Factors affecting coleoptile lengths at leaf emergence, days to emergence, and relative growth rate in covered and hullness, two- and six-rowed barley (Hordeum vulgare L. and Hordeum distichum L.)
by Albert A Schneiter

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agronomy
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Abstract:
Coleoptile length at leaf emergence, days to emergence, and coleoptile relative growth rate was studied in several varieties and crosses of two and six-rowed hulled and hulless barley. Special emphasis was placed on a hulless Stamm x Compana7 genotype which has a short coleoptile.

High temperature was found to adversely affect the three criteria of measurement studied.

Seed preconditioning by environmental conditions such as fertilizer levels, year grown, and dryland or irrigated conditions were found not to be a major factor effecting the three criteria. The presence of a, hull was shown to have a slightly detrimental effect on coleoptile length leaf emergence, days to emergence and coleoptile relative growth rate.

Coleoptile growth was shown to continue for only a short distance after leaf emergence in hulless Stamm x Compana7 composites.

IAA at 5 and 10 ppm was found to retard coleoptile length of the hulless Stamm x Compana7 but not that of Compana, the covered parent, or the derived Stamm x Compana7 genotype.

Greenhouse soil emergence tests showed that laboratory determined coleoptile length at leaf emergence was positively associated with coleoptile emergence, leaf emergence, and total seedling emergence from the soil.

In one field trial, yield was not related to laboratory determined coleoptile length at leaf emergence.

FACTORS AFFECTING COLEOPTILE LENGTHS AT LEAF EMERGENCE, DAYS TO EMERGENCE, AND RELATIVE GROWTH RATE IN COVERED AND HULLESS, TWO- AND SIX-ROWED BARLEY (*HORDEUM VULGARE* L. AND *HORDEUM DISTICHUM* L.)

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This thesis is dedicated to my mother and father.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Coleoptile length at leaf emergence, days to emergence, and coleoptile relative growth rate was studied in several varieties and crosses of two and six-rowed hulled and hulless barley. Special emphasis was placed on a hulless Stamm x Compana^7 genotype which has a short coleoptile.

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Seed preconditioning by environmental conditions such as fertilizer levels, year grown, and dryland or irrigated conditions were found not to be a major factor effecting the three criteria. The presence of a hull was shown to have a slightly detrimental effect on coleoptile length, leaf emergence, days to emergence and coleoptile relative growth rate.

Coleoptile growth was shown to continue for only a short distance after leaf emergence in hulless Stamm x Compana^7 composites.

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Greenhouse soil emergence tests showed that laboratory determined coleoptile length at leaf emergence was positively associated with coleoptile emergence, leaf emergence, and total seedling emergence from the soil.

In one field trial, yield was not related to laboratory determined coleoptile length at leaf emergence.

INTRODUCTION

Hulless or naked barley has attributes which would make it more desirable than common hulled types for some purposes. Hulless barley may have great potential in spring barley growing areas of this country.

It would appear to the author that the absence of the hull would result in barley having increased export value. Many countries of the world, especially in the far east, utilize pearled or otherwise de-hulled barley for food. The weight loss by pearling would be reduced. For some products where pearled barley is desired or essential, such as for dog food, hulless barley could be used without pearling. It would appear that the absence of a hull would enable barley to be used with greater efficiency in almost any situation where barley is fed. Since the hull has little by-product value, a hulless barley would be preferred in barley processing plants in the manufacture of starch and carbohydrate utilizations of barley.

Many carloads of corn are shipped into Montana each year for use in rations where high fiber content is undesirable. With a surplus of barley produced in this state, it would seem to be desirable to replace this corn with low fiber hulless barley at a saving in cost for feed.

Because of its possible desirable attributes, a research program was initiated at Montana State College in 1953 to develop varieties of hulless barley which would be comparable in agronomic performance to hulled varieties presently being grown and produced.

Hulless varieties were crossed with several common hulled varieties and many genotypes evolved. One of the promising genotypes developed was a backcross-derived hulless Compana. The most important criterion used in selecting promising lines was high percent threshability.

Woodward (26) and others have reported poor germination or poor emergence in some types of hulless barley. Preliminary observations indicate this could be a problem in the hulless derived types being developed in Montana.

This study was initiated to determine the possible existence and causal factors affecting poor emergence.

The objectives of this project were (1) to determine coleoptile length and its growth rate in several barley genotypes as affected by temperature, environmental conditions, and the presence or absence of a hull; (2) to isolate factors determining coloeptile growth; and (3) to determine if coleoptile length has any effect on emergence.

LITERATURE REVIEW

Hulless or naked barley, according to Vavilov (23), had its origin in the mountainous regions of central and western China. Much of the world's hulless barley is still grown in Asia with Japan being one of the world's major producers.

Hulless barley has never been widely accepted or produced on a large scale in this country. There is good reason for this. Hulless barley varieties now available have several faults. Germination is apt to be low, disease susceptibility is high, and yields are relatively poor as compared to hulled varieties. Woodward (25) found that quite often the spike only half emerged from the leaf sheath. Ten to twenty percent of the kernels produced a "loose" coleoptile which failed to penetrate the soil crust.

