THE RESPONSE OF THE BARLEY GENOTYPE TO NIGHT TEMPERATURE

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THE RESPONSE OF THE BARLEY GENOTYPE TO NIGHT TEMPERATURE

By

KULDIP SINGH BAINS

AN ABSTRACT

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF
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Kuldip Singh Bains

THE RESPONSE OF THE BARLEY GENOTYPE TO NIGHT TEMPERATURE

The performance of a genotype is determined by its response to environment. A study was initiated with four barley varieties to observe their response to three night temperatures and to determine the association of certain physical characteristics of barley to night temperature. The characters observed were plant height, date of heading, green and dry weight of culm, weight of main head, and number of seeds set.

A significant variety night temperature interaction was observed for plant height, date of heading, green and dry weight of culm, number of seeds set, and green and dry weight of the main head. The interaction variances seem to indicate differential behavior of genotypes at different night temperatures.

A linear relationship was observed between respiration and temperature in the dark. The Q_{10} recorded for respiration was much greater than 2 which strongly indicated that an enzyme system is involved. This would appear to have great bearing on the adaptation of genotypes.

Broadly speaking, high night temperature has been found to decrease the number of days to heading, decrease the number of seeds on the main head, and increase rate of respiration. Significant negative correlation between temperature and date of heading and number of seeds set on the main head was observed.

Respiration was found to be closely associated with night temperature with an r value of +0.9999.

The data suggest that the adverse effects of increased earliness, decreased seed set and increased respiration rates may be responsible for low yields of barley.

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TABLE OF CONTENTS

INTRODUCTION

Temperature has been observed to be one of the most important factors of the climatic complex affecting plant growth. The influence of temperature upon plant growth has been the object of intensive study particularly in vegetable crops. These studies have brought out the fact that regardless of how favorable the other environmental factors such as light and soil moisture may be, a certain optimal temperature is required not only for different species but also for the different stages in the growth cycle of the same species for successful crop production.

The importance of the genotype x night temperature interaction has been stressed (9)* in analysing the yield of barley and oat nursery data and a mathematical basis has been developed to measure it, to a limited extent, in the field. The object of the present study was to determine the response of certain physical characteristics of barley genotype to night temperature.

The experimental work was conducted under controlled conditions in the green house.

* Numbers in parentheses refer to the "literature cited"

REVIEW OF LITERATURE

Sachs (18) studied the role of temperature as it influenced plant growth and development and visualized periods of optimum, maximum and minimum temperature ranges associated with specific stages of plant growth for particular species. He concluded that an increase or decrease of temperature from the optimal temperature affected the plant adversely.

Thompson and Knott (20) working with lettuce observed that at 70° to 80° F no heads were formed regardless of the photoperiod, whereas at 60° to 70° F head formation was most satisfactory. They concluded that high temperature is an important factor involved in premature seeding of lettuce.

In a study of the responses of some ornamental plants to temperature, Post (13) noted striking differences in their behavior as to growth and flower formation. He observed that Trachyme and Clarkia produced vegetative growth below 60° F but produced flowers at higher temperatures whereas Cytisus and Mathiola's behavior was the reverse.

In an analysis of the physiological factors affecting blossom drop in tomatoes, Radspinner (14) concluded that high temperatures and low humidities favored abscission of tomato blossoms. Went (22) (23) found an optimal temperature of 18°C for stem elongation of tomato plants when the whole plant was raised at this temperature, but noted that the growing zones, when exposed to 26°C, elongated much faster. Went and Cosper (24) found a controlling effect due to temperature on fruit set in tomatoes which was also confirmed by Wittwer and Schmidt (26).

Binkley (3) concluded that the blossoming period of garden beans is very sensitive to variations in environmental conditions, i.e., high air temperatures, sudden fluctuations in air temperature and inadequate moisture supplies, causing reduced seed set.

Boswell (4) (5) in his papers analysing certain factors affecting the yield and quality of peas emphasized the importance of temperature. He observed that the higher the mean temperature above the optimal temperature, the lower the yield. He advocated the theory of a fairly constant amount of effective heat required by a strain of peas to attain blossoming stage and maturity.

