

A Numerical Index to Assess Early Inflorescence Development in Wheat¹

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ABSTRACT

Understanding of environmental effects on floral initiation and spikelet differentiation in winter wheat requires a quantitative method of assessing inflorescence development. This note presents a numerical staging scheme for measuring progression of inflorescence development for material which has been preserved in formalin-acetic acid-alcohol. The assessment is based primarily on the production of successive floral appendages; but, since these are difficult to observe in preserved material, additional criteria involving spike shape and size are included. The system works for club and for common wheats, and permits clear delineation of the timing of occurrence of floral initiation and of termination of spikelet differentiation.

Additional index words: Winter wheat, *Triticum*, Floral initiation, Cereal grain, Phenology.

THE sequence of morphological changes in developing inflorescences or spikes of small grains is well-described (Bonnett, 1966; Briggles, 1967; Fisher, 1973). However, few studies have been made under field conditions (Hay, 1978) or have described environmental effects on the time-course of inflorescence development (Ahrens and Loomis, 1963; George, 1982). Since observation of early stages of head development is destructive, sequential measurements on the same plant are not practical. If destructive observations are done on representative samples, statistical analysis allows extension of these data to the rest of the population. This note describes a numerical index based on appearance of successive phyllomes of wheat inflorescences and illustrates the index for a club and a common wheat. Nicholls (1974) used a similar scheme for describing development of barley spikes.

MATERIALS AND METHODS

All plant material was grown in the field at the Columbia Plateau Conservation Research Center near Pendleton, Ore. Two cultivars of soft white winter wheat (*Triticum aestivum* L. 'Faro' and 'Yamhill') were planted on 25 Oct. 1977 with a John Deere HZ714 Hillside Press Drill³ with split press wheels at 72 kg ha⁻¹ in 36-cm rows. Faro is a club and Yamhill is a common wheat; both are beardless. They are adapted for production in the Pacific Northwest.

During March and April of 1978, plants were harvested periodically and brought into the laboratory where the shoot axis of the main stem was dissected and preserved in formalin-acetic acid-alcohol (Koch, 1973). This preservative rendered tissues less translucent and thus limited observation of internal structure. General shape was not affected (Fig. 1). The staging system was developed for preserved material for convenience in field experiments which require examination of large numbers of apices.

DESCRIPTION OF STAGES

The apical meristem of wheat produces leaf primordia until it differentiates into the inflorescence or spike. In most modern cultivars, the most mature spikelets are found about one-third of the way from the base of the spike. Stage of development is based primarily on observation of these more mature spikelets, but the condition of less developed parts at either extreme of the spike is sometimes useful as supplemental information. Figure 2 illustrates application of the system outlined below to two wheat cultivars. Since photographs of each stage were not available, those in Fig. 2 are generally intermediate stages.

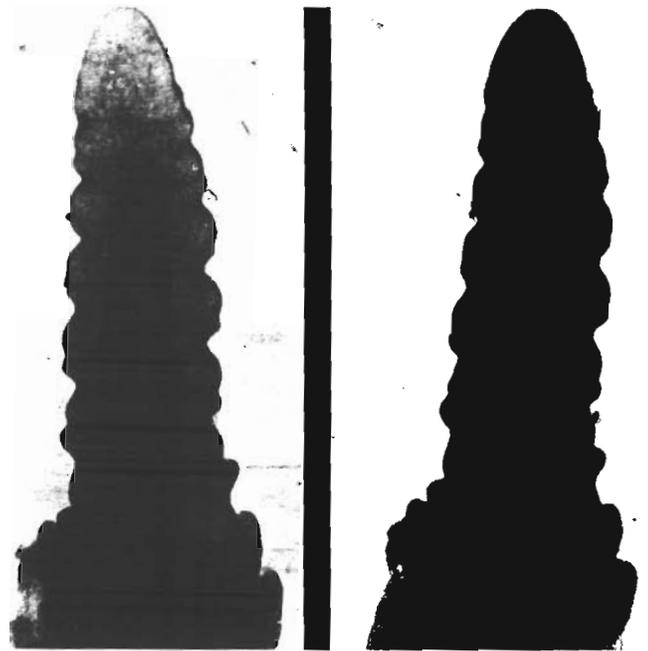


Fig. 1. Inflorescence of Yamhill wheat in water (left) and in formalin-acetic acid-alcohol (right). The preservative causes tissues to become opaque so that internal structural detail is lost. Although this inflorescence would be scored 2.5, the fresh material shows early rachis development which is not evident in preserved specimens before 4.0.

