

AN ABSTRACT OF THE THESIS OF

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Title: PHYSICAL AND PHYSIOLOGICAL SEED CHARACTERISTICS  
INFLUENCING WHEAT STAND ESTABLISHMENT

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Rate of emergence is an important character for stand establishment. Ability of wheat seeds to germinate and emerge rapidly under different climatic conditions may be regulated by physical and/or physiological characteristics.

Seeds of 26 wheat varieties representing five classes were produced in two different environments (Moro and Corvallis, OR). Seed lots were uniformly sized to remove size as a variable. Sized seed lots were compared for emergence rate index (ERI) at three different locations. The germination rate index (GRI) for each seed lot under 15 different combinations of water potential and temperature was determined in the laboratory.

Seed characteristics (SC) data collected for all the seed lots were 1000-seed weight, protein quantity per 1000 seeds, base temperature, embryo fresh weight, alpha-amylase activity, glutamine synthetase activity, and embryo and endosperm soluble protein.

Base temperature (BT) was variety and seed source dependent. BT requirement was reduced with the advancement of the development stage and moisture stress.

Wheat varieties showed differential behavior among and in some cases within the classes for ERI.

Significant relationships with the ERI for five wheat classes were 1000-seed weight, protein quantity per 1000 seeds, base temperature, embryo weight, glutamine synthetase activity, embryo and endosperm soluble protein.

Data showed that the ERI can be estimated by GRI determination. The GRI giving the most accurate estimate of ERI is generally location dependent. An exception was at the Moro location where the GRI was seed source dependent for spring varieties.

In winter varieties, the GRI and ERI were significantly related to a common SC, BT, at all locations for the Moro source. For the Hyslop source endosperm soluble protein was significantly related to GRI and ERI only at Pendleton. Embryo fresh weight was the SC most closely related to spring varieties only at the Hyslop location for both seed sources.

Yield x ERI relationship is positive for fall planted and negative for spring planted wheat under soil moisture stress.

Seed characteristics and source may have important implications seed vigor testing, determining the best seed production area, and breeding for specific environments.

PHYSICAL AND PHYSIOLOGICAL SEED CHARACTERISTICS INFLUENCING  
WHEAT STAND ESTABLISHMENT

by

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PHYSICAL AND PHYSIOLOGICAL SEED CHARACTERISTICS INFLUENCING  
WHEAT STAND ESTABLISHMENT

INTRODUCTION

Wheat is one of the primary sources of nutrition for people around the world. Every year the demand for wheat increases because of the continual increase in world population. Although some potential for increasing the amount of land for agricultural production does exist, the most important potential for increasing total agricultural production is through development of technology to increase yields on land already being used for growing crops.

Germination and seedling emergence of wheat are the first two critical stages of growth in dryland production. Obtaining an adequate stand for optimum crop production is difficult under many dryland conditions because of adverse soil and other environmental conditions which may limit germination and seedling emergence.

Stand establishment of wheat is a critical management problem that affects both crop production and soil erosion. Inadequate stands and late establishment often markedly reduce the crop yield potential, and the resultant sparse soil cover greatly increases the over-winter erosion hazard as compared with early, well-established stands. Maximum wheat yields are partially dependent upon obtaining a rapid and uniform emergence of seedlings in the field. A better understanding of the interactive effects of environmental and management factors upon wheat emergence would be of use

in establishing desirable stands.

Rate of emergence is an important character for plant establishment. The speed of seedling emergence in cereals is influenced by environmental factors such as soil temperature and soil moisture. Ability of wheat seeds to germinate and emerge rapidly under different climatic conditions may be regulated by physical and/or physiological characteristics.

Several experiments have been conducted on wheat to determine those factors which influence stand establishment and subsequent yield including the proper planting date, the effect of temperature on the plant growth and also the total stand count but very little is known about the seed characteristics which influence the emergence rate of wheat.

The objectives of this study were to:

1. Compare representative wheat varieties from five different classes for the rate of emergence in the field under different climatic conditions.
2. Determine the effect of seed sources on field emergence rate of winter and spring wheats.
3. Determine the base temperature requirement of winter and spring varieties.
4. Establish the relationship between germination rate in the laboratory and emergence rate in the field to estimate the field emergence rate from a rapid and reliable laboratory test.

