# Paper 2
# DEVELOPMENT AND YIELD OF BARLEY

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## INTRODUCTION

In this brief review I have attempted to describe the development of the barley plant from germination through to maturity, emphasising those growth stages where various yield components are determined. To describe development and yield in reasonably quantitative terms meant that some generalising was necessary, and it must be appreciated that development varies greatly depending on such factors as cultivar, time of sowing, soil type and season. These factors are the subject of another review in this symposium.

Various forms of growth scale have been used to describe growth and development of small grains (e.g. Large, 1954; Tottman and Makepeace, 1979; Zadoks *et al.*, 1974), using obvious external features such as number of leaves and nodes that can be observed without sophisticated equipment or techniques. Some of the information required for these scales is included here, although most emphasis has been placed on apical development, which is more precise for scientific purposes.

Much of the material for this review was taken from the "Cereal Development Guide" by E.J.M. Kirby and Margaret Appleyard, who taught me most of what I know about cereal development. Any mistakes or omissions, however, are mine, not theirs.

## GERMINATION

The mature barley seed consists of the caryopsis surrounded by the lemma and palea, often termed the husk. Following imbibition, the first visible sign of germination is the appearance of the seminal roots at the distal end of the seed. Although the shoot also originates from the distal end of the seed, it first becomes visible as it emerges from the terminal end having first grown around under the husk (Fig. 1).

## VEGETATIVE GROWTH

The embryo plant found at the base of the barley grain contains up to four leaf primordia and a shoot apex (Kirby and Jones, 1977). Following germination, the shoot apex begins to produce more primordia and, depending on cultivar and environment, the first 7 to 14 of these primordia develop into leaves on the main stem (Kirby, 1977).

Tiller buds soon develop in the axils of the leaves on the main stem, but the extent of their growth, development, and survival into mature ears depends on many factors, particularly plant density, soil fertility, and moisture. Thus, in a dry year on light soil, Engledow (1926) found that 85% of the plants were uniculms, producing a main stem only, while in a wet year on heavier soil only 39% of the plants were uniculms, 35% produced two ears, and 22% produced three ears, i.e. a main stem and two tillers.

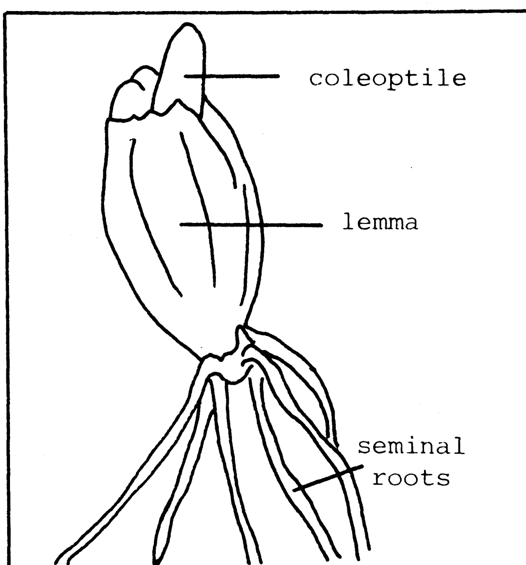


**Figure 1: The germinating barley grain showing the coleoptile and roots emerging from different ends (Kirby and Appleyard, 1981).**

## REPRODUCTIVE DEVELOPMENT

After several primordia destined to become spikelets have been laid down, the first obvious sign of reproductive development appears on the shoot apex. This is the double ridge stage, which occurs when single ridges, destined to become spikelets, appear immediately above the leaf ridges; hence the name (Fig. 2). It is not until the shoot apex has passed the double ridge stage, and initiated perhaps 25 to 30 primordia, that one can distinguish between the primordium destined to become the flag leaf and that destined to become the collar or lowermost node on the ear (Kirby, 1977).