Cordner (7) found that pod yields of lima beans are closely correlated with bearing area and temperature, and as the temperature increased above the optimal, the fruit setting decreased. Andrews (1) (2) found that lowered maximum temperatures and high humidities were accompanied by increased yields of lima beans. During conditions of high temperature and medium to low humidities, the blossoms of Fordhook lima beans become dehydrated. Consequently, the enclosed pollen did not germinate while the pistil was receptive and flower abscission resulted. Lambeth (11) explored the problem of seed set and yield of lima beans and found that responses to constant air temperatures of 62°, 72° and 86°F were a varietal characteristic. It was noted that Fordhook 242 set 91 percent of its blossoms while Fordhook set only 37 percent at 62°F whereas at 72°F both varieties yielded similarly. He found that tube growth at pollen germination was greater for the Fordhook 242 than Fordhook at 62°F which corresponded with their seed set behavior.

Decker (8) studied the effects of temperature on photosynthesis and respiration in red pine and found lower P/R ratio at higher temperatures. Murneek (12) attributed continuous vegetative growth or premature bud initiation to certain environmental factors, especially temperature and light.

Roberts and Struckmeyer (15) (16) observed the inhibitory effect of cool and long days on flowering on cosmos and soyabeans. They found that the temperature factor is not only essential for bud initiation but also to the actual process of fertilization and subsequent fruit development as well.

Roberts (17) showed that warm nights and cool days caused reduction in setting of Alaska peas and alfalfa while cool nights and warm days increased fruiting.

Thayer (19) noted that the growth of barley crop is markedly influenced by seasonal environment. Harlan, Martini and Stevens (10) found that during long continued heat the pollen ripened at earlier and earlier stages in the development of the barley spike, resulting in a reduction in percent seed set and a reduction in the size of kernels obtained. It was found that temperature had a significant negative correlation with the seed set five days before emasculation. Wiggans (25) advocated a heat unit accumulation theory to mature a crop. It was noted that the accumulation of temperature over 40^{o}F required to mature a given variety of oats was about the same for the plantings made in April to early May. Minor variations were recorded from year to year for a specific variety. Walster (21) working on barley under controlled conditions found less carbohydrates at higher night temperature 20^{o}C than at 15^{o}C.

MATERIALS AND METHODS

The study included four barley varieties, Moore, Montcalm, Kindred and Plains. They were grown under controlled conditions in the green house with six replications at three constant night temperatures 75°, 70° and 63°F with a range of ±2°F. It was not possible to control temperature during day-time and it represented the weather conditions prevailing at the time of the experiment.

Planting in the first experiment was done on October 20, 1955 in 8" size earthen pots filled with loam soil and sand in the ratio of 2:1. Four seeds were seeded in each pot and allowed to germinate at a constant night temperature of 60°F maintained in the experimental room. On germination three seed-lings were left in each pot for experimental use. Night temperature control was exercised on the completion of germination. The pots were arranged in circles under the infrared bulbs of 250 watts each which were hung on the top of growing seedlings for radiating artificial heat at night. The first circle under the infrared bulbs comprised the temperature 75°F, second circle the night temperature 70°F, and the third temperature comprising pots at 63°F. However, some uncontrol-lable fluctuations in the temperature range of ±2°F did occur during the course of the experiments. The heat bulbs were raised as the plants grew and artificial heat at night was radiated from 6 P.M. to 6 A.M. Watering was done daily or on alternate days and the plants were fed with standard nutrient solution at an interval of about 10 days.

Data were taken on the height of main shoot, date of heading of main shoot, green and dry weight of Culm, green and dry weight of main ear and tillers, and number of seeds set on main head. One plant from each pot was harvested 78 days after seeding. In the meantime, mice caused damage to most of the heads of the standing plants and rendered the results of these plants unus able.

The second experiment was planted on March 3, 1956. The material and procedure was the same except that the infrared bulbs were now adjusted parallel to the growing plants instead of at the top to expose the entire plant length to as uniform an artificial heat as possible. Accordingly the pots were arranged in a semicircle opposite to infrared bulbs. On account of warm and open weather the plants made rapid growth and the three plants of each pot were harvested individually 56, 63, and 70 days after seeding. Data were taken as for the first experiment.

Rate of respiration determinations were made in a controlled temperature room at 65°, 70° and 75°F in the dark for a ten hour period for a barley introduction from Iran C I No 6658. Three tin cans containing growing plants were placed in the respiration jar. Before placing the plants in the respiration jar, the earth surface in these pots around the growing plants was sealed with melted paraffin.

