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Tillering Dynamics of Winter Barley as Influenced by Cultivar and Nitrogen Fertilizer: A Field Study[1]

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ABSTRACT

A thorough knowledge of tiller development is essential in the analysis of grain production in most cultivated cereals, since the final number of ears produced by these plants is dependent on tillering. The object of this study was to investigate, under field conditions, the pattern of tillering, ear production, and survival of the component tillers in six barley cultivars: four six-rowed (*Hordeum vulgare* L.) and two two-rowed (*H. distichon* L.). The cultivars were grown in Granada, Spain, during 1980 and 1981 on a fine-loamy, carbonatic, thermic, Calcixerollic Xerocrept soil, and each was subjected to two levels of N fertilizer (25 and 40 kg ha^{-1}), both at seeding and as a top-dressing. From the data collected on tiller development during this study, the existence of a critical survival height for tillers is postulated: tillers less than one-third the height of the main stem at the end of shooting would fail to produce ears. The end of shooting corresponds to stages 8 and 9 of Feekes' scale when the last leaf or the ligule of the last leaf, respectively, is just visible. Nitrogen treatments at seeding, when added at maximum dosage, increased significantly both the number of tillers at the end of shooting (maximum increase = 21%) and the final number of tillers with ears (maximum increase = 31%), while the N treatments at topdressing (midway during shooting) did not affect the number of tillers at the end of shooting or at harvest.

***Additional index words:* *Hordeum vulgare* L., *Hordeum distichon* L., Tillers survival, Critical height.**

FOR barley (*Hordeum* spp.), tillering is one of the most important developmental stages, since it has a decisive influence on yield (Kirby and Faris, 1972). Both quantity and survival of tillers depend on environmental conditions during tillering. The number of tillers per plant reaches its maximum sometime after seedling establishment, diminishes rapidly before ear emergence, and finally stabilizes with very little change thereafter until harvest (Watson et al., 1958; Cannell, 1969).

The addition of N, especially when applied early, increases the number of tillers and their survival, thereby increasing yield (Thorne, 1966; Needham and Boyd, 1976). Nitrogen deficit, however, reduces tillering due to: (a) retarded appearance of the lateral buds (Hewitt, 1963); (b) limited root growth (Briggs, 1978); and (c) small, weak shoots whose leaves contain reduced levels of chlorophyll and carotenoids (Briggs, 1978).

Water deficit reduces the number of tillers produced and, if prolonged or severe, will cause tillers to die (Jones and Kirby, 1977; Lawlor et al., 1981). Tillering rate is also markedly affected both by plant density and date of sowing. Generally, low plant density increases the number of tillers per plant or per unit area (Kirby, 1967). Late sowing decreases the number of tillers (Pfund, 1974).

This study investigates the pattern of tillering, ear production, and survival of the component tillers in six barley cultivars over 2 years under field conditions in Southern Spain. Different N levels and application times were included in the experimental design, since these factors probably have the greatest influence on variation in tiller numbers.

MATERIALS AND METHODS

During 1980 and 1981, six cultivars of winter barley, four six-rowed (Astrix, Monlon, Albacete, and Hâtif de Grignon) and two two-rowed (Pallas and Logra) were grown in an area typical of the Province of Granada (Spain). All the cultivars were sown at 120 kg ha^{-1} at the end of November in a fine-loamy, carbonatic, thermic, Calcixerollic Xerocrept soil. Harvest was at the end of June.

The experimental area measured approximately 3000 m^2 and was divided into 24 plots of 100 m^2 (four per cultivar) separated by 1 m-wide uncultivated pathways. Two levels of N fertilizer (25 and 40 kg ha^{-1}) were tested and applied