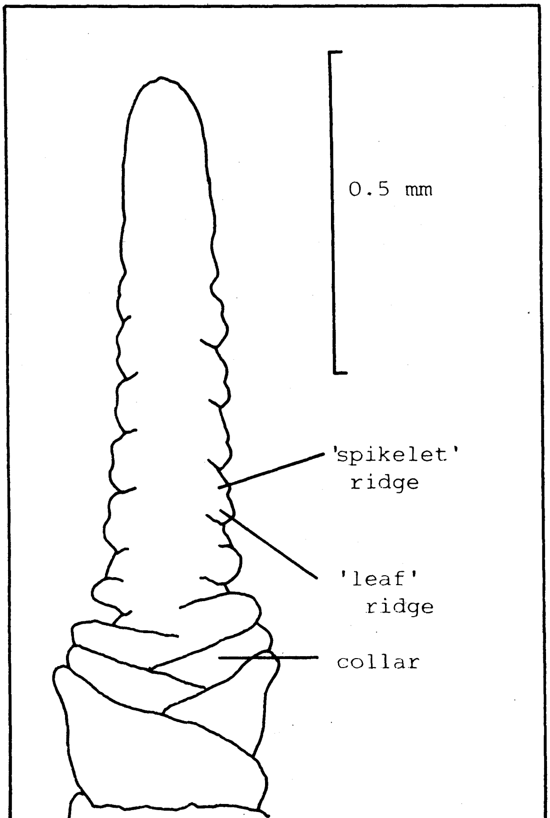


**Figure 2: A stem apex of barley at the double ridge stage (Kirby and Appleyard, 1981).**

However, more subtle and microscopic changes occur at the stem apex well before the double ridge stage, to indicate that ear initiation has commenced; ear initiation being defined as the time when the primordium destined to become the collar is laid down. The more obvious of these changes are in the apical dome, which assumes an elongated cylindrical shape (Kirby, 1977). Less obvious, except in retrospect, is the fact that the rate of primordium production increases once ear initiation has commenced (Fig. 3). Thus, although the double ridge stage is often considered critical in agronomic and physiological studies, reproductive growth commences well before the double ridges are visible.

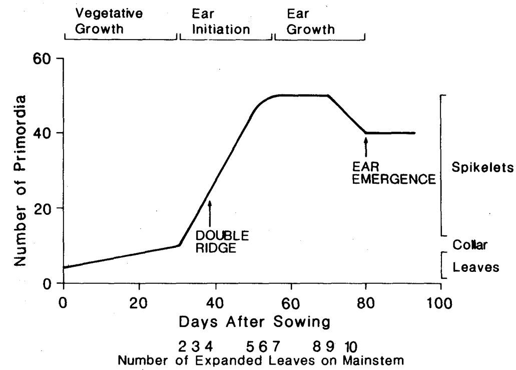


**Figure 3: Development of the barley plant (adapted from Kirby, 1973).**

During the ear initiation phase, spikelet primordia are laid down at the rate of about 1.9 per day (Kirby, 1973), the actual rate depending very much on temperature. The spike of barley is indeterminate in that an apical spikelet does not form (Fisher, 1973). Once the maximum number of spikelet primordia has been reached, the apical dome ceases activity, although it still appears turgid and viable (Kirby, 1977). Inevitably, the dome begins to shrink and spikelet primordia begin to die-back progressively from the tip of the ear. Once this die-back is complete, the number of spikelets per ear has been determined; this is usually at about the time of ear emergence. As about one-third of the potential number of spikelets in the ear are lost in this way (Kirby, 1973), it is surprising that the factors controlling the die-back process are little understood.

The period from maximum number of primordia to anthesis is defined as the period of ear growth (Kirby, 1973), as during this time the initiated floral organs develop, while at the same time the ear increases considerably in length and dry weight.

The structure of the barley inflorescence is well documented (Bonnett, 1966). At each node of the spike there are three spikelets, each subtended by two filamentous glumes. Each of these spikelets contains one floret and in the vast majority of the commercially grown barleys only the central spikelet of the three is fertile, giving rise to a two-row barley. Where all three spikelets at each node are fertile, an ear with six rows of grains usually results, although in some barleys this may appear to be reduced to four rows (Briggs, 1978). The sterile spikelets of a two-row barley remain small. The anthers are small and malformed and do not contain any pollen at anthesis (Riggs and Kirby, 1978).

In barley, pollen dehiscence and fertilisation, or anthesis as it is commonly called, can occur and yet remain unnoticed, particularly if it occurs before full ear emergence or if the cultivar has closed flowering because the lodicules do not swell. This inconspicuous anthesis poses problems for the plant breeder and also for the agronomist or physiologist, who may want to estimate the time of anthesis or apply surgical treatments to florets at this stage.

