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EDITORIAL

Precise knowledge of plant growth stages enhances applied and pure research

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It must be clear even to the least observant of us that plants are not static organisms. As they grow, they pass through a series of different growth stages, beginning with germination, the development of leaves, a stem elongation stage, preceded in some plants such as cereals, with a tillering stage, through to a flowering and fruiting stage, prior to senescence and death. Although these phenological stages are continuous and gradual, it is possible to recognise, with a fair degree of precision, at which stage an individual plant or crop is at on a particular date. It is also generally well known that plants show seasonal patterns in their physiology, with, for example, rapid meristematic growth in the spring, and in many plants, a virtual cessation of leaf development in the summer, followed by the development and ripening of reproductive organs is seen. These seasonal patterns in growth are reflected in the chemical composition of the plant's tissues and water content of their foliage and woody parts. It has been known for some time that these changes in plant physiology affect the growth, development and survival of the animals and microbes that attack them (Dixon, 1966; Awmack & Leather, 2002). In addition, the timing of the infestation or infection, in terms of the plant's growth stage affects the degree and intensity of the damage and loss of yield (Apablaza & Robinson, 1967; George, 1974; George and Gair, 1979). The resistance of cereals to fungal infection, for example, varies according to the timing of inoculation (Brokenshire & Cooke, 1978); different species of aphids reproduce more quickly at different growth stages (Watt, 1979, 1984) and pesticides show differing rates of uptake according to the growth stage of the plant at which they are applied (Tottman, 1977).

Furthermore, the temperature at which plants are reared affects the timing of their passage through their various developmental stages and their chemical status (Went, 1953). Despite this, many scientists still describe their experimental plants by their age, rather than their growth stage (Simmons *et al*., 2006; Ninkovic & Ahman, 2009). Exactly, what is a 10-day-old bean plant, what does a 12-day-old wheat plant look like? It is surprising that in these days of fast throughput molecular biology research that depends on a detailed and precise knowledge of gene sequences and positions, many papers published in high-impact journals omit such important details. We see for example papers investigating the genetic basis of resistance and immunity (Chakravrthy *et al*., 2010) which make no mention of what growth stage their plants are at even when, as in one case, they admit in the discussion that leaf age may have an effect on the responses seen (Hayes *et al*., 2010). Factor in nutrition and other environmental factors and these descriptions become even more inadequate.

Such lack of precision does not help scientific research and in most cases, there is absolutely no excuse for it. In fact, the importance of knowing the precise developmental stage of crop plants has been recognised for many years, for example Kohler (1942) reported on the chemical changes occurring in grasses as they grew through the season. Perhaps, one of the problems has been not so much the lack of phenological growth stage guides and descriptions, but the diversity of outlets in which they have been published. For example, an early description of cereal growth stages (Large, 1954) was published in the journal *Plant Pathology*, a description of rape growth stages (Berkenkamp, 1973) was published in the *Canadian Journal of Plant Science*, that of cabbages (Andaloro *et al*., 1983) in *New York's Food and Life Sciences Bulletin*, the growth stages of bird cherry (Leather, 1996) in the *Journal of Ecology*, those of the potato tuber (Shepherd *et al*., 2010) in *Metabolomics*. The *Annals of Applied Biology* has, however, over the last 40 years published a number of papers describing developmental growth stages for a range of economically important plants, for example cereals (Tottman, 1987), faba bean (Knott, 1990), potatoes (Jefferies & Lawson, 1991), linseed (Smith & Froment, 1998) and even for weeds (Lawson & Read, 1992), ornamentals such as roses (Meier *et al*., 2009) and trees such as willows (Saska & Kuzovkina, 2010). The *Annals* has also published a large number of papers describing the effects of plant growth stages on pest and disease infestations (Griffiths *et al*., 1975; Southwell *et al*., 1980; Holt *et al*., 1984; Lassois *et al*., 2010). These and many others can be read in the two virtual issues recently produced by the *Annals of Applied Biology*, which can be viewed at the following site http://www.wiley.com/bw/vi.asp?ref=0003-4746&site=1#570.

A full understanding of the interactions between pests and diseases and the growth stages of their host crops is essential in developing an effective strategy for the improvement of global sustainable agriculture and food security. It is up to us, as professional scientists, to use precise terms when describing our experimental methods. The use of universally recognised descriptors of plant growth stages has enabled scientists to model the effects of pest and disease infestations, to devise and implement action thresholds for pest management, to develop plant breeding programmes and to describe experiments that can be sensibly compared with other similar work. If such a scale does not exist for your study plant, then please devise one and submit it to the *Annals of Applied Biology* for publication. A standard set of plant growth stages is an obvious solution for commonality in research methods and should be espoused by all of us working with plants.

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