Differential Responses of Wheat Varieties to Temperature During Vegetative and Reproductive Stages.[1]

GEORGE A. GRIES, FOREST STEARNS, and RALPH M. CALDWELL,
Purdue University

Many aspects of the problem of the adaptation of crop varieties to limited geographical ranges are unsolved, even though numerous studies have been made on the ecology of crop plants. Some progress has been made in the understanding of this phenomenon by the work done on the responses of plants to vernalization, photoperiod, and thermoperiod. An example of a problem which cannot be completely resolved in the light of the previous experimental work as summarized by Murneek and Whyte (2) is found in the performance of certain winter wheat varieties in Indiana. During the past several years, a number of new selections of early winter wheats have markedly and consistently out-yielded standard season varieties in Southern Indiana. These same selections have not shown the same advantage in comparable field trials in Northern Indiana. Data comparing the yields of one of these early selections (4117A16-5-1), an intermediate variety (C.I. 12557), and a medium season variety (Vigo) in replicated rod-row yield trials near Vincennes in Southern Indiana and Lafayette in Northern Indiana for the years 1948-1950 inclusive are presented in Table I.

TABLE I. Average yield in bushels per acre of three lines of winter wheat at Vincennes and Lafayette, 1948-1950 inclusive.[2]

Variety	Season of Maturity	Average Yield Vincennes	Average Yield Lafayette
4117A16-5-1	Early	49.7	38.5
C.I. 12557	Medium Early	42.3	39.2
Vigo	Medium	37.6	39.3

No single factor can be expected to explain the differences in performance of these varieties at the two locations. Limited studies at the Purdue Agricultural Experiment Station have indicated that photoperiod is not a major factor in the adaptation of wheat varieties. Chinoy (1), in India, reported that the yield of wheat varieties may decrease as the temperature during the maturation period increases. The present paper discusses preliminary studies on the relative requirements of the three varieties listed above for vernalization, and on the effect of temperature on the length of time required for vernalized plants to reach flowering and maturity.

[1] Contribution by Department of Botany and Plant Pathology, Purdue Agricultural Experiment Station Journal Paper No. 510.

[2] Data of Caldwell et al, Ann. Rpts. Purdue Univ. Agr. Expt. Sta. 1948-1950.

Experimental

The three varieties A16 (4117A16-5-1), 12557 (C.I. 12557), and Vigo were space planted in field plots near Lafayette on October 13, 1949. Plants were collected periodically during the following winter and spring and were transferred to pots in a greenhouse maintained near 65° F. Data on the subsequent development of the plants were obtained to determine the relative rapidity of vernalization of the three varieties and the relative rates of growth following vernalization. A portion of the data obtained, based on a sample of twelve plants of each variety, is tabulated in Table II.

TABLE II. Development of wheat plants transferred to the greenhouse from the field at different dates

Date Transferred	Variety	Days following transfer from field	
		to "shooting"	to maturity
11-10-49	A16	124	179
	12557	108	179
	Vigo	120	179
12-3-49	A16	76	135
	12557	80	135
	Vigo	84	135
12-27-49	A16	58	110
	12557	57	114
	Vigo	59	114
2-3-50	A16	27	87
	12557	30	87
	Vigo	30	96
3-4-50	A16	9	78
	12557	10	86
	Vigo	10	90
4-14-50	A16	7	63
	12557	7	73
	Vigo	7	73

Prior to complete vernalization the three varieties required the same length of time to mature under greenhouse conditions. With more nearly complete vernalization in the field, the early A16 matured more rapidly than the other two. This seems to be associated with the speed of development following "shooting" rather than with the length of the period prior to this stage in four of the six collections. For example in the first collection the plants of A16 matured in 55 days following "shooting" whereas 12557 and Vigo required 71 and 59 days respectively. The data in Table II are interpreted as indicating that vernalization is gradual and accumulative rather than being suddenly effected following a given minimum period of exposure to low temperatures.

In another experiment the three varieties were transferred from the field to the greenhouse on January 12, 1950. Thirty plants of each of the three varieties were grown under each of the following experimental conditions:

A. Grown to maturity at 65° F.
B. Grown to maturity at 80° F.
C. Grown to flowering at 65° F. and allowed to mature at 80° F.
D. Grown to flowering at 80° F. and allowed to mature at 65° F.

The effects of these conditions on the dates of flowering and maturity are summarized by the data in Table III. The data in Table IV present the effect of the same variables on mature plant and head size.