5. Examine the association of seed physical and physiological characteristics with germination rate in the laboratory and emergence rate in the field.

6. Determine the effect of field emergence rate on final yield under different climatic conditions.

## LITERATURE REVIEW

### STAND ESTABLISHMENT

Stand establishment of wheat (Triticum aestivum L.) in the semiarid areas, is a critical management problem that affects both crop production and soil erosion throughout most of these areas. Inadequate stands and late establishment often markedly reduce the crop yield potential, and the resultant sparse soil cover greatly increases the over-winter erosion hazard as compared with early, well established stands (Cochran et al, 1970). Rapid emergence is an important pre-requisite for obtaining satisfactory stands. Environmental conditions determine in large measure the success or failure of stand establishment. Establishing adequate stands from optimum seeding dates is an uncertainty in most of the low-rainfall areas because soil moisture is often marginal for plant growth.

### VARIETAL DIFFERENCES IN STAND ESTABLISHMENT

Helmerick and Pfeifer (1954), using mannitol solutions, demonstrated genetic differences in wheat for germination and seedling growth under moisture stress. Morrison et al. (1981) found significant differences among four soft red winter wheat cultivars for percent emergence and also mean rate of emergence under laboratory conditions.

Hopper et al, (1979) noticed soya bean cultivar differences for emergence rate in simulated field conditions. Lafond and Baker (1986) observed the same results

when wheat cultivars were compared in the field, the cultivars were different for emergence speed and the results were consistent for two years. The relative performance of cultivars was similar for speed of emergence.

Burleigh, et al, (1965) noticed varietal differences in emergence rate index which was found parallel to coleoptile length. It appeared in this study that the high temperature caused sub-optimal coleoptile elongation in all wheat varieties and selections tested and this condition is directly applicable to poor seedling emergence.

Sunderman (1964) reported significant difference among winter wheat cultivars for their emergence percent in the field and DasGupta and Austenson, (1973) observed yield variations in wheat, dependent on field emergence.

Magoon and Culpepper (1932) working with different varieties of sweet corn, concluded that the amount of heat required to bring sweet corn to canning maturity varied not only with different varieties but also with strains within varieties.

#### FACTORS AFFECTING STAND ESTABLISHMENT

Factors affecting crop establishment such as soil temperature and soil moisture may vary widely between years or in a given year and across locations, making it difficult to predict the rate and extent of plant emergence based solely on planting date. Minimum, optimum and maximum temperatures for effective germination vary with other environmental conditions. Mean seedbed temperatures during

fall planting may vary from above 20°C to < 5°C including diurnal fluctuations. Seedbed moisture may vary from near field capacity to levels too dry for germination. Low moisture delays emergence and, combined with warm temperatures, hastens seed rot or increases fungal damage to seedlings (Lindstrom et al, 1976).

Ashraf and Abu-Shakra (1978) observed that wheat cultivars differ inherently in their response towards drought. Only those adapted to arid and semiarid conditions become established into uniform and vigorous stands during germination under moisture and sub-optimal temperature conditions.

## SOIL TEMPERATURE

### EFFECT ON SEED GERMINATION

Usually the term "seed germination" refers to a complex array of successive processes which lead to radicle emergence. Seeds will not germinate unless they are placed under favorable environmental conditions. Among these conditions are adequate water and oxygen supply, a favorable temperature, and favorable light conditions (Hadas, 1969).

The first process to occur in a germinating seed is water uptake or as it is known otherwise, water imbibition. This process is a function of water availability, either in liquid or gaseous form, seed chemical composition, and seed cover permeability (Mayer and Poljakoff, 1975).

Although a substantial body of empirical information concerning the temperatures at which seeds will germinate has now been accumulated (Mayer and Poljakoff-Mayber, 1975), little attempt has been made to determine what it is that prevents the germination of seeds such as tobacco and cucumber at temperatures around  $10^{\circ}\text{C}$  Simon et al. (1976). Germination entails a variety of biophysical and biochemical processes from the initial imbibition of water and the re-establishment of membrane integrity (Simon, 1974) to the activation of numerous enzymes and metabolic pathways (Mayer and Shain, 1974), and finally the elongation of the root which ruptures the testa. Simon et al. (1976) stated that it is not easy to identify the particular point at which low temperature prevents germination. Moreover, this may not be the same in all cold-sensitive seeds. El-Sharkawi and Springuel (1977) found that the lowest water potential at which the seeds can germinate largely depends on temperature.