The colorimetric method for CO_2 determination in respiration studies as described by Claypool (6) was followed. Briefly, the procedure consisted in passing a known volume of compressed air with constant per cent CO_2 through the respiration jar containing plants and then equilibrating the outcoming air sample with a dilute solution of sodium bicarbonate containing phenol red indicator. The test tube containing this solution through which the out coming air from the respiration jar was passed was then placed in a colorimeter and the percent transmission determined. A 565 filter with transmission limits 550 and 585 was used. The test tube was made air tight with a rubber stopper immediately on changing the flow to the second test tube containing the solution with indicator. The test tubes were used in turn and the readings were recorded at an interval of 10 minutes. The solution in the test tubes was changed after recording 6-8 readings. The rate of air flow was regulated by flowmeters.

The internal temperature of the stem and the air inside the jar in the respiration experiment at the three temperatures was recorded by introducing separate thermocouples and reading millivolts resistance with a potentiometer.

The data was subjected to analysis of variance and correlations between night temperature and date of heading, number of seeds set on main head and rate of respiration were worked out.

EXPERIMENTAL RESULTS

I. EFFECT OF NIGHT TEMPERATURE ON PLANT GROWTH

Several aspects of plant growth under the different night temperatures were observed. In general the results were as expected. Significant differences due to different night temperatures were observed for date of heading, dry matter in the main culm, plant height, seed number and ear weight. These data together with analysis of varience are presented in tables 1 to 9.

The real purpose of these experiments was to observe relative rather than absolute differences. It was hoped that a significant variety-temperature interaction could be found as this would indicate some varieties to be better adapted to high night temperatures than others. Such a case was observed for plant height, date of heading, green and dry weight of culm, number of seeds set on main head and green and dry weight of main head. This would seem to indicate that the genotypes behave differently at one night temperature in comparison to another night temperature thus affecting the performance of barley genotypes at different night temperatures.

Table 1 indicates that plants grown at relatively low night temperatures attained greater final height. It can be seen from table 2 that relatively low temperatures lengthened the period of growth and delayed the date of heading of barley varieties. Significant differences were observed between night temperatures for these characters.

There seemed to be a general trend in the accumulation of more green as well as dry weight of the culm, as illustrated in table 3 at comparatively low temperatures, although, some fluctuations have been recorded. Significant differences were recorded between night temperatures for green and dry weights of culm in experiment 1 in the plants harvested after 85 days (table 4). In general, the number of seeds set increased with a decrease in night temperature as shown in table 5. However, the differences are not significant. A significant interaction was recorded between varieties and night temperatures as illustrated in table 6. This indicated differential behavior of genotypes at different night temperatures.

Average green as well as dry weights of all tiller heads per plant are given in table 7. It can be seen that per cent dry matter at all temperatures was very low as compared to that recorded for the main head, table 8, indicating an immature stage of heads at harvest. The green and dry weight of the main head, table 8, was considerably depressed at high temperature 75°F as compared to 70° or 63°F. Significant differences were obtained for green weight between night temperatures and a significant interaction between varieties and night temperature is shown in table 9.

TABLE I

THE EFFECT OF NIGHT TEMPERATURE ON THE GROWTH OF BARLEY GENOTYPES

Variety	Height of main shoot at harvest					
	Expt. I			Expt. II		
	63°F (inches)	70°F (inches)	75°F (inches)	63°F (inches)	70°F (inches)	75°F (inches)
Moore	24.3	22.9	22.8	27.2	28.5	26.6
Montcalm	23.6	23.6	18.6	26.9	28.7	26.0
Kindred	23.4	25.3	20.3	27.7	30.5	30.1
Plains	18.4	18.3	16.9	23.0	21.4	20.5

Analysis of variance for Height of main shoot

Source of variance	Expt. I			Expt. II	
	D.F.	M.S.	F.	M.S.	F.
Total	71	-	-	-	-
Blocks	5	7.723	-	5.051	-
Varieties	3	90.024	3.31	194.402	29.73**
Night Temp.	2	59.416	2.19	15.947	2.44
Var.xN. Temp.	6	27.193	7.94**	8.168	1.28
Error	55	3.425	-	6.361	-
Pooled Error	61	-	-	6.538	-

* F value exceeds 5% level of significance.