Harlan (10) gives reasons for and against the production of hulless barley. He has stated that brewers do not want it because the hull is necessary to filter wort. More recently cellulose filters have been developed and this statement no longer applies. Those who feed cattle and horses don't want it because the hulls are of some advantage in feeding these classes of livestock. He states that hulless barley is good only for hog and chicken feed and in the manufacture of pearled barley.

Generally speaking, hulless barley would have several advantages as compared to hulled types. Hulled barley may be considered to be about 13 percent hull.

Advantages of hulless barley are (7):

1. 13 percent less weight to handle in harvesting, storing, shipping and processing operations.
2. Test weight is typically increased from 48 to 60 pounds per bushel resulting in a net storage requirement of about 2/3 of a comparable hulled crop and also a saving of 2/3 in transportation costs required to move a given crop when charges are based on bulk.
3. Reduction in barley grinding costs.
4. Increase in feed value equal to or greater than that of corn on a per pound basis.

The absence of the hull affects chemical composition of barley. A comparison of the chemical composition of a typical hulless barley with a hulled high and low grade feed barley is given by Morrison (14) and is recorded below.

Barley Type and Grade	Total Dry Matter, %	Digestible Protein, %	Total Digestible Nutrients, %	Nutritive Ratio	Protein %	Fat, %	Fiber, %	Nitrogen-Free Extract, %	Mineral Matter, %
Hulless Barley	90.2	9.2	80.4	7.7	11.6	2.0	2.4	72.1	2.1
Feed Barley, High grade	90.3	10.8	73.2	5.8	13.5	3.5	8.7	60.5	4.1
Feed Barley, Low grade	92.0	10.0	61.3	5.1	12.3	3.5	14.7	56.2	5.3

From the analysis reported in the above table hulless barley compares quite well to the covered types in almost all aspects. It is much higher in T.D.N. and N.F.E., lower in fat, much lower in fiber and equal to covered barley now being used in the other components. It should be noted that these differences of hulled and hulless barley are confounded with varietal differences.

Three year average analysis of barley varieties being used in Montana to develop hulless barley are given below (7).

Variety	Fat %	Fiber %	Protein %
Compana	2.00	5.00	10.2
Stamm*	2.45	2.20	10.0
Titan	2.20	5.00	10.8
Shortawn*	2.30	2.40	10.2

* Hulless varieties.

From these analyses we can see that in these particular hulless varieties fat is higher, fiber lower, and protein equal to the hulled types.

The chemical analysis of the hull and grain of the hulless barley variety Stamm is given in the following table.

Item	Barley Hulls	Hulless Barley	Percent of total lost if hulls are removed.
Weight - Grams	4.21	41.48	9.21 (yield)
Moisture, %	4.9	7.5	
Protein, %	3.2	9.6	3.28
Ether Extract, %	0.5	1.9	2.60
Ash, %	11.2	1.9	37.46
Crude Fiber, %	15.3	1.4	52.57

From this tabulation it could be concluded that the presence of the hull adds little to the grain which can be utilized by the animal.

One aspect of this study dealt with the emergence of barley seedlings. A seed is essentially a young plant whose life activities are at a minimum. The drying out of a young seed as it ripens on the plant brings about this reduction of activities. The dry seed is in a condition to be held, stored and preserved until the time and place are suitable for the beginning of a new plant (19).

As the process of germination begins water is absorbed, chemical reactions begin and cell division is initiated. The result is growth. As growth proceeds, cell differentiation and the development of the root, coleoptile and other organs begin.

The coleoptile (Gr. koleos, sheath + ptiton, down, feather) is defined as the first leaf in germination of monocotyledons. It sheaths the succeeding leaves (18).

The coleoptile consists of parenchyma cells and two vascular bundles which are oriented length-wise. The coleoptile is hollow in the center and it is in this area that the first true leaf of the seedling is contained (11).

Coleoptile growth has two distinct phases or steps. The first of these steps is cell division and the second is cell elongation. Avery, Piper and Smith (4) found that, in the oat coleoptile, cell multiplication ceased when the coleoptile was 8 mm. long and thereafter growth was by elongation. Wright (26) found wheat coleoptile cell number and volume by age followed sigmoid curves. He found that maximum rate of cell division was reached at 30 to 42 hours after sowing and then declined until 60 hours, at which time it ceased, at a length of about 17 mm. He found that cell volume increased 52 fold from 18 hours after sowing until 120 hours, when the coleoptile was fully mature.

Haber and Luippuld (9) found that temperature had a significant effect on the relative rate of cell division and elongation. At 10°C. it was discovered that cell elongation exceeded cell division while at 26°C. cell division and elongation were equal. It has been shown that as soil temperature increases the mean seedling length becomes proportionally less (12).

Cell elongation is affected by auxins which are contained in the coleoptile tip and diffuse downward through the coleoptile resulting in elongation. By removing the tip it is possible to stop coleoptile cell elongation (13).

It has been shown that an auxin, indoleacetic acit (IAA), can adversely affect coleoptile length (17). In a study made with barley it was found that the mean coleoptile length of a mutant type was less as the concentration of IAA was increased.