Slow germination and low seedling vigor limit establishment of crops, and temperature is a major environmental factor influencing both processes. Temperature is often the main environmental factor governing rate of seed germination (Garcia-Huidobro et al., 1982) and also have a major effect on time required for germination (Woods and McDonald, 1971). Temperature requirements for germination of wheat are reported as: minimum,  $3.5$  to  $5.5^{\circ}\text{C}$ ; optimum  $20$  to  $25^{\circ}\text{C}$  and maximum,  $35^{\circ}\text{C}$  (Peterson, 1965). Schimper (1903)

stated that the cardinal points for germination are higher for seeds of plants from warm countries than for those from cold regions. But in contrast on the basis of results obtained by Wilson and Hottes (1927) it appeared that there was no noticeable change in the cardinal points of temperature for the germination of wheat from North Dakota as contrasted with those of wheat from Texas or Virginia.

Coffman (1923) stated that all small grains, including wheat, can germinate at the temperature of melting ice, and it appears advantageous to use lower temperature for the germination of cereals than those commonly used in seed testing laboratories. Went (1953) divided temperature effects on germination into (i) effects on dormancy, (ii) direct effects on germination, and (iii) indirect effects on further seedling development. Went (1950) emphasized that the effect of temperature is a complex one. It cannot be expressed just as heat units. The assumption is false that the relationship between temperature and growth is a direct one throughout the range at which plants grow.

Lafond and Baker (1986) from their two year field study of nine spring wheat cultivars found that the reciprocal of median germination time, a measure of rate of germination, was linearly related to temperature.

Woods and MacDonald (1971) reported the germination of Lotus corniculatus was delayed by temperatures lower than 15°C, and delayed and reduced by temperature of 30°C or higher. Germination was buffered against in the region



10-15°C.

Germination of several cool and warm-season grasses was better at alternating temperatures than at constant temperature (Mc-Elgunn, 1974; Harty and Butler, 1975; Stubbendieck and McCully, 1972). However, some range grasses were reported to have similar germination under alternating and constant temperatures (Ellern and Tadmor, 1967; Young et al., 1981).

Time to reach 50% of final germination (Gt50), decreased with increasing temperature and the corrected germination rate index (CGRI) of all the species under study increased as temperature increased (Hsu et al. 1985).

#### EFFECT ON EMERGENCE

Soil temperature is an important factor in seedling emergence. Allan, et al, (1962) showed that soil temperatures greatly reduce coleoptile length and, in turn, lessens the ability of seedlings to emerge properly. Morrison et al. (1981) reported an increase in emergence time with the decrease in temperature.

In another study conducted by Dubetz et al (1962) revealed that the percent emergence of wheat was not affected when it was planted at four different constant temperatures (6, 13, 18 and 24°C) but the rate of emergence was the best at 24°C compared to other three temperatures under study.

Hopper et al, (1979) demonstrated using soya bean

cultivars that time required for 50% germination decreased (18.8-4.0 days) as the temperature increased from 10 to 30°C. Emergence (50%) from a sand-soil-peat mixture was more rapid (19.8-6.3 days) as the simulated date was pushed towards the warmer regime.

Muendel (1986) reported an increase in days to 80% emergence of soybean from 29 for the coolest temperature and to 11 for the warmest in the phytotron and from 27 days for 22 May planting to 13 days for 5 June planting in the field. He found that each 1°C decrease in mean soil temperature between 17.3 and 8.5°C resulted in a 2-day delay of emergence.

#### HEAT UNIT SYSTEM

The heat unit system has found a wide spread use. Although the system as it is used is accurate enough to be a valuable tool, considerable error may be involved. This error manifests itself, in part, as a variation in the number of heat units required for a particular variety to complete a particular phase of development. However, this variation is not completely at random, but shows a definite relationship to trends in the climatic conditions under which the variety has been grown. This variation may be summarized as follows: (a) increased summation in warm compared to cool parts of the season, (b) higher summations in warm compared to cool years, (c) higher summations in southern compared to northern latitudes, and (d) higher summations at low versus high altitudes (Arnold, 1960).