- 1.0 Shoot apex is dome-shaped. Vegetative apex is still producing leaf primordia.
- (1.5)—Shoot apex is cone-shaped or like the tapered end of an egg, due to elongation of apical tissues. Single ridges are visible but not pronounced. Generally the uppermost, clearly developed, single ridge is about at the midpoint of the spike.
- (1.5-1.9)—Apex has become further elongated and single ridges are more clearly defined.
- 2.0 The first visible sign of formation of the upper ridge after elongation has separated the single ridges.
- (2.5)—Most spikelet primordia have double ridges with the upper ridges more or less equal in size to the single ridges except for the less mature primordia at either extreme.
- 3.0 Spike is fusiform-shaped because enlargement of spikelet primordia has begun at a point about one-third of the distance from the base. Internal differentiation in individual spikelets has not occurred. Rachis is not evident in preserved material. Single ridges are no longer visible except at extreme ends of spike.
- 4.0 Empty glumes differentiate in more mature parts of spike. Rachis differentiates and becomes observable, especially in fresh material. Spikelet primordia become separated and rachillae begin to differentiate.

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³ Trade names and company names are included for the benefit of the reader and do not infer any endorsement or preferential treatment of the product listed by the USDA.

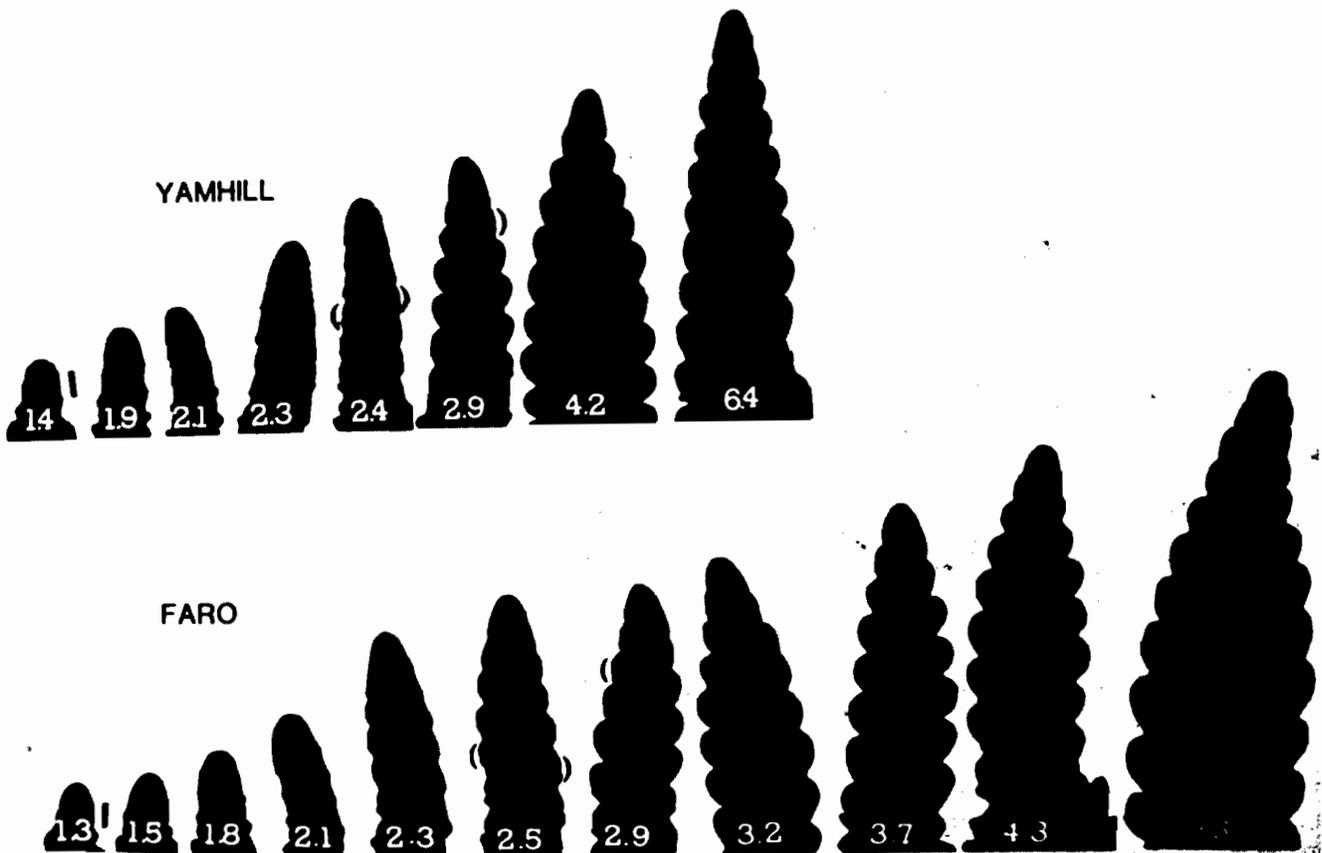


Fig. 2. Inflorescences and scores attributed to each for Yamhill, a common wheat (upper) and Faro, a club wheat (lower). The bar is 0.1 mm long. Examples of double-ridges are shown with brackets. Note apical elongation in early stages and the fusiform shape after 2.9.

