THE EFFECT OF GLUME PIGMENTATION ON THE POST-HARVEST DORMANCY OF COMMON WHEAT, TRITICUM AESTIVUM L.

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ABSTRACT

THE EFFECT OF GLUME PIGMENTATION ON THE POST-HARVEST DORMANCY OF COMMON WHEAT, Triticum aestivum L.

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The lines used in these studies were derived from a back-cross population.

Genesee, a white seeded-red glumed nondormant variety was used as a recurrent parent and Redcoat, a red seeded-white glumed dormant variety was used as a donor parent. Both threshed and unthreshed seeds were used in these studies.

The effect of a low germination temperature for breaking dormancy of threshed seed was highly significant while it was nonsignificant for unthreshed seed.

The period of post-harvest dormancy of threshed seeds was much shorter than that of unthreshed seeds. These differences were due to the presence of latent factors in the glumes which directly or indirectly suppressed germination.

Analysis of variance showed that white glumes had more latent factors than did red glumes, in the eight pairs of lines studied in this experiment.

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REVIEW OF LITERATURE

Dormancy of seeds is manifested by a delay in germination or no germination when held under favorable germinating conditions. Crocker (1916) described the mechanisms by which seeds may be delayed in germination as follows:

(a) Rudimentary or immature embryo.

(b) Complete inhibition of water absorption by surrounding structures.

(c) Mechanical resistance to the expansion of the embryo by enclosing structures.

(d) Inhibition of gas exchange by enveloping structures.

(e) Failure of embryo to grow.

(f) Assumption of secondary dormancy.

Dormancy in the seed could also be due to the presence of substances with germination-inhibiting properties.

Link and Walker (1933) isolated substances from pigmented onion scales which retarted the growth of some onion diseases. Cox et al. (1945) reported the existence of a germination inhibitor in the seedcoat of certain varieties of cabbage.

Smith (1948) observed that aqueous solutions of wheat chaff were sometimes, but not consistently, effective in inhibiting seed germination. Elliott and Leopold (1953) found that the

INTRODUCTION

Seed from unthreshed heads of common wheat varieties has usually demonstrated greater post-harvest dormancy than comparable threshed seed.

Aqueous extracts of wheat chaff (Smith, 1948) were sometimes, but not consistently, effective in inhibiting seed germination. Numerous papers report the association of wheat seedcoat pigmentation and post-harvest dormancy. Miyamoto et al. (1961) reported the isolation of a dormancy factor from a red wheat variety. This study will attempt to answer the question as to whether or not there is a dormancy factor in the glumes associated with pigmentation which would operate independently of seed dormancy.

hulls from seeds of Avena sativa contain substances which suppress germination. Nagao et al. (1957) reported on an association of seedcoat pigmentation with some germination inhibitors in red and brown rice varieties. Black (1959) demonstrated the existence of some germination retarding agents in the seeds of wild oats.

Many investigators (Lomejko 1937 - Wellington 1956 - Everson and Hart 1961 - Belderok 1961 - and others) have shown that red-grained varieties of wheat are more resistant to unfavorable climatic conditions than white-grained ones.

Variation in the tendency to sprout has been observed among red-grained varieties but very little variation has been recognized among white-grained ones.

Wellington (1956, a.b.) stated that the mechanical properties of the covering layers are responsible for the condition of post-harvest dormancy in wheat seed. The outer layers of the wheat grain during shrinkage is thrown into folds over the dorsal region of the seed where the embryo is located, whereas in the red grain both outer and inner layers contract simultaneously and no folding takes place. The behavior of the epidermis in the two seeds at this stage of maturation indicated a difference in its mechanical properties which may subsequently affect the expansion of the embryo.

While in white grain the folded epidermis proves no impediment to the expansion of the embryo, in red grain no expansion can take place without developing tension in the epidermis. Wellington also believed that the osmatic value of embryonic cells increases either by the transporation of carbohydrates from the endosperm to the embryonic cells or by the hydrolization of the starch present in the embryo. These ideas are supported by two facts. First, breaking the seed coat of the dormant grain at the distal end promotes germination by facilitating the transportation of carbohydrate from the endosperm to the embryo. Second, desiccating the dormant grain stimulates germination by hydrolyzing the starch present in the embryo.