## BASE TEMPERATURE

Base temperature is the threshold temperature at which plant growth and dry matter accumulation cease and the physiological processes are at equilibrium. Arnold (1959) compared methods of determining base temperature, explored its significance as a source of error in heat unit system, and pointed out the possible relation of the factors responsible for discrepancies which appear in the literature. He found that three procedural errors lead to the use of an erroneous base temperature, namely: (i) the use of standard deviation of heat unit summations in the computation of the base temperature, (ii) the rejection of the correct base temperature on the basis that it is too low to be physiologically feasible, and (iii) the failure to take into account the effect of other environmental factors which affect the rate of development in the computation of the base temperature.

The nature of the error introduced into a linear heat unit system by the use of an incorrect base temperature is generalized by saying that (a) when the selected base is too high heat unit summations will increase as the mean temperature during the developmental period increases and that if the selected base is too low the reverse trend will take place, (b) the base temperature resulting in the lowest coefficient of variation of heat unit summations rather than the one resulting in the lowest standard deviation is shown to be the appropriate one, and (c) the

base temperature resulting in a zero regression coefficient in an equation relating mean temperature to heat unit summations is shown to agree closely with that giving the lowest coefficient of variation of heat unit summations.

Magoon and Culpepper (1932) reported that the differences in the response of corn and peas to environmental conditions seem to be due primarily to differences in the level and range of effective temperatures. He concluded that the base temperature used in the study of temperature relations of corn should not be the same as that used in the study of peas or other crops having a different temperature minimum. He also found that the minimum temperature base line for sweet corn differ, not only with different varieties but also with different strains.

Hoover (1955) used a different method to calculate the base temperature of southern peas. It consisted of first determining the growth coefficients by plotting the heat unit summations (heat units on plantings) at the different trial base temperatures. A line was drawn through the points for each trial base temperature and linear regression coefficients determined for the heat-unit summations of the five consecutive plantings which deviated the least from linearity. The linear coefficient or rate of change of regression line was taken as the growth coefficient for that trial base temperature. The growth coefficients were negative for the temperatures below the base and positive when above the base. After the growth coefficients were

determined, they were plotted. When line was drawn through the positive and negative coefficients, the two lines intersected at zero. The point on the X axis at which the two lines intersected was taken as the base growth temperature under field conditions.

#### DEGREE DAYS

A direct summation of daily heat units, calculated by subtracting a base temperature--below which growth practically ceases--from the daily mean temperature, has been used most frequently as a measure of heat requirements. These heat units have been referred to as degree days.

Ecologists often use heat accumulation above a given threshold to measure or predict the effect of temperature on biological processes. This heat accumulation is most commonly expressed in degree-days and is estimated by measuring the area contained above a threshold temperature and under the trace on thermograph chart. The principal assumption of the method is that the diurnal temperature curve, which is typically skewed to the right and contains minor variations, is similar to the trigonometric sine curve, which is symmetrical and smooth (Baskerville and Emin, 1969).

Heat sum calculations are based on the assumption that there is a direct proportionality between growth and temperature. That such a simplified relationship does not always exist has been suggested by Went (1950) and demonstrated by Nuttonson (1948).

Lindsey and Newman (1956) concluded that a sufficiently close parallelism exists between the official meteorological records and temperatures actually influencing the plant for such records to be ecologically useful when interpreted by a suitable method.

Arnold (1960) devised a method of estimating accumulated heat units by means of daily maximum and minimum temperatures only.

Gilmore and Rogers (1958) used 15 methods to calculate maturity dates in heat units, based on silking, from the data of five plantings of 20 corn lines and reported that the number of heat units required for silking of corn, designated as effective degrees, remained relatively constant for crops with different planting dates, while calendar days varied widely.

Bierhuizen and Wagenvoort (1974) found that germination can be predicted at optimal soil moisture conditions by means of heat sum in degree days and a minimum temperature for germination. These constants were analysed for 31 vegetables in temperature range of 3 and 25°C.

Bauer, et al. (1985) noted that under a wide range of management and several cultivars, growing degree days accounted for about 93% of the variation in hard red spring grain dry matter assimilation on an area basis in the semiarid northern Great Plains.

Lallukka et al. (1978) reported that the temperature sums computed in different ways have proved more effective

in depicting the length of the growing period than the growing period computed in days. The average temperature of the growing period did not have a significant effect on the magnitude of the sum of growing period temperatures above  $+2^{\circ}\text{C}$ . Computed in this way, the temperature sum would appear on average to be the best estimate of the growing period for barley under Finnish conditions .

