels of abiotic stress, and an expanding global population is likely to fuel the need to grow crops in land not currently suitable for agriculture in stressful conditions, such as regions with salty and arid lands, in the future.

EFFECTS OF ABIOTIC STRESS

Although the types of abiotic stress are many and varied, all result in excess production of toxic reactive oxygen species (ROS). These ROS are extremely reactive and cause damage to cell organelles, membranes and proteins. Plants have mechanisms to absorb ROS, but under either extreme stress conditions or prolonged stress conditions its mechanisms fail to cope, resulting in damage.

During photosynthesis, singlet oxygen ($^1O_2$) – a type of ROS – is formed, but is neutralised in normal circumstances by carotenoid pigments associated with the chloroplast. In stress conditions the level of singlet oxygen production is elevated and cannot be adequately absorbed by the plant. This leads to a series of reactions whereby various other ROS are also formed (including hydrogen peroxide (H_2O_2), superoxide (O_2^-) and hydroxyl radicals (OH)).

Because all kinds of stress affect all species of plants in fundamentally the same way (through ROS damage), effective stress-tolerance chemistry, if developed, is likely to be ubiquitously effective across the full range of climates and crops. Given the magnitude of crop losses because of abiotic stress, it is difficult to understand why more focus has not been applied to product development in this area.

Traditionally, stress tolerance has been achieved via breeding (by selecting crops that grow well in particular climates) or by improving cultural conditions through agronomic practice. Genetic manipulation of plants to enhance stress tolerance has been difficult, as the tolerance mechanisms in plants are complex, involve more than one metabolic pathway and are

AVERAGE AND RECORD YIELDS OF SOME MAJOR CROPS

Crop	Record yield (kg/ha)	Average yield (kg/ha)	Average yield (% of record yield)	Average loss due to biotic stress (% of record yield)	Average loss due to abiotic stress (% of record yield)
Wheat	14,500	1,880	13.0	5.0	82.1
Barley	11,400	2,050	18.0	6.7	75.4
Soybean	7,390	1,610	21.8	9.0	69.3
Maize	19,300	4,600	23.8	10.1	65.8
Potato	91,400	28,300	30.1	18.9	54.1
Sugar beet	121,000	42,600	35.2	14.1	50.7

Source: Data from Bray et al (2000)

Table 1: In crops such as wheat, average yield is only 13% of the maximal yield. The data clearly indicates that the largest influence on growth is climate (abiotic stress), not pests and disease.

regulated by more than one gene. This means that, in the case of stress tolerance, there is unlikely to be any one 'silver bullet' involving a single gene. Because of this, genetic manipulation for stress tolerance is considerably more difficult to achieve than that for pest-tolerant crops.

Plants' natural ability to cope with stress involves an escalation of the ethylene hormone. Ethylene is usually associated with ripening, and its key effects are reducing cell-to-cell adhesion and weakening cell walls (by moving calcium out of them). When stressed, the plant produces high levels of ethylene, which acts in the same way during the ripening process – calcium migrates from cell walls into the cytoplasm. This calcium is involved in neutralising ROS. The loss of calcium results in an increase in disease during stress conditions (cell wall weakening) and a decrease in quality.

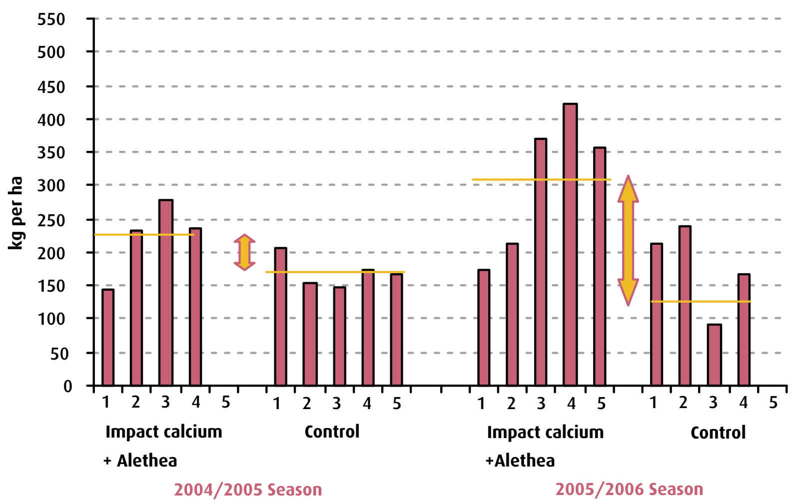
As stress conditions are alleviated, the plant needs to reduce ethylene and strengthen the cell wall. It does this by producing salicylates (chemicals similar to benzoic acid), which decrease ethylene production and encourage production of polyamines. Polyamines can substitute for calcium in the cell wall – giving strength.