Audus (3) states that growth of tissue will decrease if high concentrations of IAA are used on plant tissue.

Light destroys auxins in the coleoptile. If a seed is germinated in light the coleoptile will be much shorter than if it has been germinated and grown in the dark (13).

Cells capable of showing a positive growth response when IAA is added also show an increased respiration rate which is usually 115-130% of the control rate (5).

Studies have indicated that a successful stand of a cereal crop depends largely upon how rapidly the seedlings emerge after sowing. Rate of emergence appears to be related to coleoptile length and seedling growth rate.

Much research has been done on coleoptile length and its association with emergence. Allan, Vogel, Burleigh, and Peterson (1) have found a high correlation between coleoptile length and culm lengths in several dwarf and semidwarf wheat crosses. Chowdhry and Allan (6) associated coleoptile length with seedling and plant height. Allen, Vogel and Peterson (2) showed high correlations (.923 and .905) between coleoptile length and plant height at 50^{o}F. and 90^{o}F. for eleven miscellaneous standard height wheat selections. This correlation is much higher than that which was observed within dwarf and semidwarf varieties. Sunderman (21) obtained good correlation of coleoptile length with plant emergence and plant height using such standard winter wheat varieties as Itana, Turkey, Wasatch, Gaines, and others. Gaines had the shortest coleoptile, least plant height, and the poorest emergence.

Coleoptile length is not the sole factor affecting seedling emergence. It can be affected by many factors such as soil type, environmental conditions, soil water, and seed size. The emergence force, or the force with which the coleoptile or leaf is able to push its way through the soil, is an important factor. Emergence force in legume species has been studied (24) and it was found that the correlation coefficient for seed weight and emergence force was 0.999. Ninety-nine percent of the variation in emergence force among the species studied was accounted for by seed weight.

Many methods and devices have been used (24, 15) to determine seedling emergence force. No satisfactory method has been perfected.

According to Takahashi (22), the length of the coleoptile is a characteristic peculiar to a variety and has a stable value if the seeds are well chosen and the growing conditions are constant. With certain varieties in different tests he has had a coefficient of variability as low as 3.3%.

Takahashi (22) has made a very detailed study of the coleoptile length of three hundred barley varieties of Japan. The study was in effect a study of the association of coleoptile length with plant characteristics. The coleoptile lengths of the varieties were found to fall into two bimodal curve categories, one with long coleoptile and one with short coleoptile. This classification of varieties into the two categories based on coleoptile length was associated with the U_zu or dwarf gene. Those coleoptile affected by the U_zu gene had a mean coleoptile length of 25 mm. while the normal coleoptile, not affected by this gene, had a mean coleoptile length of 46 mm.

Those plants affected by the U_zu gene had many characteristics which distinguished them from normal plants. Their leaves were shorter and wider than normal plant leaves, the stem was short and thick, and the leaves were held at a more acute angle.

Genetic study (16) has shown that elongated coleoptile length is controlled mainly by a single gene segregating in a 3:1 ratio in the F_2, the long coleoptile being dominant over the short.

In most barley types natural crossing is less than 0.5%. However, in hulless types natural crossing is more prevalent, having been observed to be as high as 21% in one year (20).

W. K. Finlay (8) made a study of 800 different barley varieties, both two- and six-row types, from different parts of the world. The varieties were grown for several seasons and the germination behavior of the resultant seed was studied. He found, almost without exception, that hulless barley germinated more rapidly than hulled barley. Only a few hulled varieties germinated as rapidly as the hulless types. He observed that removing a hull from a hulled variety increased the rate of germination and the range of variability of rate of germination was less. He found that the ranking of the various barleys was not altered by environmental conditions. The rate of germination was not affected by position on the head. The very top and the very bottom seed showed lack of complete maturity and a slight difference in chemical composition.

According to most authors (16) the presence or absence of a hull is controlled by a single gene -- hulled (N) being dominant over hulless (n). The degree of semi-nakedness is also controlled by a single recessive gene.

MATERIALS AND METHODS

Measurements were standard throughout these trials. Coleoptile length at leaf emergence was measured by using a divider and a ruler marked in metric units. All measurements were recorded in millimeters. Upon leaf emergence from the coleoptile tip, the distance between the base and the tip of the coleoptile was scribed with the divider which was then placed on the ruler from which the distance between the base and tip of the coleoptile was read and recorded.

The number of days of growth required for leaf emergence of each individual coleoptile was also recorded.

The experimental unit in the laboratory germination trials was a 5¼ x 5 inch plastic box with blotter kept moistened with tap water. In each box 15 seeds were planted and 10 random seedlings measured. The number of replications was either 2 or 4.

Germination was in the dark in a standard water-cooled germinator used by the Montana State Grain Laboratory at Bozeman for standard germination tests. Thermometers were kept in the germinators at all times.

Replications were placed in random order within the germinator and were moved daily to equalize position effect. Samples were germinated at 65°F. except where otherwise noted.