Cross and Zuber (1972) evaluated 22 thermal unit formulas for their ability to account for variation in flowering dates, using data from six plantings of corn over a two year period. They used both hourly and daily temperature data in the equations. They found that the daily measurements appeared to be approximately as accurate as the hourly measurements and the best equation for predicting flowering dates on the basis of thermal units used a base temperature of  $10^{\circ}\text{C}$  and an optimum of  $30^{\circ}\text{C}$ . The excess temperature above  $30^{\circ}\text{C}$  was subtracted to account for high temperature stress.

Davidson and Campbell (1983) found from their study on spring wheat that the number of days to the various developmental stages was inversely and linearly related to mean daily temperatures over the  $15\text{-}25^{\circ}\text{C}$  range. They concluded that the degree day equation was a good index of wheat development and under field conditions the number of degree days to progress a crop to flowering stage was 703 and to the soft dough stage 1086.

Katz (1952) reported that there is some variation from

year to year in the total heat requirements necessary to bring the crop to a given stage of maturity. He suggested that this is due to two main factors, namely, variation in soil conditions from field to field such as fertility, topography, and drainage, and yearly differences in the climate from field to field.

Pruess (1983) in his critique postulated if the day-degrees are to achieve their potential for practical applications, some compromise may be necessary between precision and utility.

DeJong and Best (1979) found that in hard red spring wheat, the heat sum required to attain 50% seedling emergence did not increase significantly with decreasing soil water potentials but the minimum temperature for emergence dropped from 1.3 to 0.2°C as the water potential decreased from -1/3 to -10 bar. It was suggested that the seedlings compensated for the increased water stress by lowering their minimum temperature requirement.

Reath and Wittwer (1952) found that in mid season and late pea varieties the number of degree-days required for flowering was reduced progressively by exposure to 12- and 16-hour photoperiods. For field plantings the multiple of degree days summations and average length of day light was found to be a less variable expression than the heat sum alone.

In another study, it was found that photoperiod is not an important variable, obviously, if flowering date were



controlled only by the astronomically determined daylength, an individual would flower on the same date every year. The wide deviations from the average date over many years show the controlling effect of a factor or factors other than photoperiod Lindsey and Newman (1956).

Russelle and Bolton (1980) found that wheat required 149 and 210 degree days above a minimum of 0.7 and 0.4°C to obtain first and 70% emergence, respectively. They expanded that required minimum temperature decreases as more time is allowed between planting and emergence (that is, the extra time between first and 70% emergence). Hur and Nelson (1985) reported the threshold temperature for germination of birdsfoot trefoil as 4.7°C.

#### SOIL WATER

Soil water potential controls seed germination and emergence either through effects on conductivity during imbibition or, like temperature, through effects on physiological processes during embryonic development and seedling growth (Hillel, 1972). Studies generally reveal that the germination (and emergence) rate of wheat is progressively delayed as the soil water potential is lowered from field capacity, and in the absence of other factors, the germination percentage is not influenced until some threshold potential is approached (Hanks and Thorp, 1956, and Hunter and Erickson, 1952).

In order for seeds to germinate, crop seeds have to attain a specific moisture content and seeds of all crops

germinate in a shorter time at high soil moisture than at low soil moisture (Doneen and MacGillworay, 1943). This minimum moisture content was approximately 30.5% for corn, 26.5% for rice, 50.0% for soybean, and 31.0% for sugar beet seeds (Hunter and Erickson, 1952).

Rate of emergence is an important character for plant establishment in much of the semiarid wheat belt. Ability of wheat seeds to germinate and emerge under moisture stress conditions is an important factor for successful wheat crop production.

Gul and Allan (1976) concluded from the study of 93 wheat lines that the time required for emergence nearly doubled for each decrease of water potential of -4 bars within the range of -2.2 to -14.4 bars. Total stand, coleoptile length, seedling height, and root weight were similarly progressively reduced as water potential decreased.