** F value exceeds 1% level of significance.

TABLE II

THE RESPONSE OF DATE OF HEADING OF BARLEY GENOTYPES AT DIFFERENT NIGHT TEMPERATURES

	Days seeding to heading					
	Expt. I			Expt. II		
Variety	63°F	70°F	75°F	63°F	70°F	75°F
Moore	52.3	49.3	45.2	35.5	32.9	31.5
Montcalm	52.2	49.4	46.9	35.6	34.5	31.1
Kindred	50.3	46.5	42.2	34.7	32.3	29.3
Plains	42.8	41.1	38.3	30.6	29.6	26.0

Analysis of variance for date of heading

Source of variance	D.F	Expt. I M.S	Expt. I F	Expt. II M.S	Expt. II F
Total	71	-	-	-	-
Blocks	5	2.299	-	.458	-
Varieties	3	303.503	73.24**	92.598	22.68**
Temp. Treatments	2	252.382	60.95**	128.741	31.54**
Var. x Temp. Tr.	6	4.141	2.85*	1.917	0.47
Error	55	1.453	-	4.318	-
Pooled Error	61	-	-	4.082	-

* F value exceeds 5% level of significance.

** F value exceeds 1% level of significance.

TABLE III

DRY MATTER BY HARVEST DATES IN CULM OF BARLEY GENOTYPES GROWN AT DIFFERENT NIGHT TEMPERATURES

Variety	Night Temp. (°F)	Experiment I								
		Average weight culm per plant in grams and % dry matter by days seeding to harvest								
		78			85			92		
		G.W	D.W	% D.M	G.W	D.W	% D.M	G.W	D.W	% D.M
	63	4.515	.973	21.55	4.375	.975	22.29	3.015	.781	25.90
Moore	70	4.097	.855	20.87	3.675	.780	21.22	3.573	.830	23.23
	75	3.557	.727	20.44	3.939	.838	21.27	4.726	1.006	21.29
	63	2.907	.628	21.60	2.843	.632	22.23	2.751	.637	23.16
Montcalm	70	2.869	.647	22.55	2.963	.615	20.76	2.763	,646	23.38
	75	2.418	.527	21.80	2.032	.487	23.97	2.207	.532	24.11
	63	2.620	.525	20.04	2.996	.624	20.83	2.792	.719	25.75
Kindred	70	2.456	.493	20.07	3.061	.616	20.12	2.344	.534	22.78
	75	2.510	.497	19.80	1.926	.443	23.00	2.187	.523	23.91
	63	2.659	.607	22.83	2.836	.697	24.58	2.647	.749	28.30
Plains	70	2.586	.563	21.77	2.580	.619	23.99	2.112	.566	26.80
	75	2.608	.577	22.12	2.411	.580	24.06	2.078	.571	27.48

TABLE III (Continued)

Experiment II

Average weight culm per plant in grams and % dry matter by days seeding to harvest

56			63			70		
G.W	D.W	% D.M	G.W	D.W	% D.M	G.W	D.W	% D.M
3.394	.702	20.68	3.028	.653	21.57	2.321	.647	27.88
3.099	.621	20.00	3.050	.640	20.98	2.583	.682	26.40
3.757	.765	20.36	4.297	.826	19.22	3.463	.789	22.78
3.102	.599	19.31	3.000	.599	19.97	2.930	.713	24.33
3.824	.767	20.06	2.770	.610	21.97	2.832	.665	23.48
3.862	.735	19.03	2.996	.612	20.61	3.136	.734	23.41
3.553	.706	19.87	2.926	.620	21.19	2.581	.597	23.13
3.010	.633	21.03	2.275	.522	22.95	2.193	.583	26.59
3.236	.619	19.13	2.913	.643	22.07	2.089	.697	22.56
2.987	.646	21.63	2.914	.680	23.34	2.748	.681	24.87
2.643	.592	22.40	3.015	.670	22.22	2.634	.661	25.10
2.811	.622	22.13	2.762	.666	24.11	2.060	.504	24.47

TABLE IV

ANALYSIS OF VARIANCE FOR GREEN WEIGHT AND DRY WEIGHT OF CULM BARLEY GENOTYPES BY HARVEST DATES GROWN AT DIFFERENT NIGHT TEMPERATURES