Belderok (1961) recalls Tetyurev who suggested the embryonic appendage as one of the most important obstacles to the germination of wheat. Tetyurev thought that the oxygen transport to the interior of the grain depended to a great extent on the embryonic appendage and its mucilaginous properties. As soon as water reached these mucilaginous cells they swelled and prevented oxygen from reaching the embryo through the micropyle. If dry, warm weather prevails during the maturation processes, the behavior of the embryonic appendage changes due to less swelling.

Thus, oxygen penetration and carbon dioxide eleimination was permitted and dormancy terminated.

This suggestion is substantiated by the fact that wheat seeds are more prone to sprouting if they are exposed to dry, hot weather during maturation rather than to wet and cold.

Mosheov (1938) was the first investigator to study the influence of the water extract of wheat grain upon germination and growth. The germination of a sample of nondormant wheat seeds was inhibited for several days when soaked in a water extract of dormant wheat seeds. The inhibitory action of the wheat extract, however, was eliminated by heating.

Miyamoto and Everson (1958) studied the biochemical and physiological aspects of wheat seed pigmentation. They illustrated an association of seedcoat pigmentation and some germination inhibitors. As the quantity of the kernel pigmentation precursors were increased the degree of seedcoat color also increased. They concluded that the condition of dormancy in red wheat seed is apparently due to the existence of germination suppressing substances in the seedcoat. However, these inhibitors were water soluble. Similar germination suppressors were found in the seedcoat of red and brown rice by Nagao et al. (1957).

In 1961, Miyamoto et al. conducted another experiment on the dormancy of wheat seed. Four inhibitory fractions were extracted from the red seedcoat. In addition to showing germination inhibitors in the red seedcoat, they demonstrated that post-harvest dormancy was not caused either through water restriction, gas exchange, or an immature embryo. The loss of post-harvest dormancy was explained as inactivation of the inhibitors located in the seedcoat. Ching and Foote (1961) carried out an experiment on the post-harvest dormancy of several wheat varieties considerably different in rates of germination. They demonstrated that covering layers were neither the barriers for gas exchange nor amount of water uptake in dormant and nondormant wheat seeds. Since the water extract of dormant seeds retarded the germination of nondormant seeds, they concluded that delayed germination of dormant seeds was due to the presence of inhibitors in the seeds, probably located in the seedcoat. They stated that the growth inhibitors were oxidized more readily at high temperature and thus lowered dormancy compared to low temperature. This is why post-harvest dormancy could be kept in the seeds if they were stored in a cool place. They also assumed that the overcoming of post-harvest dormancy by a low germination

temperature could be due to synthesis of new substances in the seed which stimulated germination.

Belderok (1961) found that the amount of water available to the wheat plants and the relative humidity of the atmosphere before harvesting were not involved in determination of post-harvest dormancy. Temperature during the stage of mealy-ripeness was considered by Belderok to be the most important climatic factor in determination of post-harvest dormancy. A negative correlation was found between temperature at this stage of maturation and the duration of post-harvest dormancy. He also illustrated the occurrence of some chemical compounds with oxygen absorbing properties in the covering layers. Positive correlation was found between the quantity of these substances and post-harvest dormancy. Belderok (1965) suggested temperature-sum as an index for determination of duration of post-harvest dormancy in wheat seed. The temperature-sum is obtained by multiplying the period of mealy-ripeness (days) by the excess of temperature above 12.5C. during this period. The duration of post-harvest dormancy is in a reverse relation to the temperature-sum.

Harrington (1932), Harrington and Knowles (1940), Hutchinson et al. (1948), Harrington (1949), Wellington and

Durham (1958), and Everson and Hart (1961) have demonstrated greater post-harvest dormancy of unthreshed wheat seed than of comparable threshed seed. These differences may be due to a stimulating action of some compounds in the glume on some latent factor within the grain itself or competition between glumes and the grain for free moisture. In the case of ample water, thin layers of water between the glumes and kernel may obstruct gas exchange. Smith (1948) believed the lower germination of unthreshed seeds of certain varieties of wheat was neither due to lack of water nor oxygen reaching the embryo. He noticed that the aqueous extract of wheat chaff, sometimes but not consistently, was effective in suppressing seed germination.

Inheritance of Dormancy in Wheat

Nilson-Ehle (1914) was the first scientist to pay attention to the phenomenon of dormancy in wheat seed. The conclusions of Nilson-Ehle according to Lomejko (1937) are:

1. The dormancy characteristic is an inherited trait.
2. This character is independent of the character of earliness and winter hardiness.