The relative growth rate of plant material is derived from the formula $\frac{\log e\ F - \log e\ I}{\text{days of growth}}$. In this formula an initial (I) uniform coleoptile length for all varieties and types is assumed. The log e of this is then subtracted from the log e of coleoptile length at leaf emergence (F). This difference is divided by the days required for emergence and the resultant figure is a measure of the relative growth rate of the tissue. This is referred to as R.G.R. of the coleoptile in this paper, even though it does not include growth subsequent to first true leaf emergence.

In these trials genetic materials from the barley breeding program at Montana State College were used. Two donor parents of the hulless gene were involved in the parentages, Stamm (PI 194555) from Germany and Short Awn (PI 166186) from India. Stamm is a 2-row variety and Short Awn is a 6-row variety. Four covered commercial parents, Glacier (CI 6976), Titan (CI 7055), Vantage (CI 7324), and Compana (CI 5438) were used as recurrent parents in a backcross system of breeding. Superscripts following the cross designation indicate the number of times the recurrent parent occurs in the pedigree. It should be noted that the short awn ($Lk_2 lk_2$) of PI 166186 is linked with the hulless gene (Nn).

The seed for increase of the hulled-hulless isogenes (49-N-21, 49-n-21, and 50-N-21, 50-n-21) developed by selfing for twenty-one generations, was supplied by Dr. G. A. Wiebe of the U. S. Department of Agriculture.

All materials were grown during the crop years 1962 and 1963 at Bozeman. In 1962 the barley was grown on fallow and in 1963 it was grown on fallow and on land previously cropped to small grain to provide high and low protein (nitrogen) barley respectively. From the 1963 crop, barleys grown at 5 dryland and 4 irrigated locations in Montana were available for testing. Only hulless seed from the cleaned lots was used for the trials, except for one trial where the hulless genotype seed remaining in the hull was used "in the hull" and "out of the hull" by hand removal of the caryopsis.

Indoleacetic acid (IAA) was used in some trials in the manner described below.

In a test in which the IAA concentration was 5 ppm, four methods of IAA application were studied and were as follows:

I. Dry Compana and hulless Stamm x Compana[7] seed was soaked overnight in the IAA solution and then transferred to a germination dish and tap water.

II. Seeds were soaked overnight in water, removed, soaked 8 hours in IAA solution and transferred to a germination dish and tap water.

III. Dry seed was placed in a germination dish and supplied with the IAA solution.

IV. Seed was soaked in tap water and then placed in a germination dish supplied with an IAA solution.

Checks were planted using the check solution. Since IAA is highly insoluble in water it was necessary to dissolve it in 5 ml. of ethyl alcohol per liter of solution. The ethyl alcohol was also added to the check solution so that any difference between the check and IAA treatments could be ascribed to the IAA. With a concentration of 10 ppm IAA 10 ml. of ethyl alcohol were used.

A greenhouse study was conducted in a bench filled with Manhattan Fine Sandy Loam soil and with daily watering. Laboratory germination of non-damaged seed was over 98%. Only non-damaged seed was used for the greenhouse trial.

A field trial was conducted in 1964 using 4 row plots 10 feet long of five entries in five replications in a latin square design. The test was planted May 16 and irrigated twice.

Analysis of the data was by standard statistical procedures with the aid of the 1620 IBM computer. Statistical significance among means was determined by the application of Duncan's multiple range test.

RESULTS

The results and analyses of a study of coleoptile length at leaf emergence, days to emergence and coleoptile relative growth rate as affected by genotype, temperature, and year grown are given in Tables I and II.

In this trial the varieties Compana, Glacier and Titan were used as the covered genotype and the hulless genotypes were Stamm x Compana[7], Stamm x Glacier[7], and Shortawn x Titan[7] (short awned) respectively.

It may be noted that as temperature increased coleoptile lengths at leaf emergence and days to first true leaf emergence were less. Coleoptile relative growth rate increases as the temperature increases.

Generally, days to first true leaf emergence are less in the hulless types. The coleoptile R.G.R. is lower in the hulless types (see Figure 1). Calculated relative growth rate may be an artifact when it is a measurement of comparison between two items where time is held constant and one of the items ceases growth for a portion of the time period or where the time period is not constant. In this graph the coleoptile growth rate appears to be similar in the two types for the period of active growth. The relative growth rate, calculated for time period, between the initial coleoptile length development and the coleoptile length at first true leaf emergence is not similar.

Hulless Stamm x Compana[7] reacts quite differently from all other types. Coleoptile length is much less, days to first true leaf emergence is less and coleoptile R.G.R. is higher. As temperature increases

Table I. Effect of temperature on coleoptile growth of hulless and covered genotypes within five genotypes of barley from two crop years.