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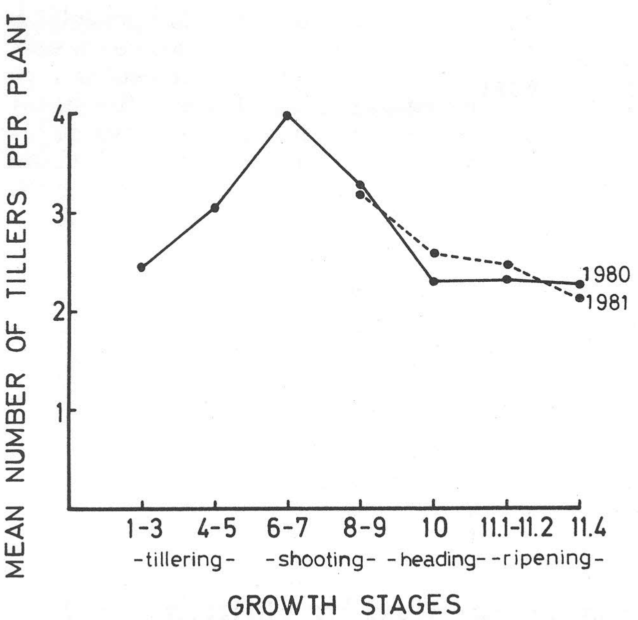

Fig. 1. Pattern of tillering during the development of winter barley grown during 1980 and 1981 in Granada, Spain.

to each cultivar both at seeding and as a topdressing with a 2×2 factorial design over the six cultivars. Each plot also received 18 kg ha^{-1} of P and 25 kg ha^{-1} of K at seeding.

Samples of six plants per plot were collected at intervals of about 15 days during the principal stages of development as laid out on Feekes' scale modified by Large (1954). In each sample the following data were collected: (a) number of shoots, (b) number of tillers with ears, and (c) lengths of main stem and of each tiller (measured from crown to apex, disregarding the ear). From these data, the dynamics of tillering throughout plant development could be established for each cultivar within each N treatment.

Data were analyzed by a test of differences between means (Student's *t*) and correlation techniques.

RESULTS AND DISCUSSION

The pattern of tillering (Fig. 1) was very similar to that described for temperate cereals in Europe (Cannell, 1969). In 1980, the number of tillers increased progressively during early stages of development, reached a maximum at the beginning of shooting (stages 6 and 7 for Feekes, first and second node of stem formed, respectively) and stabilized at considerably less than maximum thereafter. The maximum value ranged from 2.3 to 4.0 tillers per plant. In 1981, tillers were not counted in the early stages, but the pattern of development was similar to that of 1980 from stages 8 and 9 until harvest (Fig. 1).

Before ear emergence, at Feekes' stages 8 and 9 (the end of shooting), the number of living tillers started to decline, reaching maximum levels of tiller abortion at harvest, within the cultivars of 46% in 1980 and 49% in 1981 (Table 1), and 35% in 1980 and 36% in 1981 for the N treatments (Table 2). These stages 8 and 9 (last leaf visible and ligule of last leaf just visible, respectively) probably constitute a critical period in tillering. At this time, the smaller, presumably less competitive, tillers either die or produce ears. In effect, there may be a minimum tiller length (relative to the main stem length) below which tillers show a limited earing capacity. In this study, tillers shorter than one-third their main stem at stages 8 and 9 did not form ears (Tables 1 and 2). This was demonstrated by the high correlations between the percentage of tillers shorter than one-third of the height of the main stem at stages 8 and 9 and percentage of tillers lost at harvest (cultivars $r = 0.99$, $P < 0.01$; N treatments $r = 0.93$, $P < 0.01$). Thus the existence of a critical height for tiller survival is postulated: tillers less than one-third the height of the main stem at the end of shooting fail to produce ears. This is probably due to competition for a limited supply of resources (Kirby and Jones, 1977), some hormonal effect, or both.

Nitrogen fertilization (Table 3) influenced significantly both the mean number of tillers at stages 8 and 9 (maximum increases of 17% in the year 1980, 21% in 1981, and 19% for both years combined), and the mean number of tillers with ears at harvest (maximum increases of 27% in 1980, 31% in 1981, and 29% for both years combined).