3. Several genes are involved in the dormancy characteristic.
4. Among these genes those that distinguish the degree of pigmentation play an important role in dormancy.
5. Varieties with all the genes for red color germinate slowest while those without any gene, white grain, germinate the quickest.

Hutchineson et al. (1948) recalls Åkerman and Feekes who confirmed the observation of Nilson-Ehle and considered a genetic linkage between the factors for redness and resistance to sprouting. Muller (1964) found that sprouting occurred in the F_1 as readily as in one of the parents, the susceptible one. The correlation value between selected resistant descendants in the F_2 generation was 0.12. Thus, Muller declared that the phenomenon of sprouting was controlled polygenetically, and selection in the F_2 was not effective. A higher correlation value, $r = 0.38$, was obtained between selected F_3 parents and their descendants. From Everson and Hart's (1961) experiment one could speculate that one or more of the three pairs of genes for kernel pigmentation are partially responsible for resistance to kernel sprouting in wheat.

Inheritance of Seedcoat Pigmentation in Wheat

According to Percival (1921), Nilson-Ehle found that three similar pairs of dominant genes control wheat grain pigmentation. These genes were not linked. The genotype containing all three pairs of these dominant genes is designated by $R_1R_1R_2R_2R_3R_3$. The effect of these genes is cumulative. Therefore, an F_2 plant may have any number of such genes ranging from one to six. Thus, seven different homozygous heritable degrees of intensity of color are possible. However, environmental factors such as temperature, light, etc., also affect the intensity of the color.

Everson and Hart (1961) stated that the genes causing dormancy must be cojoined with only one, or two, but not all, of the genes for seedcoat pigmentation, since the association between the red seedcoat characteristic in wheat and dormancy is not a complete one. Which heritable association, linkage or pleotropic, exists between seedcoat color and dormancy has not yet been determined.

Inheritance of Glume Pigmentation in Wheat

The colors of the glumes, lemma and palea, in wheat are generally described as some shades of black, red, or white. The red color contains various shades of brown and red. The

white color embraces numerous shades of yellowish-white. Black and red color, are according to the numerous crosses, more or less dominant over white, and black also masks the red tins (Percival, 1921).

In some crosses between black-glumed varieties and red-glumed ones the appearance of several individuals with the white-glumed characteristic has been reported in the F_2 generation (Keyzer and Boyack, 1918). Similar observations have been shown between crosses of red-glumed varieties. Intermediate individuals, from the point of view of glume color, may be obtained among F_1 and F_2 individuals from crosses between red- and white-glumed varieties.

According to Percival (1921), Nelson-Ehle has reported a 15 red to 1 white segregation in the F_2 generation of some crosses made between white- and red-glumed varieties. The intensity of red color produced by the two genes was not the same. These dominant genes were recognized to have additive or cumulative effects. It was believed that pigmentation was fully developed only in seasons which were hot, dry and bright.

MATERIALS AND METHODS

A cross was made between a nondormant - white seeded - red glumed variety, Genesee, and a dormant - red seeded - white glumed variety, Redcoat.

At harvest, seed of individual F_2 plants were germinated using methods described by Everson and Hart (1961), and selections exhibiting seed dormancy were isolated. The F_3 progeny of the dormant lines were rechecked for dormancy and the dormant lines were again crossed to Genesee. This backcross population was selfed for 6 generations, selecting for dormancy in the F_3-F_6 generations.

Twenty-three dormant F_7 lines from the backcross Genesee^2 x Redcoat were grown both in the greenhouse (in 10-12 cm pots) and the field (in 1-1.5 m head rows) during the 1965-1966 season. Dormancy was determined by germination tests employing both threshed and unthreshed seed, the latter to determine the effect of the glumes on germination.

Threshed Seed Test

In the test on greenhouse grown threshed seed, 50 seeds of each line and the Genesee check were chosen and placed on a 9^{cm} x 13^{cm} folded germination blotter presoaked in a 1/200,000

solution of panogen to control mold. The moisture content of the seeds at harvest was below 14 percent. The blotters were placed in wooden flats containing 5^{cm} of wet sand and the flats covered with polyethylene plastic, held in place by a heavy rubber band to maintain humidity. Each flat contained a Genesee check. The test temperature was held at 24 C. Each sample was read at 5, 7, 10, 12, 15, and 19-day intervals.