The plant's other major strategy for protection from ROS damage is through increasing the production of antioxidants. These include carotenoids (which are associated with chloroplasts – the source of most ROS).

ENTER ALETHEA CHEMISTRY

Alethea is a chemistry developed by Plant Impact plc (British & International patent pending No 0409011.4) that combines a benzoic acid donor with a novel molecule – magnesium-dihydrojasmonate.

COCOA YIELDS* IN MATURE PLANTATION TRIAL (MPT) IN COSTA RICA IN 2004/2005 AND 2005/2006



Note: *dried cocoa seeds, extrapolated to kg ha-1 yr-1

Figure 1: The orange horizontal lines indicate corrected averages per treatment, the arrows the resulting, observed yield increase.

The benzoic acid donor encourages the maintenance of cell-wall integrity (preventing weakening during stress conditions). Like other products based on ethylene reduction, this strategy can improve some of the deleterious effects of stress – for example, cell-wall weakening that leads to higher disease incidence and a reduction in quality and shelf life.

However, all methods of ethylene reduction leave the plant less able to cope with ROS damage inside cells, which can cause yield loss and cell death. This has been a limitation of the technology based on moderating ethylene, and is one of the reasons trials using salicylates and similar chemicals can be inconsistent.

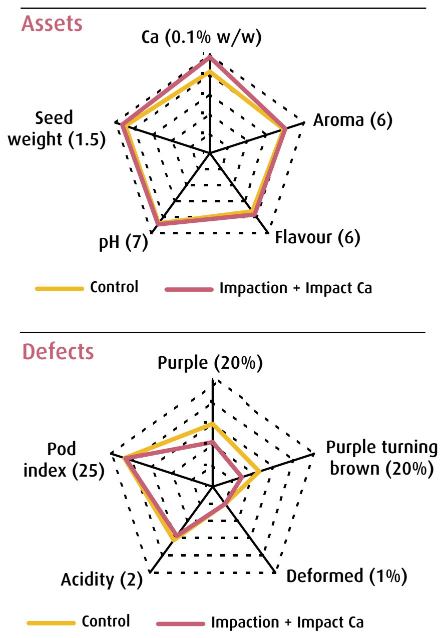
The inclusion of magnesium-dihydrojasmonate accelerates production of antioxidants by the plant, allowing Alethea to maintain cell strength during stress conditions. Its combination with a benzoic acid donor also reduces yield loss from ROS damage.

Alethea has been shown to increase growth in extreme stress in independent GLP studies, and has consistently achieved yield increases of >50% in field trials when incorporated into fertiliser products (patent applied for). Figure 1 shows data from independent trials carried out by CABI Bioscience between 2004 and 2006. These trials, now entering a third season, have shown statistically significant yield increases of >55% for two successive seasons. These yield increases have been achieved under normal climatic conditions (not extreme stress).

Figure 2 shows that yield increases in cacao (and many crops) can often result in a decrease in crop quality, but this has not been the case in the yield increasses achieved using Alethea chemistry.

FIGURE 2: CALCIUM CONTENT AND QUALITY ANALYSIS OF FERMENTED AND DRIED COCOA SEEDS

Mature Plantation Trial (MPT)



Note: Axis lengths in spidergrams are scaled and the maximum level, together with its unit of measurement, is given in parentheses for each parameter. Data were averaged over the two trial seasons.

Following development of the anti-stress chemistry, Alethea has been refined so that it can be incorporated into a range of different product types (liquid, powder and granular). Incorporation of Alethea chemistry into fertiliser products (British and international patent pending) is now possible and, to this end, trials have been carried out on several crops.

Abiotic stress is the single largest factor in yield variation in global agriculture, and therefore represents a large market opportunity for products that can reduce its impact. As many processes are at work within a plant under stress conditions, it is highly unlikely that a single molecule-based product will be effective. Combining molecules that act in tandem to influence the plant's ability to resist damage from stress will allow further progress in abiotic stress products in future.

RESEARCH DATA

Alethea chemistry has shown significant yield increases in GLP studies, conducted under CEMAS supervision, under stress conditions on a variety of crops. Results include:

Heat stress

- 60% decrease in phytotoxicity (tomato)

Cold stress

- 71% increase in fresh root weight (spring onion)
- 77% increase in fresh shoot weight (spring onion)
- 140% increase in fresh root weight (petunia)
- 87% increase in fresh shoot weight (petunia)

All the above results were statistically significant (P</=0.05).

David Marks is co-founder, director, and head of research of UK-based Plant Impact plc, a company focusing on an eco-friendly and highly effective range of crop health products.

For more details on Alethea, please email: info@plantimpact.com or visit: www.plantimpact.com