		Germination Temperature										
	Year	55°F.		65°F.		75°F.		85°F.		All temperatures-Avg.		
Genotype	Grown	Covered	Naked	Covered	Naked	Covered	Naked	Covered	Naked	Covered	Naked	Avg.
		Coleoptile length at leaf emergence, mm. avg.										
Compana	1962	57.7	39.7	66.5	35.1	52.7	41.9	36.3	32.0	53.3	37.2	45.3**
Compana	1963	58.8	36.4	66.7	33.2	58.3	44.5	36.2	32.9	55.0	36.8	45.9**
Glacier	1963	59.2	58.8	52.1	50.9	55.4	46.5	49.8	44.3	54.1	50.1	52.1**
Titan	1963	53.0	58.1	50.1	56.2	44.9	44.4	40.5	41.3	47.1	50.0	48.6*
49-Norm-21	1962	57.5	60.6	55.2	57.0	46.4	46.2	32.7	37.5	47.9	50.3	49.1*
50-Norm-21	1962	57.3	55.7	60.2	56.5	49.6	52.8	39.4	43.6	51.6	52.2	51.9
Avg.		57.3	51.6	58.5	48.2	51.2	46.1	39.2	38.6	51.5	46.1	48.8**
		Days to first true leaf emergence										
Compana	1962	10.6	8.5	8.8	4.9	6.2	4.7	4.4	3.0	7.5	5.3	6.4**
Compana	1963	11.8	8.6	8.6	5.8	5.2	4.2	4.3	3.2	7.5	5.5	6.5**
Glacier	1963	12.8	11.4	7.5	8.1	4.2	3.9	5.0	5.3	7.4	7.2	7.3
Titan	1963	11.2	10.3	6.8	6.3	4.2	4.1	3.6	3.3	6.0	6.0	6.0
49-Norm-21	1962	10.7	10.4	7.1	5.8	5.0	5.5	3.6	3.5	6.6	6.3	6.4
50-Norm-21	1962	10.7	8.4	8.3	6.5	5.3	4.3	4.3	3.4	7.2	5.6	6.4**
Avg.		11.3	9.6	7.8	6.2	5.0	4.4	4.2	3.6	7.0	6.0	6.5**
		Coleoptile relative growth rate, mm/mm/day										
Compana	1962	1.3	1.5	1.5	2.6	2.1	2.8	2.9	4.3	1.9	2.8	2.3**
Compana	1963	1.1	1.5	1.6	2.2	2.6	3.1	3.0	4.0	2.1	2.7	2.4**
Glacier	1963	1.0	1.2	1.8	1.6	3.1	3.3	2.6	2.5	2.1	2.2	2.1
Titan	1963	1.2	1.3	1.9	2.1	3.1	3.2	3.6	4.0	2.4	2.6	2.5
49-Norm-21	1962	1.2	1.6	1.9	2.3	2.6	2.4	3.6	3.7	2.3	2.5	2.4
50-Norm-21	1962	1.2	1.3	1.6	2.0	2.5	3.1	3.0	3.8	2.1	2.5	2.3*
Avg.		1.2	1.4	1.7	2.1	2.7	3.0	3.1	3.7	2.2	2.6	2.4

* covered and naked different at the 5% probability level

** covered and naked different at the 10% probability level

Table II. Analysis of variance of Table I data.

Source of variation	Degrees of Freedom	Mean Squares: Coleoptile length at leaf emergence	Days to 1st true leaf emergence	Relative growth rate of coleoptile
Replications	1	14.27	0.32	0.12
All genotypes	9	352.29**	6.40**	0.78**
Naked vs covered Compana, 1962	1	1374.56**	16.20**	1.51**
Naked vs covered Compana, 1963	1	1028.81**	20.03**	2.92**
Naked vs covered Glacier	1	64.00**	0.14	0.00
Naked vs covered Titan	1	33.06*	0.86	0.15
49-N-21 vs 49-n-21	1	23.04*	0.39	0.03
50-N-21 vs 50-n-21	1	1.10	8.70**	1.17**
Naked vs Covered	1	84.70**	3.16**	0.19
Germination temperature	3	1188.64**	205.73**	21.64**
All genotypes x temperature	27	63.14**	1.35**	0.23**
Error	55	5.69	0.21	0.06