From each line selected from the greenhouse material 5 head rows were planted in the field and a sample of 25 seeds from each row was tested for germination. The field grown lines were tested at 10 C. and 24 C. in darkness. The flats contained both Genesee and Redcoat as checks. The samples were watered each day throughout the study. Daily germination readings were recorded for each sample. In the threshed seed test, the seed was considered germinated when the seedcoat over the embryo split due to swelling of the embryo. When 40 percent or more of the seeds germinated, the sample was considered germinated.

Unthreshed Seed Test

In the greenhouse study 5 heads of each line were tested to determine the effect of glumes on germination. The heads

were randomly chosen and placed in a wooden flat containing 5cm of moist sand. Five heads of Genesee were used in each flat as a check. The flats were covered and watered as described above. Test temperature was 24 C. Readings were made at 5, 7, 10, 12, 15, and 19-day intervals. A head was considered germinated when rootlets or coleoptiles from 3 seeds were visible. In the study of field grown materials 3 heads from each of the 5 head rows were germinated. Germination readings were taken daily. The study was run at 10 C. and 24 C. in darkness. The flat contained both Genesee and Redcoat as checks.

After the results of the dormancy test on greenhouse grown seed were obtained, 8 lines with red glumes were paired with 8 lines with white glumes on the basis of similar threshed seed dormancy. With the field grown materials both the threshed and unthreshed seeds were used in a paired comparison replicated experiment utilizing the same 8 pairs.

The pairing process was done to investigate the effect of glume pigmentation on germination.

A split-plot design with temperature as the whole plot and pair of lines as the subplot was employed to analyze the data obtained from the field study.

To apply the analysis of variance procedure to the results of the field study, the data was scaled as below to favor the lines with higher dormancy:

Threshed seed which germinated after 2, 3, 4, 5, 6, 7, or 8 days received a value of 1, 1, 2, 4, 6, 9, or 12, respectively.

Unthreshed heads germinating after 3, 4, 5, 6, 7, 8, 9, or 10 days received values of 1, 1, 2, 4, 6, 9, 12, or 15, respectively.

By this scaling a subsample of the threshed seed may receive a minimum value of 1 to a maximum value of 12 and a sample from 5 to 60. In the unthreshed test a subsample may have a value as low as 1 and as high as 15 and a sample from 5 to 75.

Table 1. Germination of 27 freshly harvested, 1966 greenhouse grown Genesee ^{2}x Redcoat, F_7 lines which varied for glume color and post-harvest dormancy and the check variety Genesee

Row No. in 1966 Greenhouse	Seed-Coat Color	Glume Color	Threshed Seed Day 5	7	10	12	15	19	Unthreshed Seed Day 5	7	10	12	15	19
111	red	white	19+	19	20	22	22	22	0	0	2++	3	4	4
112	"	red	5	5	6	9	14	18	0	0	0	0	2	2
113	"	"	0	2	4	7	11	11	0	0	0	0	0	4
114	"	"	0	6	11	13	17	19	0	0	0	0	2	4
115	"	"	5	9	15	17	20	21	0	0	0	0	0	5
116	"	"	0	2	2	3	5	7	0	0	1	1	2	5
117	"	white	0	0	3	8	13	16	0	0	0	0	0	0
118	"	"	29	32	33	34	36	38	0	0	1	1	1	4
119	"	"	0	0	0	3	8	11	0	0	0	0	1	3
121	"	red	14	19	20	23	29	30	0	0	0	0	1	3
122	"	"	0	0	0	1	4	9	0	0	0	0	1	1
123	"	white	6	7	8	9	14	19	0	0	0	0	0	2
124	"	"	3	4	5	5	5	8	0	0	0	0	0	5
125	"	"	16	20	22	22	27	33	0	0	0	0	2	5
126	"	red	1	5	7	7	12	17	0	0	0	0	1	3
127	"	"	0	0	0	1	6	10	0	0	0	0	0	5
128	"	"	4	7	8	10	14	17	0	0	0	0	0	5
129	"	"	9	14	15	15	16	18	0	0	0	0	0	5
130	"	"	13	35	35	35	36	37	0	0	0	0	1	4
131	"	"	1	2	11	15	20	25	0	0	0	0	0	0

Table 1, cont.