Source of Variance		Experiment I						Experiment II					
		73 Days		85 Days		92 Days		56 Days		63 Days		70 Days	
	D.F	M.S	F	M.S	F	M.S	F	M.S	F	M.S	F	M.S	F
GREEN WEIGHT													
Total	71	-	-	-	-	-	-	-	-	-	-	-	-
Blocks	5	.521	-	2.678	-	.583	-	1.172	-	1.102	-	1.060	-
Varieties	3	9.328	11.33**	8.441	10.18**	8.343	2.94	2.016	3.43*	1.882	2.72	.792	1.33
Heat Treatments	2	1.002	1.22	2.998	3.62*	.084	.03	0.489	0.833	1.299	1.88	.939	1.57
Var. x Heat Tr.	6	.292	-	.667	-	2.098	2.84*	0.628	1.077	0.964	1.55	1.128	2.09
Error	55	.823	-	.829	-	.739	-	0.583	-	0.665	-	.539	-
Pooled Error	61	-	-	-	-	-	-	0.587	-	0.691	-	.597	-
DRY WEIGHT													
Total	71	-	-	-	-	-	-	-	-	-	-	-	-
Blocks	5	.016	-	.091	-	.019	-	.030	-	.068	-	.023	-
Varieties	3	.407	12.72**	.354	11.80**	.318	7.40*	.026	1.08	.050	2.00	.043	1.87
Heat Treatments	2	.062	1.94	.127	4.23*	.041	.95	.007	.29	.036	1.44	.007	.30
Var. x Heat Tr.	6	.020	-	.019	-	.069	-	.030	1.30	.018	0.69	.038	1.81
Error	55	.032	-	.030	-	.040	-	.023	-	.026	-	.021	-
Pooled Error	61	-	-	-	-	-	-	.024	-	.025	-	.023	-

* F value exceeds 5% level of significance.

** F value exceeds 1% level of significance.

TABLE V

AVERAGE* NUMBER OF SEEDS SET ON MAIN HEAD BY HARVEST DATES FOR BARLEY VARIETIES GROWN AT DIFFERENT NIGHT TEMPERATURES

Variety	Night Temp. (°F)	Expt. I	Expt. II		
		78 Days No seeds	56 Days No seeds	63 Days No Seeds	70 Days No seeds
	63	2.3	17.0	17.2	17.0
Moore	70	7.8	15.0	16.2	19.0
	75	11.5	13.5	12.5	10.0
	63	7.0	8.3	10.8	15.3
Montcalm	70	3.2	10.8	10.8	12.7
	75	2.5	7.0	9.2	6.8
	63	8.2	16.0	15.2	14.7
Kindred	70	15.0	16.5	14.8	16.7
	75	8.2	14.5	13.3	14.0
	63	.2	2.7	1.8	2.8
Plains	70	-	2.8	3.2	3.2
	75	2.2	2.5	2.2	2.8

* Average of six replications

TABLE VI

ANALYSIS OF VARIANCE FOR SEED SET ON MAIN HEAD AT PROGRESSIVE DATES OF HARVEST FOR BARLEY GENOTYPES GROWN AT DIFFERENT NIGHT TEMPERATURES

Source of		Experiment I		Experiment II					
		78 Days		56 Days		63 Days		70 Days	
Variance	D.F	M.S	F	M.S	F	M.S	F	M.S	F
Total	71	-	-	-	-	-	-	-	-
Blocks	5	49.2	-	-	-	-	-	-	-
Varieties	3	307.407	4.76	677.889	38.09**	625.125	30.49**	612.458	15.93**
Night Temperature	2	29.167	.37	25.598	1.44	30.681	1.50	199.292	3.88
Var. x Night Temp.	6	78.685	3.86**	7.431	-	6.569	-	38.458	2.35*
Error	55	20.328	-	17.795	-	20.498	-	16.398	-

* F value exceeds 5% level of significance.

** F value exceeds 1% level of significance.

TABLE VII

AVERAGE GREEN AND DRY WEIGHT PER PLANT IN GRAMS FOR TILLERS EARS AND PERCENTAGE DRY MATTER OF BARLEY GENOTYPES GROWN AT DIFFERENT NIGHT TEMPERATURES