TABLE III. The differential response of wheat varieties to temperature at different growth stages

Temperature (°F)		Days from potting to flowering*			Days from flowering to maturity**			Days from potting to maturity**		
Before Flowering	After Flowering	A16	12557	Vigo	A16	12557	Vigo	A16	12557	Vigo
65	65	34	39	43	35	37	32	69	76	75
80	80	27	41	57	32	28	27	59	69	84
65	80	34	39	43	30	40	28	64	79	71
80	65	27	41	57	42	40	28	69	81	85

* Average of 60 plants.
** Average of 30 plants.

TABLE IV. The effect of temperature at different growth stages on mature plant and head sizes. (Averages of 30 plants)

Temperature (°F)		Height of Mature Plant (inches)			Dry weight of Mature Heads (grams)		
Before Flowering	After Flowering	A16	12557	Vigo	A16	12557	Vigo
65	65	38.7	41.9	43.6	0.97	1.08	0.98
80	80	23.7	29.1	29.5	0.41	0.63	0.53
65	80	36.0	42.6	43.2	0.79	0.91	0.88
80	65	28.5	32.3	29.5	0.69	0.67	0.65

Under both cool and warm conditions plants of A16 flowered earlier and matured earlier than those of the other two varieties, with 12557 being intermediate, and Vigo being late. The varieties showed striking differences in their responses to the contrasting temperature levels before and after flowering. For example, A16 flowered one week earlier at 80° F. than at 65° F. whereas Vigo flowered two weeks earlier under the cool conditions. Temperature seemed to have no effect on the length of the period from potting to flowering of 12557. Maturation of A16 and Vigo following flowering proceeded more rapidly under warm than cool conditions. The temperature under which plants were grown to flowering influenced the rate of maturation. For example plants of A16 grown to flowering at 65° F. and maintained at that temperature matured one week earlier than plants grown to flowering at 80° F. and then transferred to the cooler temperature. In most situations the latest variety, Vigo, matured the most rapidly following flowering. It was pointed out in the discussion of Table II, that A16 required less time to mature following the onset of the "shooting" stage than did Vigo. This implies that the period between the onset of "shooting" and flowering is much shorter for A16 than for Vigo. An analysis of the detailed data supports this conclusion.

The temperature sequence under which the plants were grown had a marked influence on the final plant size and yield. All varieties produced larger plants when grown at the cool temperature prior to flowering. The greatest dry weight of the heads resulted when the plants were continued to maturity at cool temperatures. With a minor exception in 12557, a direct relation appeared between the plant height and dry weight of the heads.

Discussion

No problem in adaptation can be expected to be resolved by a study of any single factor. These preliminary studies indicate the importance of the effect of temperature on performance at the different stages of growth of wheat and further disclose a marked interaction between this factor and earliness of maturity. Variety tests at Vincennes, Indiana have shown yield of these three varieties to be inversely related to the length of their growing period. In view of the findings of Chinoy it may be that the high yields of A16 in southern Indiana result from its ability to mature early and consequently at lower temperatures than do later varieties. The failure of A16 to show superior performance at Lafayette is not clear but presumably results from the retarded onset of the "shooting" stage due to the lower spring temperatures. Although A16 is earlier than Vigo and 12557 at Lafayette, Indiana, it is not so much earlier there as it is when grown farther south at Vincennes. This may in part explain its failure to show a yield advantage at Lafayette.

Summary

1. Three varieties of winter wheat varying in their earliness of maturity and adaptation to northern and southern Indiana were utilized in preliminary field and greenhouse experiments to determine the importance of the temperature factor in their development.

2. Vernalization appeared to be a gradual process that required

no critical minimum low-temperature period. With inadequate periods of field vernalization, both early and late varieties required the same length of time to mature under greenhouse conditions. As the degree of vernalization increased varietal differences in time required for maturation became more pronounced.

3. Field vernalized plants of the medium variety (Vigo) flowered much sooner under cool than under warm conditions, while the early variety (4117A16-5-1) showed the reverse response. The intermediate variety (C. I. 12557) was not greatly influenced by temperature in respect to flowering. Two of the three varieties tested matured more rapidly at warm temperatures than cool, although the temperature prior to flowering had an influence on the rate of maturation.

4. Vegetative growth of all varieties was favored by cool temperatures and the average dry weight of the heads produced was directly related to plant height.

5. It is suggested that the superior performance of certain early lines of winter wheat in southern Indiana may be accounted for by their response to the milder temperatures prevailing during their late winter and spring growth.

Literature Cited

1. CHINOY, J. J. 1947. Correlation between yield of wheat and temperature during ripening of grain. Nature **159**:442-444.

2. MURNEEK, A. E. and R. O. WHYTE. 1948. Vernalization and photoperiodism. Chronica Botanica Co., Waltham, 196pp.