Row No. in 1966 Greenhouse	Seed-Coat Color	Glume Color	Threshed Seed Day 5	7	10	12	15	19	Unthreshed Seed Day 5	7	10	12	15	19
132	red	white	0	0	2	2	3	6	0	0	0	0	0	3
134	"	red	0	0	1	1	3	5	0	0	0	1	1	1
135	"	"	23	24	24	24	24	24	0	0	0	0	0	1
137	"	"	11	14	14	16	19	31	0	0	0	0	0	3
138	"	"	14	17	23	27	28	33	0	0	0	0	0	4
139	"	"	3	3	8	8	10	11	0	0	0	0	0	2
140	"	"	3	4	4	6	8	11	0	0	0	0	1	3
Genesee	white	red	50	-	-	-	-	-	0	0	0	2	5	-

+ Number of germinated threshed seeds - accumulative

++ Number of germinated unthreshed seeds (heads) - accumulative

Table 2. Paired lines of 1966 Greenhouse grown dormancy lines with their properties and tendency for sprouting

Pair Number	1966 - Greenhouse Row No.	Seed-Coat Color	Glume Color	Threshed Seed Day 5	7	10	12	15	19	Unthreshed Seed Day 5	7	10	12	15	19
P_1	111	red	white	19+	19	20	22	22	22	0	0	2++	3	4	4
	135	"	red	23	24	24	24	24	24	0	0	0	0	0	1
P_2	117	"	white	0	0	3	8	13	16	0	0	0	0	0	0
	126	"	red	1	5	7	7	12	17	0	0	0	0	1	3
P_3	118	"	white	29	32	33	34	36	38	0	0	1	1	1	4
	130	"	red	13	35	35	35	36	37	0	0	0	0	1	4
P_4	119	"	white	0	0	0	3	8	11	0	0	0	0	1	3
	113	"	red	0	2	4	7	11	11	0	0	0	0	0	4
P_5	123	"	white	6	7	8	9	14	19	0	0	0	0	0	2
	112	"	red	5	5	6	9	14	18	0	0	0	0	2	2
P_6	124	"	white	3	4	5	5	5	8	0	0	0	0	0	5
	140	"	red	3	4	4	6	8	11	0	0	0	0	1	3
P_7	125	"	white	16	20	22	22	27	33	0	0	0	0	2	5
	138	"	red	14	17	23	27	28	33	0	0	0	0	0	4
P_8	132	"	white	0	0	2	2	3	6	0	0	0	0	0	3
	134	"	red	0	0	1	1	3	5	0	0	0	1	1	1

+Number of germinated threshed seeds - accumulative

++Number of germinated unthreshed seeds (head) - accumulative

Table 3. Scaled data (means) of the germination test on threshed seed of 1966 field grown dormancy lines with red seed but either red or white glumes

Pair	Glume Color of Line	Replication I Temperature		Replication II Temperature	
		20C.	10C.	20C.	10C.
p_1	white	1.2+	1.2	1.8	2.0
	red	1.8	1.0	2.8	2.4
p_2	white	2.0	1.0	3.2	2.0
	red	8.2	1.2	7.8	2.4
p_3	white	2.8	1.0	3.2	2.0
	red	6.4	1.0	8.8	2.0
p_4	white	2.0	1.0	2.4	2.0
	red	1.2	1.0	1.6	2.0
p_5	white	4.4	1.4	5.6	2.0
	red	2.6	1.2	2.4	2.0
p_6	white	5.6	1.2	9.2	2.0
	red	10.8	1.6	12.0	2.0
p_7	white	5.2	1.2	8.2	2.0
	red	11.4	2.0	12.0	2.0
p_8	white	9.6	1.6	12.0	2.4
	red	6.8	1.6	10.8	2.0

+ Low values indicate less dormancy - high values more dormancy

EXPERIMENTAL RESULTS

The results of the germination test of the 27 greenhouse grown Genesee ^{2}x Redcoat F_7 lines which varied for glume color and post-harvest dormancy are shown in Table 1. On the basis of different glume color and similar germination values of threshed seed, lines 111-135, 137-126, 118-130, 119-113, 123-112, 124-140, 125-138, and 132-134 were paired. The paired lines and their respective germination data are given in Table 2. Red and white glume lines in a pair had very similar threshed seed germination. Differences in germination between paired lines existed in the unthreshed seed tests but since these were not replicated no valid conclusions could be drawn. Table 3 presents the scaled data of the germination test on threshed seed from the 1966 field grown dormancy lines. These lines all had red seed but the lines of a pair differed in glume color.

An analysis of variance of this data (Appendix A, Table a) showed the differences between the following treatments and interaction were highly significant: temperature, pair, temperature x pair, glume color (glume was not present in this test but the term used to designate the lines of a pair),

temperature x glume color, pair x glume color, and temperature x pair x glume color.