Variety	Night Temp. (°F)	Experiment I			Experiment II								
		78 Days			56 Days			63 Days			70 Days		
		G.W	D.W	% D.M	G.W	D.W	% D.M	G.W	D.W	% D.M	G.W	D.W	% D.M
	63	.820	.304	37.1	-	-	-	.210	.052	24.8	-	-	-
Moore	70	.270	.094	34.8	.255	.064	25.1	.289	.069	23.9	.289	.086	29.8
	75	.330	.123	37.3	.318	.096	30.1	.214	.045	21.0	.702	.231	32.9
	63	.180	.075	41.7	-	-	-	.146	.039	26.7	.507	.172	33.9
Montcalm	70	.220	.104	47.3	.342	.072	21.1	.444	.118	26.6	.380	.095	25.0
	75	.220	.067	30.5	.747	.220	29.5	.307	.105	34.2	.975	.363	37.2
	63	.330	.140	42.4	.344	.086	25.0	.305	.099	32.5	.375	.143	38.1
Kindred	70	.310	.068	21.9	-	-	-	-	-	-	-	-	-
	75	.540	.231	42.8	.220	.060	27.3	.454	.155	34.1	.519	.176	33.9
	63	.220	.087	39.6	.300	.081	27.0	.419	.126	30.0	.452	.181	40.0
Plains	70	.330	.160	48.5	.278	.085	30.6	.370	.125	33.8	.562	.216	38.4
	75	.430	.179	41.6	.319	.084	26.3	.442	.172	38.9	.150	.056	37.3

TABLE VIII

AVERAGE WEIGHT OF MAIN HEAD IN GRAMS BY HARVEST DATE AND PERCENTAGE DRY MATTER FOR BARLEY GENOTYPES GROWN AT DIFFERENT NIGHT TEMPERATURES

Variety	Night Temp. (°F)	Experiment I			Experiment II								
		78 Days			56 Days			63 Days			70 Days		
		G.W	D.W	% D.M	G.W	D.W	% D.M	G.W	D.W	% D.M	G.W	D.W	% D.M
	63	.573	.229	39.97	1.394	.619	44.40	1.529	.812	53.11	.877	.784	89.40
Moore	70	.568	.296	52.11	1.186	.603	50.84	1.081	.741	68.55	.948	.858	90.51
	75	.590	.405	68.64	1.049	.584	55.67	.643	.565	87.87	.486	.442	90.95
	63	.450	.173	38.44	.920	.380	41.30	1.030	.559	54.27	.957	.824	86.10
Montcalm	70	.263	.129	49.04	1.023	.509	49.76	.777	.550	70.79	.665	.609	91.58
	75	.253	.128	50.59	.732	.386	52.73	.524	.445	84.92	.386	.350	90.67
	63	.585	.309	52.82	1.338	.614	45.89	1.343	.685	51.01	.747	.651	87.15
Kindred	70	.790	.438	55.44	1.345	.699	51.97	.978	.664	67.89	.821	.746	90.87
	75	.503	.308	61.23	1.143	.632	55.29	.696	.619	88.94	.655	.592	90.38
	63	.165	.081	49.09	.434	.187	43.09	.219	.154	70.32	.223	.198	88.79
Plains	70	.058	.048	82.76	.413	.186	45.04	.250	.189	75.60	.217	.194	89.40
	75	.122	.105	86.07	.303	.186	61.39	.178	.152	85.39	.219	.199	90.87

TABLE IX

ANALYSIS OF VARIANCE FOR GREEN AND DRY WEIGHT OF MAIN HEAD BY HARVEST DATES OF BARLEY GENOTYPES GROWN AT DIFFERENT NIGHT TEMPERATURES

Source of Variance	D.F	Expt. I 78 Days M.S	Expt. I 78 Days F	Expt. I 56 Days M.S	Expt. I 56 Days F	Expt. II 63 Days M.S	Expt. II 63 Days F	Expt. II 70 Days M.S	Expt. II 70 Days F
GREEN WEIGHT									
Total	71	-	-	-	-	-	-	-	-
Blocks	5	.153	-	0.151	-	0.070	-	0.068	-
Varieties	3	1.018	16.69**	2.986	30.47**	2.815	22.89**	1.189	8.62*
Temp. Treatments	2	.037	0.61	0.325	3.32*	1.603	13.03**	0.490	3.55
Var. x Temp. Tr.	6	.062	-	0.032	-	0.200	-	0.138	5.15**
Error	55	.061	-	0.105	-	0.114	-	0.026	-
Pooled Error	61	.061	-	0.098	-	0.123	-	-	-
DRY WEIGHT									
Total	71	-	-	-	-	-	-	-	-
Blocks	5	.033	-	.041	-	0.005	-	0.049	-
Varieties	3	.365	12.17**	0.789	31.56**	1.072	30.63**	0.958	9.30*
Temp. Treatments	2	.007	.02	0.021	0.84	0.080	2.29	0.362	3.51
Var. x Temp. Tr.	6	.030	2.73*	0.008	-	0.017	-	0.103	4.91**
Error	55	.011	-	0.027	-	0.037	-	0.021	-
Pooled Error	61	-	-	0.025	-	0.035	-	-	-

* F Value exceeds 5% level of significance.