A barley carpel has two styles, and within a day of anthesis these styles curve outwards to expose the filamentous stigmas. At this stage the three anthers within each floret are a bright yellow colour and held on very short filaments around the carpel. The actual process of pollen dehiscence only takes several seconds to occur, and involves rapid elongation of the filaments together with the splitting of the anthers to release the pollen. Following pollen shedding by the anthers, the stigmas, now dusted with pollen, remain in a turgid condition for less than a day before they collapse, presumably in response to fertilisation.

A barley floret is contained within the palea and lemma, which ultimately become firmly attached to the caryopsis and are often referred to as the husk. Median grains are heavier and have heavier husks than lateral grains (Scott *et al.,* 1983). The fact that final husk weight is determined by the time of anthesis (Porter *et al.,* 1950) suggests that potential grain weight may also be determined by this time.

A recently fertilised barley carpel or caryopsis occupies less than 10% of the volume enclosed by the lemma and palea, but in terms of length initial growth is very rapid. Final grain length is attained about seven days after anthesis but width increases until about day 14, with dry weight continuing to increase for even longer (Briggs, 1978). Dry weight accumulation during grain filling normally occurs in two distinct phases. For approximately the first 10-14 days after anthesis, growth in absolute terms is slow, as the grain increases from about 2.5 mg to 4 mg. Most of the dry weight of the barley grain is laid down at a fairly uniform rate, starting about 10 days after anthesis and continuing for about 20 days; this is often called the linear phase (Porter *et al.,* 1950; May and Buttrose, 1959; Gallagher *et al.,* 1976; Riggs and Gothard, 1976). Those cultivars producing large grains usually have a high rate of grain growth during the linear phase, although differences in the duration of this period may also be associated with differences in kernel weight (Gallagher *et al.,* 1976).

## YIELD COMPONENTS — SOME GUIDELINES

Yield in barley can be thought of as being the product of a number of grains each of a certain weight. A survey of certified seed received at the Seed Testing Station from the 1979 harvest found that the mean weight per seed of Zephyr barley was 43 mg with a range of 37-50 mg between lines (Hampton, 1981). Allowing for the rejection of some of the smaller seeds as screenings, a mean seed weight of 40 mg is probably a realistic figure to aim for in most situations.

To obtain even a modest yield of 4.5 t/ha would require the production of 11,250 grains/m², each weighting 40 mg. The number of ears per unit area is probably the yield component which has the most influence on the number of grains per unit area, and around 500 ears/m² would be expected in the above situation (Hampton, 1981). Each ear would then have to produce an average of 22.5 grains, a value between the 18 found in late-sown Ark Royal barley at Lincoln (Scott, unpublished data) and the 30 found in Zephyr barley by Hampton (1979). The number of grains per ear is obviously a component that is very sensitive to environmental and managerial influence. Treatments which reduce the number of ears generally do so by killing off tillers, which have fewer grains that main stems (Kirby and Jones, 1977). In analysing data on yield components, it is important to realize that this change in the tiller population may be misinterpreted as an increase in the number of grains per ear caused by the treatment.

In physiological terms, the potential number of grains per ear is set by the number of spikelets per ear, the actual number being determined by the number of grains per spikelet, sometimes referred to as spikelet fertility. For Ark Royal grown at Lincoln, a figure of about 0.70 for median spikelet fertility has been consistently maintained (Scott, unpublished data), a value of almost identical to that found by Rackham (1972) and within the range of 0.50 to 0.87 described by Kirby and Jones (1977).

While the figures on yield components quoted above are reasonably typical, considerable interaction and compensation can occur between them, so that the same final grain yield can be achieved by an almost infinite number of different yield component combinations.

## ACKNOWLEDGEMENTS

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## DISCUSSION

White: Is it realistic to think in terms of 5 tonnes per hectare when we are talking about 10-tonne wheat crops?

Scott: I think it is totally realistic. It is still above the average quoted by Jim Malcolm. I was not game to set out the yield components for a 10-tonne crop under New Zealand conditions — frankly I didn't know.

McCloy: For a 7 tonne/ha crop, which is slightly more realistic than a 10 tonne one, the grain number is approaching the order of 17,000/m². We know crops that ended up with 20,000/m², but these have had very high screenings — as high as 70% in fact. So from the limited amount of work we have done on high-yielding crops, it appears that 17,000 grains/m² gives yields of about 7 tonnes/ha.

Scott: How many ears per square metre for seven tonnes?

McCloy: From memory, in the range of 700-800, and if we get about 20,000 grains/m² in crops with 900-1000 ears/m² there are high screenings.