* significant at 5% level

** significant at 1% level

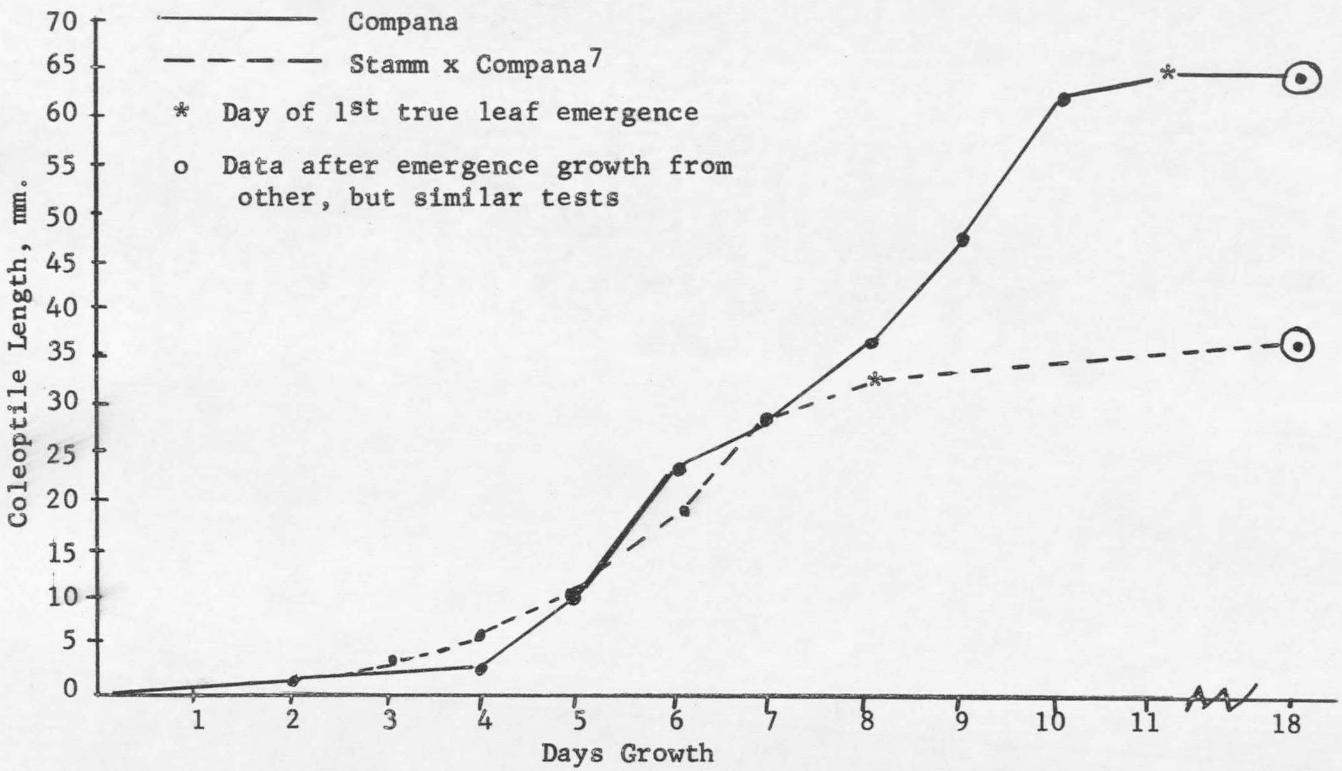

Figure 1. Coleoptile growth rate of Compana and naked Stamm x Compana[7] at 65° F.

coleoptile length does not change significantly as it does for all other types. Days to emergence and R.G.R. react similarly in this type, as compared with the others, with respect to temperature.

To continue the study of the effect of environmental conditions, seed from Compana and Stamm x Compana[7] grown at different locations was selected for study. The seed used was from replicated trials grown at 5 dryland and 4 irrigated locations in Montana.

The results and analysis of variance are given in Tables III and IV. It can be seen that the hulless genotype seed has a shorter coleoptile and a more rapid relative growth rate. These observations are consistent for all locations and conditions.

To obtain further information on the effect of environmental factors on the seed and subsequent coleoptile development of hulless Stamm x Compana[7] as compared to Compana, seed from two separate years and previous land treatment were used. The results and analysis of variance are given in Tables V and VI. There appears to have been no effect of the growing condition on the seed so as to influence coleoptile length, days to emergence or R.G.R.

A test to determine if coleoptile length at leaf emergence, days to emergence and R.G.R. were affected by the presence or absence of a loosely fitting hull provided the results shown in tables VII and VIII. The genotype used was hulless Stamm x Compana[7] and treatment consisted of selecting kernels which were unthreshed for trial, and hand removal of the hull from a similar set of kernels to provide the hulless.

Table III. Comparison of coleoptile length at leaf emergence, days to emergence and coleoptile relative growth rate as affected by seed source effect, location, genotype, and environmental conditions.

	Environmental Factor		Coleoptile length at leaf emergence			Days to 1st true leaf emergence			Coleoptile relative growth rate		
Genotype	Location	Condition	Covered	Naked	Avg.	Covered	Naked	Avg.	Covered	Naked	Avg.
Compana	Creston	Dryland	55.9	43.2	49.6	7.0	6.4	6.7	1.87	2.01	1.94
Compana	Creston	Irrigated	61.1	49.6	55.3	6.9	6.4	6.6	1.91	2.04	1.97
Compana	Moccasin	Dryland	59.1	44.1	51.8	6.9	6.5	6.7	1.91	1.99	1.95
Compana	Sidney	Dryland	63.3	50.8	57.0	6.8	6.5	6.6	1.95	2.00	1.97
Compana	Sidney	Irrigated	61.0	46.1	53.6	6.9	6.3	6.6	1.91	2.00	1.98
Compana	Huntley	Dryland	63.5	48.4	55.9	6.7	6.6	6.6	1.99	1.96	1.97
Compana	Huntley	Irrigated	59.2	48.5	53.8	7.0	6.8	6.9	1.89	1.90	1.89
Compana	Havre	Dryland	57.1	48.8	52.9	6.9	6.3	6.6	1.90	2.05	1.97
Compana	Bozeman	Irrigated	57.3	46.3	51.8	7.0	6.1	6.5	1.89	2.13	2.01
	Average		59.7	47.3**	53.5	6.9	6.4**	6.6	1.91	2.02**	1.96

Table IV. Analysis of variance of Table III data.