** F Value exceeds 1% level of significance.

II. EFFECT OF TEMPERATURE ON NIGHT TIME RESPIRATION

It would seem logical to assume that variations in night temperature would affect respiration rates. The rate of increase of respiration of immature barley plants in the dough stage is shown in table 10.

TABLE 10

Rate of respiration in a dark room of C. I. No. 6658 barley at three temperatures. Data in milligrams of CO_2 per hour per kilogram of green weight.

Hours after start of expt.	65 - 65.5°F		70 - 70.5°F		75 - 75.5°F	
	Plant Material (grams)	$MgCO_2$ Kg/HR	Plant Material (grams)	$MgCO_2$ Kg/HR	Plant Material (grams)	$MgCO_2$ Kg/HR
4	96.3	737.8	82.0	1098.4	75.0	1464.2
5	96.3	731.9	82.0	1104.5	75.0	1448.4
7	96.3	709.8	82.0	1108.5	75.0	1438.4
9	96.3	712.4	82.0	-	75.0	-
10	96.3	712.4	82.0	1103.5	75.0	1412.3

It will be noted in table 10 that the relationship between respiration and temperature is linear. It is of interest to note that the Q_{10}[1] is much greater than 2 indicating that an enzyme system is involved. Temperature responses of this magnitude would appear to be of great importance in the adaptation of a species.

III. THE INFLUENCE OF RESPIRATION RATE ON PLANT TEMPERATURE

Highly significant differences were obtained between the internal plant temperature in the culms versus the air temperature by means of thermocouples. These differences are

1. The Q_{10} of any process - physical, chemical, or physiological is defined as the number of times that the rate of the process increases with a 10°C. rise in temperature.

extremely small and the experiment should be repeated for this reason.

The smallness of the differences indicates a rapid dissipation of heat into the atmosphere. More suitable means of checking this point through the use of insulation on the culm could most certainly be devised.

TABLE 11

The difference in average air temperature vs. internal temperature of culm as an indication of respiration rate.

No. of observations	Average air temperature inside jar (°F)	Average temperature inside plant stem (°F)	Difference Stem - Air (°F)	Rate of respiration $MgCO_2$/Kg/HR
24	65.1046	65.1214	+0.0168	707.0
24	70.1909	70.2500	+0.0591**	1101.2
28	75.4565	75.4913	+0.0348**	1443.6

** Differences significant at 1% level

IV. THE GENERAL EFFECT OF NIGHT TEMPERATURE ON THE BARLEY PLANT

As a general statement high night temperature has been found to decrease the number of days to heading, decrease the number of seeds on the main head and to increase respiration rate. These relationships are given in table 12.

TABLE 12

Correlation coefficients between night temperature and certain physical characteristics of barley

	Comparison	d.f	r
1.	Temperature vs date of heading of main shoot.	10	- 0.669*
2.	Temperature vs number of seeds set on main head.	70	- 0.295*
3.	Temperature vs rate of respiration.	16	+ 0.999**

* Differences significant at 5% level.

** Differences significant at 1% level.

DISCUSSION

The experimental evidence indicates that night temperature is an important environmental factor in determining the performance of barley varieties. It is of interest to note that in the early stage of the growth cycle for the barley varieties under study, stem elongation was more rapid at the higher temperatures. However, plants at the lower temperature, continued to grow for a longer period and attained a greater final height.

The number of days from planting to heading in each variety decreased as the temperature increased. In the first experiment plants grown at lower night temperatures yielded more green and dry weights of culms but this was not confirmed in the second experiment. This may be due to cloudy weather in the first experiment which considerably increased the period of growth.

Night temperature produced no significant effect on seed set when averaged over all varieties. However, the variety temperature interaction was significant. This indicated a differential response of genotypes to seed set at different night temperatures, and may explain, to some extent, the erratic behavior of barley varieties in different localities.