Comparing the amounts and timing of fertilizer applications (Table 3), it was found that, independent

Table 1. Number of tillers, ears per plant and percentage of tillers lost for six winter barley cultivars grown in 1980 and 1981.†

		Stages 8 to 9		Harvest	
Cultivar	Year	Tillers per plant	Tillers < one-third their main stem length	Ears per plant	Tillers lost
			%		%
2-rowed					
Pallas	1980	2.5	6.6	2.5	3.2
	1981	2.6	9.5	2.6	2.9
Logra	1980	3.4	19.5	2.7	20.7
	1981	3.0	22.5	2.4	19.3
6-rowed					
Astrix	1980	3.3	32.1	2.1	32.6
	1981	3.3	43.6	1.9	43.1
Monlon	1980	3.5	43.4	1.9	45.7
	1981	3.4	48.8	1.7	49.1
Albacete	1980	4.2	39.6	2.6	38.0
	1981	4.6	43.2	2.7	42.0
H. Grignon	1980	3.0	35.3	1.9	36.8
	1981	2.5	27.9	1.9	24.8

† Average of four N treatments.

Table 2. Number of tillers, ears per plant and percentage of tillers lost for winter barley grown under four N treatments in 1980 and 1981.†

N applied at:			Stages 8 to 9		Harvest	
Seeding	Topdressing	Year	Tillers per plant	Tillers < one-third their main stem length	Ears per plant	Tillers lost
kg/ha				%		%
25	25	1980	3.1	34.2	2.0	35.2
		1981	2.9	34.3	1.9	36.2
25	40	1980	3.2	32.8	2.2	32.9
		1981	3.0	34.9	1.9	36.0
40	25	1980	3.3	30.8	2.4	28.0
		1981	3.5	35.2	2.3	34.7
40	40	1980	3.6	30.2	2.5	29.5
		1981	3.5	33.9	2.4	35.7

† Average of six cultivars.

Table 3. Effects of various N treatments on tillering in winter barley.

Comparison of N treatments†	Stages 8 to 9 1980‡	Stages 8 to 9 1981‡	Stages 8 to 9 Combined§	Harvest 1980‡	Harvest 1981‡	Harvest Combined§
kg/ha	Percent increase					
25 + 40 vs. 25 + 25	4.6	3.7	4.3	8.0	4.3	6.2
40 + 25 vs. 25 + 25	8.4	18.8**	13.7**	20.0*	22.0**	21.2**
40 + 40 vs. 25 + 25	16.6*	20.9**	18.7**	26.5**	30.7**	28.5**
40 + 25 vs. 25 + 40	3.7	14.5*	9.0	11.1	17.0*	14.2**
40 + 40 vs. 25 + 40	11.5	16.5*	13.7*	17.1*	25.3**	21.0**
40 + 40 vs. 40 + 25	6.6	2.0	4.4	5.4	7.1	6.0

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
† In each pair of N rates, the first is applied at seeding and the second as topdressing.
‡ N = 6 pairs of observations.
§ N = 12 pairs of observations.

of the level of N applied as a topdressing, raising the level of N applied at seeding from 25 to 40 kg ha^{-1} increased significantly both the mean number of tillers during stages 8 and 9 (with three exceptions in 1980) and the mean number of tillers with ears at harvest. However, when the amount of N applied at seeding was maintained constant and the amount applied as a topdressing was increased from 25 to 40 kg ha^{-1} no significant differences were found in either year. From this it can be concluded that the N fertilizer had its greatest effect on tillering if applied at seeding, especially when added at maximum dosage.

The number of tillers at the end of shooting depends upon the level of N supplied at seeding (Table 3). The addition of N at topdressing (midway during shooting) did not reduce loss of tillers after stages 8 and 9, since this loss was very similar for all the treatments (Table 2).

The final number of ears depends both on the number of tillers which reach Feekes' stages 8 and 9 and the percentage lost after this period. The loss of tillers is a function of plant cultivar and environmental conditions. While the six cultivars of barley (Table 1) showed appreciable differences in tiller loss (maximum range = 3 to 49%), losses within each cultivar during both years were similar (maximum range = 25 to 37%). This constancy may possibly be due to nearly identical climatic conditions each year until stages 8 and 9. Nitrogen treatments as topdressing did not affect the loss of tillers after stages 8 and 9, since all levels produced similar results (Table 2). Thus, final production of ears depends on the number of tillers at the critical stages which, in turn, is strongly influenced by N treatment at seeding.

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