Vernalization Response of West Texas Wheat Varieties

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ABSTRACT

Vernalization, the conditioning of flowering response in plants by exposure to cold temperatures, can have a major impact upon crop productivity. For winter wheat (*Triticum aestivum* L.) grown in the southwestern Great Plains, correct response to vernalizing temperatures is critical in the development of new varieties, to assure that flowering and grain filling occur during the optimum time period. Ten winter wheat varieties commonly grown for grain production in West Texas were germinated and artificially vernalized at 40°F as seedlings at weekly intervals to provide vernalization periods ranging from 0 to 56 days. The seedlings were transplanted into pots in a winter greenhouse, and the days required to reach Feeke's stage 6 (jointing) and Feeke's stage 10.5 (anthesis) were counted for each plant. The experiment was performed in two successive years. All varieties were found to be responsive to vernalization; however, the patterns of response and ranking of varieties varied with vernalization time. Patterns of jointing response were generally similar, but not identical to patterns of anthesis response, with respect to vernalization time, for individual varieties. Ranking of varieties for either dependent variable at vernalization times of 42 or 49 days were consistent with the usual ranking of these varieties for developmental traits in field production in West Texas.

Vernalization is the process by which cold temperatures during vegetative growth of some plants permit subsequent flowering. In winter wheat (*Triticum aestivum* L.), the effective vernalizing temperature range appears to be from 33 to 50°F (Ahrens and Loomis, 1963; Pugsley and Warrington, 1979), and usually, several weeks of such treatment are required (Ahrens and Loomis, 1963; Salisbury et al., 1979). The production of hard red winter wheat in West Texas can be constrained by vernalization requirements in two ways. First, particularly in the South, an insufficient period of vernalizing temperatures can result in delayed heading, requiring pollination and grain filling to occur later in the season, increasing risk of heat-induced pollen sterility or decreased grain yield. Inadequate vernalization may also be a problem in Northwest Texas if planting is delayed due to inadequate fall moisture. Second, particularly in the North, some varieties may fulfill vernalization requirements easily and develop floral meristems rapidly in response to warm early spring temperatures, increasing risk due to late spring freezes.

The genetics of vernalization in wheat has been studied extensively. At least five

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separate genes are known to have major effects (Law, 1966; Pugsley, 1971; Pugsley, 1972). It is also well-established that vernalization requirement interacts with photoperiod requirement and post-vernalization temperature to produce a broad range of developmental rates among wheat varieties (Berry et al., 1986; Cao and Moss, 1991; Flood and Halloran, 1984; Halloran, 1975). While timing of specific developmental events (e.g. heading) is extensively measured for various individual varieties, the specific effects of vernalization on varieties have been rarely investigated (Gardner and Barnett, 1990; Jadel et al., 1986). The current study was undertaken to examine the effects of vernalization time on the development of varieties adapted to production in West Texas.

MATERIALS AND METHODS

Seeds of winter wheat (*Triticum aestivum* L. em. Thell) were sown in plastic ice-cube trays (1 inch wide x 2 inches long x 1.75 inches deep) in soil (Pullman clay loam), and permitted to germinate and grow for 10 days in a growth chamber, providing 11-hr day length and 72/64°F (day/night) air temperature. Trays of seedlings were artificially vernalized at a temperature of 40°F $\pm$ 2°F (11-hr day length) for periods ranging from 0 to 56 days. Seedlings were separated and transplanted from all treatments on the same day, so that the environment experienced by all plants during subsequent growth was the same, within each experiment. Each seedling was transplanted into a separate clay pot (7-inch top diameter, 5.5 inches deep) filled with soil. Six seedlings were transplanted for each combination of vernalization time and variety and kept in a greenhouse at Bushland, Texas until maturity. In all, nine vernalization times, 0, 7, 14, 21, 28, 35, 42, 49 and 56 days, and ten varieties, Abilene, Karl 92, Siouxland 89, TAM-W101, TAM-200, TAM-201, TAM-202, Tomahawk, Wintex and 2180, were evaluated. For each treatment combination, only five of the six plants were evaluated, since a few plants died or became diseased during the experiment. In the case of treatment combinations in which all plants were healthy, one was eliminated at random. The positioning of the pots in the greenhouse was completely randomized. Each plant was evaluated for time of initiation of jointing (first hollow stem) and for time of anthesis, each in number of days from transplanting. The experiment was performed twice, with transplantation dates of 28 Nov 28, 1993 and 5 Nov, 1994. The first experiment was prematurely terminated due to failure of the greenhouse cooling system 98 days after transplantation, which resulted in the death of most plants.

Each experiment followed a completely randomized design, with factorial combinations of variety and vernalization time. The main effects were both considered fixed effects. Standard analysis of variance was conducted, and where significant F-values were obtained, mean separation was conducted using the method of least significant difference (LSD).

RESULTS AND DISCUSSION

With respect to the onset of jointing (Feekes stage 6), varieties were observed to differ in their response to duration of vernalization (Table 1). Some varieties, such as Karl 92, TAM-201, TAM-202 and 2180 were among the earliest varieties to

Table 1. Days to jointing for ten wheat varieties as affected by length of vernalizing treatment in two experiments.