The dormancy of threshed seeds was lowered by low germination temperature. However, two pairs, 1 and 4, showed similar responses in terms of germination rate to both high and low temperature (Appendix A, Table b). One could say that there was little if any dormancy in the seeds of these two pairs to be broken by low temperature. Highly significant differences in rate of germination among the pairs were expected since the selected pairs previously exhibited different germination values. Nonsignificant results for glume color were expected since the lines were paired on the basis of similarities in their germination rates but it appeared to be highly significant (Appendix A, Table a). However, this discrepancy could be contributed to the year to year variation or to insufficient evidence for pairing processes. The initial data which was used for determining the pairing relationship was from an unreplicated test.

The significant result, however, indicates that those seeds which developed and matured in red glumes had more dormancy than those with white glumes.

Examination of the pair x glume color interaction (Appendix A, Table d) showed that in pairs 5 and 8 the seeds which were enclosed in white glumes had more dormancy than those which were surrounded with red glumes. In pairs 2, 3, 6, and 7 the opposite situation was found. In pairs 1 and 4 no differences in rate of germination were found between the two sets of seed, over all temperatures.

Interaction between temperature and glume color (Appendix A, Table c) showed that regardless of glume color a low germination temperature could terminate the state of dormancy over all pairs. Examination of the three factor interaction, (Appendix A, Tables e and f) indicated that in all the pairs seeds developed in red or white glumes had lost their dormancy when they were subjected to a low germination temperature. When they were subjected to a high germination temperature some of the seeds developed in red glumes showed more post-harvest dormancy than those developed in white glumes.

Table 4 presents the scaled data of the germination test on unthreshed seed of the 1966 field grown lines. These lines all had red seed but the lines of a pair varied in glume color.

Table 4. Scaled data (means) of the germination test on unthreshed seed of 1966 field grown dormancy lines with red seed but either red or white glumes

Pair	Glume Color of line	Replication I Temperature		Replication II Temperature	
		20C.	10C.	20C.	10C.
P_1	white	5.200+	7.733	5.066	8.333
	red	11.533	8.266	8.800	9.800
P_2	white	13.200	7.200	15.000	10.400
	red	12.666	6.800	14.600	9.000
P_3	white	6.666	7.800	13.000	9.400
	red	8.400	6.800	14.000	9.000
P_4	white	5.933	5.733	13.000	9.200
	red	3.000	9.000	4.000	9.600
P_5	white	5.133	6.133	14.200	9.800
	red	4.200	7.200	4.933	10.000
P_6	white	9.866	8.000	14.400	9.600
	red	11.333	9.733	15.000	11.000
P_7	white	4.000	9.000	6.733	10.200
	red	4.133	10.200	13.800	11.800
P_8	white	10.200	7.400	14.000	9.200
	red	4.800	8.800	13.800	9.400

+ Low values indicate less dormancy - higher values more dormancy

In this germination test the seed was enclosed by glumes throughout the study. An analysis of variance of this data (Appendix B, Table a) showed the differences between the pairs and temperature x pair were highly significant and temperature x glume color interaction was significant.

No significant differences in glume color were found in rate of germination of the seeds under the high and low temperature. However, examination of temperature x pair interaction (Appendix B, Table b) pointed out that dormancy was significantly lower only in pairs 2 and 6 when the germination temperature was low. Highly significant differences in germination rate among the pairs were expected. No meaningful differences were found between germination rate of seeds with white glumes and those with red glumes. Inspection of temperature x glume color, (Appendix B, Table c) showed that post-harvest dormancy of the seeds enclosed in white glumes was broken at low germination temperature while no differences were observed in the germination rates of the seeds enclosed in red glumes when they were subjected to the high and low germination temperature.

DISCUSSION AND CONCLUSION

Comparisons between the results obtained from germination tests of the threshed and unthreshed seed show that the period of post-harvest dormancy for unthreshed seeds was longer than comparable threshed seed. Two groups of seeds were characterized in the threshed seed tests, namely those with red glumes and those with white. The latter group showed much less post-harvest dormancy than the former. However, in the unthreshed seed test, when glumes were present with the seeds, no differences in post-harvest dormancy were found between the two groups.

The theory that dormancy was induced by an oxygen deficiency due to presence of microorganisms under the glumes did not seem entirely accurate since microbial growth was controlled by applying panogen to the water.