Source of variation	Degrees of Freedom	Mean Squares: Coleoptile length at leaf emergence	Mean Squares: Days to 1st true leaf emergence	Coleoptile relative growth rate
Location	5	30.99*	0.08	0.007
Location + Conditions	8	44.58**	0.09	0.008
Conditions	1	0.84	0.00	0.0002
Replications	3	34.89*	0.11	0.011
Genotype	1	2769.66**	3.92**	0.207**
Genotype x Location + Condition	8	10.68	0.15	0.014
Error	51	12.01	0.12	0.011

* significant at the 5% level

** significant at the 1% level

Table V. Comparison of coleoptile length at leaf emergence, days to emergence and relative growth rate of covered and hulless Stamm x Compana[7] as influenced by previous cropping practice and storage for 1 year.

Genotype	Year Grown	Previous Crop	Coleoptile length at leaf emergence, mm.			Days to 1st true leaf emergence			Coleoptile relative growth rate, mm/mm/day		
			Covered	Naked	Avg.	Covered	Naked	Avg.	Covered	Naked	Avg.
Compana	1963	small grain	57.5	34.6	46.0	7.0	5.6	6.3	1.87	2.26	2.06
Compana	1963	fallow	56.9	38.9	47.9	6.8	6.0	6.4	1.94	2.13	2.03
Compana	1962	fallow	54.1	37.4	45.7	7.1	5.8	6.4	1.83	2.21	2.02
		Average	56.1	36.9	46.5	7.0	5.8	6.4	1.88	2.20	2.04

Table VI. Analysis of variance of Table V data.

Source of variation	Degrees of Freedom	Mean Squares: Coleoptile length at leaf emergence	Mean Squares: Days to 1st true leaf emergence	Mean Squares: Coleoptile relative growth rate
Replications	3	1.02	.09	.01
Genotypes	1	2210.50**	8.76**	.61**
Year grown	1	7.54	.05	.005
Genotype x years grown	1	17.74	.08	.009
Previous crop	1	3.12	.06	.007
Genotype x Previous crop	1	39.50	.18	.02
Error	15	8.97	.10	.01

* significant at 5% level

** significant at 1% level

Table VII. Effect of the hull on coleoptile length at leaf emergence, days to emergence and coleoptile relative growth rate in Stamm x Compana[7].

Genotype	Year Grown	Previous Crop	Coleoptile length at leaf emergence, mm.			Days to 1st true leaf emergence			Coleoptile relative growth rate, mm/mm/day		
			Covered	Naked	Avg.	Covered	Naked	Avg.	Covered	Naked	Avg.
Compana	1963	small grain	36.1	37.2	36.6	8.0	7.0	7.5	1.59	1.81	1.70
Compana	1963	fallow	41.8	45.7	43.7	7.8	7.1	7.4	1.64	1.82	1.70
Compana	1962	fallow	44.2	49.3	46.7	7.6	6.5	7.0	1.69	2.01	1.85
	Average		40.4	44.5	42.4	7.8	6.9	7.3	1.64	1.88	1.75

Table VIII. Analysis of variance of Table VII data.

Source of variation	Degrees of Freedom	Mean Squares: Coleoptile length at leaf emergence	Mean Squares: Days to 1st true leaf emergence	Mean Squares: Coleoptile relative growth rate, mm/mm/day
Replications	3	3.48	.36	.02
Year grown	1	227.94**	1.02*	.09**
Previous crop	1	393.02**	.35	.04*
Presence of hull	1	68.51*	5.51**	.34**
Previous crop x hull presence	1	15.24	.0002	.003
Year grown x hull presence	1	8.50	.14	.02
Error	15	12.39	.16	.01

* significant at 5% level

** significant at 1% level

In the absence of the hull, the coleoptile was several millimeters longer at leaf emergence in all cases. In all cases days to emergence was affected by the presence or absence of the hull. Those samples which had the hull surrounding the kernel required an additional day for leaf emergence. Since coleoptile length at leaf emergence was less and days to emergence longer for those seeds which had the surrounding hull, the R.G.R. was less regardless of years grown or previous crop. It appears that the presence of a hull in this particular cross has an adverse affect on seedling growth and rate.

Since shortened coleoptiles appeared to be associated with certain genotypes it was investigated further with a more complete set of genotypes. These genotypes and their parents were tested for coleoptile length at first true leaf emergence, days to emergence and relative growth rate. The results and analyses are given in tables IX through XIII.

The recurrent parents were Compana, Glacier, Titan, and Vantage, all of which are common varieties grown for feed and/or malting barley in Montana. The hulless donor parents were Stamm and Shortawn, which are varieties of naked barley from Germany and India, respectively.

The two caryopsis phenotypes present are hulless and covered. For each cross between a covered and hulless variety both covered and naked genotypes were derived. These were tested for the three criteria of measurement.

Eighty F_3 lines from 22 families of hulless Stamm x Compana^7 and two samples of their parents were tested for coleoptile length at first true leaf emergence, days to first true leaf emergence, and relative growth

Table IX. Comparison of coleoptile length at leaf emergence, days to 1st true leaf emergence and coleoptile relative growth rate of Shortawn x Recurrent Parents and the recurrent parents.