	Weeks of Vernalization									
Genotype	0	1	2	3	4	5	6	7	8	LSD(0.05)
Expt. 1										
Abilene	42.6	42.8	40.4	41.8	41.0	39.2	36.4	33.8	33.4	3.0
Karl92	37.0	35.2	35.6	33.2	34.0	33.0	29.6	27.8	28.6	2.7
Siouxland89	46.8	47.0	42.6	43.0	41.8	37.2	36.2	32.4	30.2	2.8
TAM-W101	39.2	38.8	37.4	34.6	33.2	34.0	29.4	30.0	28.8	3.1
TAM-200	35.2	34.8	36.2	34.0	33.4	31.8	30.8	30.4	29.8	2.9
TAM-201	34.6	33.8	36.0	35.4	32.0	31.4	28.6	26.8	25.4	2.9
TAM-202	37.4	36.2	36.8	38.2	33.8	30.2	29.6	29.0	29.4	2.4
Tomahawk	41.6	43.0	40.8	38.6	37.0	36.6	30.4	30.8	30.0	3.2
Wintex	40.8	42.2	40.4	39.8	33.6	32.6	32.8	29.8	30.6	2.5
2180	38.2	37.8	33.5	34.0	32.4	29.6	29.0	27.2	24.8	4.0
LSD(0.05)	2.9	3.0	2.2	2.6	2.1	1.9	2.5	1.8	2.2	
Expt. 2										
Abilene	39.0	41.4	39.0	40.6	37.6	35.4	32.0	31.4	34.4	3.3
Karl92	36.2	33.8	37.4	34.0	34.8	33.8	30.4	29.4	28.2	3.7
Siouxland89	41.0	44.4	40.4	42.0	41.2	35.2	36.8	30.8	29.4	4.1
TAM-W101	35.6	36.8	34.8	33.6	34.2	32.4	30.8	29.8	28.0	3.5
TAM-200	34.0	36.0	35.0	36.6	33.0	30.4	31.4	31.0	28.2	3.4
TAM-201	33.0	35.8	37.2	36.8	31.6	33.4	29.2	27.4	26.2	4.3
TAM-202	35.4	32.0	35.4	36.6	34.0	29.2	30.2	30.0	28.4	4.7
Tomahawk	34.6	36.6	35.8	36.0	34.2	37.4	31.4	30.2	30.8	3.3
Wintex	33.4	35.0	32.6	33.4	32.6	31.6	30.2	30.0	29.4	2.9
2180	34.6	32.2	31.6	35.2	31.2	29.0	30.2	28.0	26.2	3.4
LSD(0.05)	3.6	4.4	3.9	3.3	2.9	3.4	2.6	2.4	3.0	

reach that phenological stage regardless of the duration of vernalization. Others, including Abilene, Siouxland 89 and Tomahawk were among the latest regardless of vernalization time. The other three varieties exhibited differences in their developmental response dependent upon duration of vernalization. Varieties TAM-W101 and TAM-200 exhibited short times to jointing when exposed to vernalizing temperature for up to five weeks, but intermediate jointing times at longer vernalization periods. Wintex exhibited short to intermediate jointing time in response to 4 or more weeks of vernalization, but long jointing time if provided less vernalization, at least in Experiment 1.

Similar, but not identical, patterns of varietal response to vernalization were observed for time to anthesis (Feekes stage 10.5)(Table 2) as were noted for time to jointing. In contrast with varietal ranks for time to jointing, those for time to anthesis were different at different vernalization times for all varieties but one, TAM-201. Among varieties, TAM-201 displayed one of the shortest times to anthesis regardless of duration of vernalization. Three varieties. TAM-W101, TAM-200 and TAM-202, displayed short times to anthesis when vernalized for 4 weeks or less, but intermediate anthesis dates when at least 6 weeks of vernalization were given. Two varieties, Siouxland 89 and Wintex, exhibited long times to anthesis when vernalization time was 5 weeks or less, but intermediate times to anthesis if 7 or 8 weeks of vernalization were provided. Two other varieties, Abilene and Tomahawk, were in the intermediate group of varieties at vernalization times of 3 weeks or less, but in the later group when over 5 weeks of vernalization were provided. The remaining two varieties were each among the intermediate group with very short vernalization times (2 weeks or less) and were in the earliest group with respect to anthesis at long vernalization times (at least 6 weeks), but 2180 became late with vernalization of 3 to 5 weeks, while Karl 92 remained in the intermediate-early group.

While the patterns discussed above were generally consistent between the two experiments, some were not. For example, times to jointing for the varieties Tomahawk and Wintex exposed to three or fewer weeks of vernalization, compared to the mean among varieties, were later in Experiment 1 than in Experiment 2 (Table 1). Also, anthesis time of TAM-W101, in comparison to the varietal mean, was longer in Experiment 2 than in Experiment 1, for all comparable vernalization times (Table 2). Such variability could have resulted from differing greenhouse temperatures, which were not controllable, or to day length effects, since the transplantation date was 23 days later in 1993 than in 1994.

