HERBICIDES AND PLANT PHYSIOLOGY

ANDREW H. COBB

THIRD EDITION

WILEY Blackwell

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Herbicides and Plant Physiology

Third Edition

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Preface

> He who has bread may have many troubles; he who lacks it has only one.
>
> (Byzantine proverb)

> A peasant must stand for a long time on a hillside with his mouth open before a roast duck flies in.
>
> (Chinese proverb)

The origin of the word herbicide is a combination of the Latin words *herba* (noun, herbaceous plant) and *caedere* (verb, to kill; R.L. Zimdhal, *Weed Science* **17**, 137–139, (1969).

It is now 30 years since the first edition of this book was published and so it is timely to reflect on herbicide use and the environmental consequences of their use. While we now have fewer products in our agrochemical armoury, farmers and growers have become dependent on fewer active ingredients, and glyphosate dominates the global market. This third edition aims to update the reader on how herbicides contribute to modern agriculture, how they are discovered and developed, and how they interact with plant growth and development and the environment. Since the publication of the second edition in 2010 there have been many advances in our understanding of plant physiology, especially regarding how plants function in tune with their ever-changing environment and how post-translational modifications provide regulatory control of most plant processes. Modern agriculture, however, still faces many challenges.

1. *The global food challenge*. To some, the continuing expansion of the human population will inevitably

outstrip the growth of our food supply, resulting in global starvation. To others, an expansion of arable land, a growing global food trade and the increases in crop yield predict a more optimistic future. Yet is it inevitable that a growing food supply will continue to meet demand?

2. *The problem*. More than half the global population will suffer some form of malnutrition by 2030 unless urgent action is taken to increase access to food of high nutritional quality. The Food and Agriculture Organization of the United Nations (FAO *et al.*, 2017) estimated that 815 million persons were hungry in 2016 (11% of the global population), an increase of 35 million since 2015. While 155 million children have stunted growth owing to poor nutrition, 2 billion persons suffer from hunger, while 1.9 billion adults and 41 million children are either overweight or obese. In addition, the human population is expected to grow by about 80 million per annum to an estimated 10 billion in 2050 (Oerke and Dehne, 2004). Furthermore, the global impact of the current covid-19 pandemic could result in at least a further 200 million undernourished persons. How can we expect to produce 70% more food to feed them all?

3. *Food security*. Food security is an increasing global problem in the face of climate change, combined with increasing populations and volatile food prices. With the global population growing at 230,000 persons each day and 60% of us now living in cities, the pressure on farmers to increase crop yields is ever present. At the same time, in the UK as an example, the land available per head of population has decreased from 0.8 to 0.2 hectares in the last 50 years. Every year 12 million hectares is degraded globally owing to drought, de-forestation and desertification, an area roughly the size

of Nicaragua, the largest country in Central America. Furthermore, global freshwater supply is becoming increasingly limited and unreliable to an estimated 700,000 persons, notwithstanding the fluctuations in weather as a result of climate change. We are experiencing greater extremes of weather, such as flooding or drought, and so we need to use the available fresh- and artesian-water more wisely. This is especially so whether we grow crops or raise animals. For example, it is estimated that 70 litres of water are needed to produce one apple, whereas 15,000 litres are needed for one kg of beefsteak! It is interesting to note that the carbon footprint of beef and lamb is three times that of pork, five times that of chicken, over 30 times that of bread wheat and 50 times that of potatoes. Urbanisation and increasing incomes generate a higher demand for animal protein, yet beef production requires four times more land than dairy, per unit of protein consumed. In addition, beef is seven times more resource intensive than pork and poultry, and 20 times more so than pulses. Not forgetting that animal production results in increased greenhouse gas emissions. It is a further uncomfortable fact that about a third of all food produced never reaches the table. This value is higher for fruit and vegetables, and such losses are even higher in the developing world, owing to the lack of effective storage and/or transport (IFPRI, 2016).

As available land for farming is in ever shorter supply and extremes in climate become more evident, many scientists predict an increased degradation of soils and a need for increased attention to land management. In recent years in the UK, for example, farmers have seen above average rainfall with increasing soil erosion, degradation and run-off. Palmer and Smith (2013) noted that 75% of fields planted with maize or potatoes in the south-west of England were severely damaged by soil degradation, with one in five sites experiencing serious rill and gully erosion. Some 60% of fields growing winter cereal crops, such as wheat and barley also displayed high to severe soil degradation. Techniques to avoid soil compaction, such as topsoil lifting or sub-soiling, are options to loosen soil layers, but the use of increasingly large and heavy machinery increases the risk. These authors concluded that soils with good agricultural properties are over-exploited in crop production and, as a result, can become highly degraded. Conversely, chalk and limestone soils degrade less.

A further definitive study, by Challinor *et al*. (2016), has predicted that gradually rising temperatures in Africa, and more droughts and heatwaves caused by climate change, will have a profound impact on maize yields. Higher temperatures reduce the length of time between planting and harvesting, which results in less time to accumulate biomass and yield. They also predict similar shortening of time to yield for maize crops across the tropics and suggest that maize breeding systems must adapt to increasing temperatures to ensure positive yields in the decades ahead. A further interesting area of research would be to investigate how the major weeds of maize crops may also adapt to increasing growth temperatures, with especial attention to weeds exhibiting C4 photosynthesis.

4. *Greater intensification?* In a comprehensive and thought-provoking study, Fischer *et al*. (2014) concluded that greater crop yields are possible through a greater intensification of agriculture, especially in Sub-Saharan Africa. This assumes more agricultural