Genotype	Coleoptile length at leaf emergence, mm.			Days to 1st true leaf emergence			Coleoptile relative growth rate, mm/mm/day		
	Covered	Naked	Avg.	Covered	Naked	Avg.	Covered	Naked	Avg.
Shortawn x Glacier[7]	---	42.7		---	7.4		---	1.74	
Shortawn x Compana[7]	50.1	48.5	49.3	7.5	7.5	7.5	1.74	1.74	1.74
Shortawn x Titan[7]	45.8	41.6	43.7	6.5	6.2	6.3	1.99	2.04	2.01
Shortawn x Vantage[7]	44.2	46.5	45.3	6.4	6.7	6.5	2.01	1.94	1.97
Glacier	51.8	---		7.3	---		1.80	---	
Compana	58.4	---		6.5	---		2.04	---	
Titan	47.0	---		6.3	---		2.05	---	
Vantage	34.8	---		6.1	---		2.06	---	

Table X. Analysis of variance of Table IX data.

Source of variation	Degrees of Freedom	Mean Squares: Coleoptile length at leaf emergence	Mean Squares: Days to 1st true leaf emergence	Mean Squares: Coleoptile relative growth rate, mm/mm/day
Shortawn donor genotypes + recurrent parents	10			
Among recurrent parents	3	72.96**	3.15**	0.23**
Naked vs. covered	1	63.86**	0.25	0.03
Shortawn donor genotype + recurrent parents x naked vs. covered	6	51.39**	1.65**	0.12**

** significant at the 1% level

Table XI. Comparisons of coleoptile length at leaf emergence, days to 1st true leaf emergence, and coleoptile relative growth rate of Stamm x Recurrent Parents and the recurrent parent.

	Coleoptile length at leaf emergence, mm.			Days to 1st true leaf emergence			Coleoptile relative growth rate, mm/mm/day		
Genotype	Covered	Naked	Avg.	Covered	Naked	Avg.	Covered	Naked	Avg.
Stamm x Glacier^7	46.5	46.0	46.2	7.2	6.4	6.8	1.80	2.02	1.91
Stamm x Compana^7	50.2	28.9	39.5	7.8	6.1	6.9	1.67	2.06	1.87
Stamm x Titan^7	43.1	38.7	40.9	6.3	6.2	6.2	2.05	2.05	2.05
Stamm x Vantage^7	38.1	41.2	39.6	6.4	6.4	6.4	1.99	1.99	1.99
Glacier	51.8	---		7.3	---		1.80	---	
Compana	58.4	---		6.5	---		2.04	---	
Titan	47.0	---		6.3	---		2.05	---	
Vantage	34.8	---		6.1	---		2.00	---	

Table XII. Analysis of variance of Table XI data.

	Degrees	Mean Squares		
Source of variation	of Freedom	Coleoptile length at leaf emergence	Days to 1st true leaf emergence	Coleoptile relative growth rate, mm/mm/day
Stamm donor genotype + recurrent parents	11			
Among recurrent parents	3	100.06**	0.80**	0.05**
Covered vs. naked	1	302.89**	3.38**	0.22**
Stamm donor genotype + recurrent parents x naked vs. covered	7	182.65**	1.39**	0.08**

** significant at the 1% level.

Table XIII. Analysis of variance of a comparison of Stamm and Shortawn derived types.

Source of variation	Degrees of Freedom	Mean Squares: Coleoptile length at leaf emergence	Mean Squares: Days to 1st true leaf emergence	Mean Squares: Coleoptile relative growth rate,mm/mm/day
Derived crosses of Stamm vs. Shortawn	1	180.02**	1.02**	0.06*
Covered vs. naked of the derived types	1	262.61**	0.59*	0.02

* significant at the 1% level

** significant at the 5% level

rate. A wide variation of coleoptile length was found and is graphed in Figure 2. The low coleoptile mean for a hulless derived Stamm x Compana[7] line was 32.0 mm. while for the high line it was 50.4 mm. Mean length was 42.5 mm. Analysis of variance showed lines and replications to be significant at the one-percent level for coleoptile length at first true leaf emergence. Lines were significant at the one-percent level in days to first true leaf emergence and relative growth rate.

To determine if rupture of the coleoptile by the emerging first true leaf caused the coleoptile to cease growth, a test was made in which coleoptiles were split longitudinally and a barley leaf placed between the split halves when the coleoptiles were approximately 8 mm. in length.

Coleoptile elongation continued even though the coleoptile was split (Table XIV). This was true in both Compana and hulless Stamm x Compana[7] and is probably true of all monocotyledons. If coleoptile elongation had been stopped by the incision and leaf placement, the length would have been substantially less than the checks. As it was, there was a small difference which could have been the result of the manipulation.

Table XIV. Comparison of coleoptile length at 1st true leaf emergence with a leaf inserted between longitudinally split halves of a Compana check and hulless Stamm x Compana[7] barley.

	Leaf inserted in split coleoptile	No leaf inserted
	mm.	mm.
Compana - covered	47.4	52.0
Stamm x Compana[7] - hulless	31.5	32.7
Average	39.5	42.3