The experiments were conducted in a manner designed to assure that environmental variation would not obscure genetic variation. Since vernalization response has been observed to decrease with plant age (Jadel et al., 1986), it was particularly important that all plants in the current study were vernalized at the same initial age. In a field environment, timing of plant development depends not only on vernalization time, however, but also on vernalizing temperatures, day length, moisture availability, post-vernalization temperature and their complex interactions (Berry et al., 1986; Cao and Moss, 1991; Flood and Halloran, 1984). Therefore, neither the precise number of days to jointing or anthesis nor the pattern of response of individual varieties observed in the current study may be reliably used to predict development in the field. Nevertheless, it is generally true that Abilene, Siouxland 89, Tomahawk and (usually) Wintex are among the later maturing varieties planted

Table 2. Days to anthesis for ten wheat varieties as affected by length of vernalizing treatment in two experiments.

	Weeks of Vernalization									
Genotype	0	1	2	3	4	5	6	7	8	LSD(0.05)
Expt. 1										
Abilene	-†	-	-	-	77.6	73.0	69.2	68.0	67.6	4.1
Karl92	-	-	-	93.4	73.6	66.2	63.0	62.2	62.4	5.0
Siouxland89	-	-	-	-	90.4	73.2	71.0	68.6	66.0	4.2
TAM-W101	-	-	-	87.4	72.8	65.4	65.8	65.4	64.8	5.8
TAM-200	-	-	-	90.0	72.4	64.4	65.2	66.8	64.4	4.1
TAM-201	-	-	-	85.2	70.2	63.0	62.4	62.6	61.4	3.9
TAM-202	-	-	-	80.0	68.2	65.2	65.6	66.6	63.8	4.9
Tomahawk	-	-	-	-	88.2	73.8	68.8	66.8	66.6	4.0
Wintex	-	-	-	-	80.4	72.0	70.4	68.0	63.2	4.7
2180	-	-	-	-	87.2	74.4	67.4	65.8	59.8	4.5
LSD(0.05)	-	-	-	5.2	4.6	3.7	4.1	3.0	3.1	
Expt. 2										
Abilene	39.0	41.4	39.0	40.6	37.6	35.4	32.0	31.4	34.4	3.3
Karl92	134.7	125.6	118.0	94.0	81.8	63.0	60.4	55.6	57.2	10.6
Siouxland89	169.0	157.5	149.2	124.8	101.2	83.0	72.2	62.4	62.0	8.3
TAM-W101	126.0	118.8	117.2	95.8	87.4	82.6	78.8	77.6	76.8	9.5
TAM-200	124.6	119.8	114.0	91.8	70.4	65.6	61.8	60.0	60.6	10.8
TAM-201	120.4	121.8	120.0	90.4	70.8	60.4	57.2	57.0	54.0	7.3
TAM-202	127.2	115.0	119.2	89.6	74.8	69.0	64.4	63.0	60.6	9.4
Tomahawk	144.3	137.0	135.7	110.0	100.2	89.0	86.2	81.6	78.8	8.8
Wintex	157.7	143.4	138.0	119.8	100.6	85.6	73.0	70.2	62.4	11.0
2180	136.0	133.3	128.0	122.8	110.8	84.0	59.8	58.0	52.8	9.1
LSD(0.05)	11.1	10.3	8.9	7.2	6.7	5.8	5.0	4.7	4.4	

†Not determined due to greenhouse overheating 98 days after transplanting.

in West Texas, and that Karl 92, TAM-201 and 2180 are among the earliest maturing varieties, consistent with the results obtained in the current study when 6 to 7 weeks of vernalization were provided. As the varieties considered here are among those most commonly grown in West Texas, it is also useful to note that five of the varieties, TAM-W101, TAM-200, TAM-201, TAM-202 and Karl 92 reached anthesis more quickly than the others with only 3 or 4 weeks of vernalization. Thus, these varieties should be favored by producers forced to plant in November or December due to unfavorable planting conditions earlier in the fall.

It should be noted that all of the varieties examined here are winter, not facultative, varieties, in that all were very responsive to vernalization, requiring about twice as long to reach anthesis when given no vernalization as when given 6 to 8 weeks of vernalization (Berry et al., 1980; Flood and Halloran, 1984; Gardner and Barnett, 1990). In contrast, the observed response of true spring varieties (no *vrn* genes) to vernalizing temperature in other studies has been longer time to anthesis than occurred in the absence of vernalization (Gardner and Barnett, 1990). Berry, et al. (1980) and Salisbury, et al. (1979) concluded that, in the Triple Dirk genetic background, the genotype vrn_1 vrn_2 vrn_3 vrn_4 produced a graded response to vernalization time, similar to the responses of Siouxland 89 and Wintex in the current study, while the presence of either Vrn_1 or Vrn_2 alleles induced a threshold relationship. Thus we might surmise that Siouxland 89 and Wintex are true winter varieties, while the others probably have one or more spring-habit alleles, though the precise genotype of the varieties with respect to *vrn* genes cannot be known.

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