Studies on the process of photosynthesis (8) have revealed that at the normal range of temperature for plant growth for a particular species, the net photosynthate was not materially affected by temperature. In the study being reported there was not an appreciable difference in the growth of plants raised at different night temperatures whereas there was a conspicuous decrease in the weight of the main head at the night temperature 75°F as compared to 70° and 63°F. The bulk weight of heads is mainly contributed by the grain which is essentially a form of stored carbohydrate. A deficiency of carbohydrate was shown at the higher night temperature 75°F in comparison to lower temperatures 70° and 63°F when the yields of main head at different dates of harvest were compared. Significant differences were obtained for the 56 and 63 day period in the second experiment for green weights of the main heads. A highly significant interaction was observed between varieties and night temperature treatments for both green and dry weights of the main head, which further substantiates the differential response of the genotypes at different night temperatures.

An increase in respiration without an accompanying increase in photosynthesis will decrease the carbohydrates available for storage and thus reduce yield. A straight line relationship between respiration rate and the temperature at 65°, 70° and 75°F was found for the first five hours of the experiment. After the lapse of 10 hours of respiration in the dark the rate of respiration was found to have decreased more at the higher temperature, 75°F than at 65° or 70°F. This indicates a more rapid exhaustion of carbohydrate material at the high night temperature. This agreed with the work of Walster (21) who found less soluble and hydrolyzable carbohydrates in barley at a higher temperature 20°C than lower one 15°C. This may also explain, in part, the low weights of

heads obtained at 75°F in comparison to 70° or 63°F. However, the main decrease in weight is probably due to increased sterility at the higher temperatures.

The difference between the internal temperature of the stem and of the air in the respiration jar in the dark was small but statistically significant. It was hoped that the release of energy in respiration could be used as a measure of respiration rates. However, the size of the differences obtained indicates a very rapid dissipation of heat into the atmosphere. Obviously, some other procedure, such as insulating the culm, must be used to either prove or disprove the assumption.

The r values recorded between night temperature and certain physical characteristics of the barley genotype under study explain why low yields are obtained at high night temperatures. The night temperature showed a significantly negative correlation with date of heading and number of seeds set. The dry weight of main head has also shown negative correlation with night temperature ($r = -0.191$) but the r value is not significant. The rate of respiration is closely associated with temperature with an r value of $+0.9999$. The data indicate that the main causes of decreased yield are: 1) close positive association of night temperature and rate of respiration, 2) shortening of the crop cycle as shown by the negative association of date of heading and, 3) significant negative correlation with seed set. Genotype night temperature interaction was indicated by the data which may explain, to some extent, the differential behavior of barley varieties at different night temperatures.

SUMMARY AND CONCLUSIONS

1. Four genotypes were grown in the green house to study the response of certain physical characteristics of barley to night temperature at 75°, 70° and 63°F with a range of ± 2°F. The night temperature was controlled by radiating artificial heat from infrared bulbs. The plants were harvested at the progressive dates of maturity of the main head.
2. The height of main shoot was affected by night temperature. The higher the night temperature the quicker was the rate of elongation of the main shoot in the early stage of development of the plants but the order was reversed in the advanced stage of growth. At harvest the plants raised at low temperature were tall as compared to the plants raised at high temperature.
3. Date of heading was found to have significant negative correlation with night temperature.
4. Average night temperature seven days after date of heading showed a significant negative correlation with seed set.
5. No significant difference in the green or in dry weight of culm was recorded between different night temperatures except in the plants harvested after 85 days in experiment I.
6. No significant difference was recorded in the dry weight of the main head between different night temperatures. A highly significant variety x night temperature interaction for dry weight of main head was recorded in

experiment I and for the plants harvested after 70 days in experiment II indicating differential response of barley genotypes to night temperature.

7. Respiration in the dark in the above ground parts of the plant increased with temperature and was found to be closely correlated with temperature with an r value of ≠ 0.9999. The decrease in the rate of respiration at 75°F after 10 hours of respiration in the dark was more than the decrease at low temperatures 65° and 70°F which indicated exhaustion of oxidizable carbohydrates at high temperature.

8. The internal temperature of the stem was higher than that of the air in the respiration jar at different temperatures. This difference, though small, was significant.

9. The data obtained in this study revealed a significant negative correlation of night temperature with date of heading and seed set accompanied by increased rate of respiration which caused a defficiency of carbohydrate at high temperature. Presumably this, could account for lower yields obtained at higher night temperatures in barley varieties.

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Date Due