There remains the theory of the existence of germination inhibitors in the glumes which directly suppress seed germination for a certain period or the presence of some latent factors which indirectly inhibit seed germination by stimulating some factors in the seed to become inhibitors (Hutchinson et al., 1948).

This theory arose from the observation that the rate of seed germination was significantly reduced from threshed to unthreshed seed. In this experiment it also seems likely that there are more inhibitory factors in white glumes than red glumes which act independently of the germination inhibitors in the seed. This conclusion is drawn from the fact that though significant differences in germination of threshed seed were noted between seeds developed in red and white glumes, this difference was not observed in the unthreshed germination tests of these same lines. Therefore, one must conclude that the white glumes have a higher level of inhibitory action to surpress germination and nullify the difference. Caution should be exercised in this interpretation since only eight pairs were studied and study of individual pairs indicate the presence of a reverse trend in some pairs. Whether the influence of these latent factors on germination of the seed is direct or indirect will require further investigation. Ching and Foote (1961) and George (1967) reported that post-harvest dormancy of threshed seeds of wheat could be broken if the seeds were subjected to low germination temperature. The results obtained from the threshed seed tests in this study compare favorably with these results. However, in the

unthreshed seed tests the treatment for terminating seed dormancy seemed to be ineffective. Further tests showed that a low germination temperature broke the dormancy in seeds enclosed in white glumes in the unthreshed seed tests. The condition of post-harvest dormancy could not be broken in this manner in the seeds enclosed in red glumes in the unthreshed seed tests.

From these observations one could state that post-harvest dormancy in unthreshed seed of wheat could be overcome by low germination temperature if the glumes are white but not where the glumes are red. Probably, a low germination temperature could block in some way the inhibiting characteristics of the latent factors both in white glume and red seed and promotes seed germination. However, in the case of red glume, it could be assumed that under low germination temperature new cellular components are synthesized which prevent seed germination directly or indirectly. The conclusions in this experiment were draw from selected material and could not be applied to wheat in general.

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APPENDIX A

Table a. Analysis of Variance of the Threshed Seed Germination Data in Table 3. Glumes not present during germination

Source of Variation	d.f.	S.S.	M.S.	E.M.S.	F Test
Replication	1	94.613	94.613		
Temperature	1	1369.513	1369.512	$\sigma_s^2 + 800\sigma_a^2 + 1600\sigma_T$	**
Error a	1	6.049	6.049	$\sigma_s^2 + 800\sigma_a^2$	
Pair	7	812.900	116.129	$\sigma_s^2 + 50\sigma_b^2 + 400\sigma_p^2$	**
T. x P.	7	718.337	102.620	$\sigma_s^2 + 50\sigma_b^2 + 200\sigma_{TP}^2$	**
Glume color +	1	72.200	72.200	$\sigma_s^2 + 50\sigma_b^2 + 1600\sigma_{Gc}^2$	**
T. x Gc.	1	59.512	59.512	$\sigma_s^2 + 50\sigma_b^2 + 800\sigma_{TGc}^2$	**
P. x Gc.	7	211.550	30.221	$\sigma_s^2 + 50\sigma_b^2 + 200\sigma_{PGc}^2$	**
T. x P. x Gc.	7	172.738	24.677	$\sigma_s^2 + 50\sigma_b^2 + 100\sigma_{TPGc}^2$	**
Error b	30	71.538	2.385	$\sigma_s^2 + 50\sigma_b^2$	
Sampling Error	256	565.000	2.207	σ_s^2	
Total	319	4153.950			

"**" means significant at .01 level of significance

+ Seed in test produced in heads with either red or white glume

Table b. Examination of the Temperature x Pair Interaction (T.xP.) for the Data of Table 3.

Pair	Temperature 20C.	10C.	$t_1 - t_2$+	F-test
p_1	1.90	1.65	0.25	n.s.++
p_2	5.30	1.65	3.65	**
p_3	5.30	1.50	3.80	**
p_4	1.80	1.50	0.30	n.s.
p_5	3.75	1.65	2.10	**
p_6	9.40	1.70	7.70	**
p_7	9.20	1.80	7.40	**
p_8	9.80	1.90	7.90	**

+ t_1 and t_2 stand for 20C. and 10C., respectively

++ "n.s." means nonsignificant at .05 level of significance
** means significant at .01 level of significance

Table c. Examination of the Temperature x Glume Color Interaction (T.x Gc.) of the Data of Table 3. Glumes not present during germination