- 5.0 Lemma primordia begin differentiation in more mature spikelets. Rachillae are clearly defined and the rachis is beginning to. Most of the other spikelets lack differentiated glumes; and, at the extremes, some may still be in the double-ridge stage.
- 6.0 Basal florets differentiate in more mature spikelets. Florets are globe-shaped. At extreme ends, spikelets still lag in development.
- 7.0 Stamens differentiate in primary florets of mature spikelets. (7.5)—Stamens continue to differentiate and apical spikelet forms.

DISCUSSION

The system was devised so that each stage, except for 3.0, represents development of another phyllome or whorl of lateral appendages. This follows the concept that spikelets are axillary buds which develop into secondary axes (Esau, 1967). Formation of the palea, the first phyllome of the developing floret, has not been included as a stage because it is scarcely ever visible (Bonnett, 1966) and is certainly not apparent in preserved material. In any case, formation of the palea happens so rapidly after lemma formation that to distinguish its occurrence serves little purpose.

The last stage (stage 7) was designated as the formation of the apical spikelet because this event indicates the termination of further spike development. The maximum possible number of spikelets has been set when the apical meristem becomes converted into the apical spikelet. This event was designated as a part of stage 7 because it immediately follows stamen initiation. Development of the spike after this point merely involves production of more florets on

each spikelet, elaboration and maturation of floral structures, and enlargement of floral parts.

The system clearly measures two factors of importance in predicting yield: 1) the occurrence of the double-ridge stage and 2) the termination of spikelet development. Occurrence of the double-ridge stage indicates that leaf initiation in a particular tiller has ceased and the potential photosynthetic surface has been more or less determined. Termination of spikelet differentiation sets the limit on spikelet numbers. For most of the material examined at Pendleton in 1978, spikelet number was set during April because stage 2 occurred in late March and stage 7 in late April. Since material is examined on successive dates, it is possible to make good estimates of the timing of floral initiation and of spike termination even though none of the material examined happens to be precisely at either of these stages.

The system can be applied with minor adjustments, both to club and to common wheats including wheats with 'Norin 10' ancestry which were identified by Fisher (1973) as having more florets per spikelet. Standard wheats move quickly into the double-ridge stage; stages 1 and 2 are very much compressed compared to genotypes with Norin 10 ancestry (Fisher, 1973). For wheats currently grown in the Pacific Northwest, stages 1.1 and 2.0 lasted up to 25 days in 1978, but development after stage 2 was rapid with about 4 to 6 days for development of each stage.

This indexing scheme was developed primarily for use on preserved material and thus some reliance is made on general changes in shape. For example, the change to fusiform shape, stage 3, was included to be certain of an easy

Table 1. Relationship of phyllome stage to spike length and to stages defined by George (1982). Values refer to Yamhill spikes pictured in Fig. 2.

Phyllome stage	Length	Approximate George stage	Approximate length as described by George
	mm		mm
1.4	0.29	2.5	0.27
1.9	0.39	5.0	0.45
2.1	0.48	5.7	0.54
2.3	0.68	6.2	0.61
2.4	0.83	6.7	0.64
2.9	0.95	8.0	0.90
4.2	1.18	8.9	1.07
6.4	1.45	11.7	1.39

point to recognize in preserved material when presence of empty glumes might be difficult to observe. Another feature which may prove useful after experience is gained for a particular cultivar is spike height or width. Figure 2 shows that the pattern of elongation during development is slightly different for these two varieties of wheat but that size progresses smoothly as inflorescences of main stems pass through successive stages. Whether size-stage relationships are the same for inflorescences on tillers other than the main stem is not yet known.

This developmental scale covers the same sequence of events covered by George's (1982) scale. Table 1 shows a comparison of the phyllome system to George's. The first two columns were taken directly from information given in Fig. 2 for Yamhill wheat. The third column was obtained by interpolation on a graph relating the two scores. This graph was obtained by scoring the photographs in Fig. 1 of George's paper (1982) with the phyllome system and plotting the two scores against one another. The last column of Table 1 was gotten by interpolation of a graph relating the approximate spike lengths given by George to his numerical scores. The table shows good agreement between spike length as measured on the individual spikes pictured in Fig. 2 and the approximate lengths given by George for his scale.

The phyllome scale differs from George's scale in three

ways. First, it uses appearance of successive phyllomes to relate spike development to a numerical scale. Second, it has been designed for use with preserved rather than fresh material although both scales can probably be used with both types of material. Finally, it is less definitive in the period prior to formation of the double ridge and more definitive afterward. For example, George (1982) recognizes four separate steps in the elongation of the spike and in the formation of single ridges but the phyllome system recognizes only one. Thus George's scale will probably find use in the winter-hardiness research for which it was designed and the phyllome scale will be useful in the development of models of wheat phenology.

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