Glume	Temperature 20C.	10C.	$t_1 - t_2$	F-test
white	4.900	1.625	3.275	**
red	6.713	1.725	4.988	**

Table d. Examination of the Pair x Glume Color Interaction (P.xGc.) for the Data of Table 3. Glumes not present during germination

Pair	Glume		W - R[+]	F-test
	White	Red		
p_1	1.55	2.00	- 0.45	n.s.
p_2	2.05	4.09	- 2.04	**
p_3	2.25	4.55	- 2.30	**
p_4	1.85	1.45	0.40	n.s.
p_5	3.85	2.05	1.80	*
p_6	4.50	6.60	- 2.10	**
p_7	4.15	6.85	- 2.70	**
p_8	6.40	5.30	1.10	**

[+] W and R stand for white and red glumes

"*" means significant at .05 level of significance

Table e. Examination of the Pair x Glume color Interaction (P.xGc.) for 10C. for the Data of Table 3. Glumes not present during germination

Pair	10 C. Glume		W - R	F-test
	White	Red		
p_1	1.6	1.7	- .1	n.s.
p_2	1.5	1.8	- .3	n.s.
p_3	1.5	1.5	.0	n.s.
p_4	1.5	1.5	.0	n.s.
p_5	1.7	1.6	.1	n.s.
p_6	1.6	1.8	- .2	n.s.
p_7	1.6	2.0	- .4	n.s.
p_8	2.0	1.8	.2	n.s.

Table f. Examination of the Pair x Glume Color Interaction (P. x Gc.) for 20 C. for the Data of Table 3. Glumes not present during germination

Pair	20 C. Glume		W - R	F-test
	White	Red		
p_1	1.5	2.3	- .8	n.s.
p_2	2.6	8.0	-5.4	**
p_3	3.0	7.6	-4.6	**
p_4	2.2	1.4	.8	n.s.
p_5	5.0	2.5	2.5	**
p_6	7.4	11.4	-4.0	**
p_7	6.7	11.7	-5.0	**
p_8	10.8	8.8	2.0	**

APPENDIX B

Table 2. Analysis of Variance of the unthreshed seed germination data in Table 4. Glumes present during germination

Source of Variation	d.f.	S.S.	M.S.	E.M.S.	F-test
Replication	1	7372.800	7372.800		
Temperature	1	500.000	500.000	$\sigma^2_s + 80\sigma^2_a + 160\sigma^2_T$	n.s.
Error a	1	215.512	215.512	$\sigma^2_s + 80\sigma^2_a$	
Pair	7	5324.537	760.648	$\sigma^2_s + 50\sigma^2_b + 400\sigma^2_P$	**
T. x P.	7	4806.350	686.621	$\sigma^2_s + 50\sigma^2_b + 200\sigma^2_{TP}$	**
Glume color	1	18.050	18.050	$\sigma^2_s + 50\sigma^2_b + 1600\sigma^2_{Gc}$	n.s.
T. x Gc.	1	484.762	484.762	$\sigma^2_s + 50\sigma^2_b + 800\sigma^2_{TGc}$	*
P. x Gc.	7	1762.000	251.714	$\sigma^2_s + 50\sigma^2_b + 200\sigma^2_{PGc}$	n.s.
T. x P. x Gc.	7	2617.088	373.870	$\sigma^2_s + 50\sigma^2_b + 100\sigma^2_{TPGc}$	n.s.
Error b	30	5185.288	172.843	$\sigma^2_s + 50\sigma^2_b$	
Sampling Error	256	4648.000	18.156	σ^2_s	
Total	319	32934.387			

Table b. Examination of the Temperature x Pair Interaction (T. x P.) of the Data of Table 4

Pair	Temperature		$t_1 - t_2$	F-test
	20C.	10C.		
p_1	7.050	8.533	- 1.483	n.s.
p_2	13.866	8.350	5.516	**
p_3	10.516	8.250	2.266	n.s.
p_4	6.483	8.550	- 2.067	n.s.
p_5	7.116	8.316	- 1.200	n.s.
p_6	12.650	9.583	3.067	*
p_7	8.833	10.300	- 1.467	n.s.
p_8	10.700	8.700	2.000	n.s.

Table c. Examination of the Temperature x Glume Color Interaction (T. x Gc.) of the Data of Table 4. Glumes present during germination.

Glume	Temperature		$t_1 - t_2$	F-test
	20C.	10C.		
white	10.141	8.487	1.654	*
red	9.162	9.150	0.012	n.s.