Lindstrom et al. (1976) reported nearly complete emergence (80%) of 'McCall' and 'Nugaines' wheats at soil water potentials as low as -10 bars. Only slight effects on emergence rate were noted as the soil water potential dropped from -0.4 to -4.0 bars. The rate of emergence was noticeably reduced as the potential decreased from -4.0 bars and the lowest water potential at which seedlings emerged was -14.5 bars. His results suggest that at soil water potentials above -10 bars, seedling emergence would not be reduced enough to be of concern to farmers. However,

rate of emergence, a criterion that greatly influences wheat yields, could be influenced by water potentials below -4.0 bars. Morrison et al. (1981) using four cultivars of soft red winter wheat demonstrated that the emergence time increased as moisture tension was increased.

Ashraf and Abu-Shakra (1978) investigated four cultivars of wheat under laboratory conditions and found that germination percent was not affected by moisture stress upto 12 atm but was significantly reduced at 15 and above osmotic tensions. Speed of germination was inversely related to intensity of moisture stress. It was found to decrease significantly with the increase of each three atmospheres in moisture tensions. Doneen and MacGillworay (1943) reported that seed germination is proportionately delayed as the initial soil moisture is decreased.

#### TEMPERATURE x MOISTURE

Studies on interaction between temperature and water stress indicate that water potential effects on germination and emergence of plant species in general increase as temperature deviates from the optimum (McGinnes, 1960, and Tadmor et al, 1969).

Morrison et al. (1981) found highly significant interaction for temperature and moisture tension for the percent emergence and emergence rate of soft red winter wheat. They reported the best combination of 3.9°C and 3 atm. tension to distinguish cultivars for emergence.

### EFFECT OF WATER STRESS ON YIELD

In a physiological study of wheat yield in India Asana et al. (1958) observed that when stress occurred during the 4 weeks after spike emergence, yellowing of the stem and leaves was hastened, grain number was reduced, and the 1000 grain weight was increased. After the leaves and stem had yellowed, the rate of increase in grain weight was higher with normal water supply. Later Asana and Saini (1958) observed that intermittent drought after spike emergence affected yield by reducing the number and size of grains. As a result of these studies Asana (1960, 1962) concluded that under conditions of stress, especially during the grain swelling period, grain number per spike, and sometimes the 1000 grain weight, had as much effect as spike number.

Robins and Domingo (1962) studied the effects of moisture stress on yield and components of yield of spring wheat in the state of Washington. They reported that moisture stress before heading caused a marked secondary growth which increased the number of spikes but delayed the date of maturity. They observed the greatest reductions in yield when moisture stress was imposed during and following heading or during maturation of the grain. Moisture stress during and following spike emergence generally resulted in fewer spikes, fewer spikelets per spike and fewer grains per spike.

Day and Intalap (1970) conducted experiments at

Tucson, Arizona, to study the effects of soil moisture stress at different stages of development (jointing, flowering, and dough) on the growth and yield of spring wheat. They said that stress at any stage of growth decreased grain yield. When wheat was stressed at jointing, reduced grain yield resulted from fewer spikes per unit area and fewer seeds per spike. However, they observed that when stress occurred at the flowering and dough stages, lower yields were caused by lighter seed weight.

Campbell (1968), working with potted Chinook wheat in the green-house, observed that the highest yields were obtained when plants were grown under dry conditions until the booting stage and under wet conditions thereafter. Conversely, minimum grain yields were obtained when plants were grown under wet conditions until the booting stage and dry conditions thereafter.

Brengle (1960) reported that the most critical period for moisture in winter wheat in eastern Colorado was during tillering and early spring growth, because it was at those times that yield potential was formulated. Higher yields were dependent on adequate moisture during jointing and heading stages, but a favorable amount of water during this period did not overcome the detrimental effect of inadequate moisture during the preceding period. He concluded that it was impossible to predict yield of winter wheat on the basis of soil moisture at planting time because during that period moisture was not sufficient to carry the crop

through maturity without additional water in the spring.

### SEED PROTEIN

The increase in nitrogen content of developing cereal inflorescences and grains is due to the movement of nitrogen-containing compounds into the spike (Neales et al., 1963.). In wheat grain the percentage of protein increases during water stress, although total yield decreases; evidently, the total protein is inhibited but total carbohydrate production is inhibited even more. (Boyer and McPherson, 1975).

Several investigators (Lopez and Grabe , 1973; Lowe et al., 1972; Lowe and Ries, 1972, 1973; Ries et al., 1970; Ries and Everson, 1973; Schweizer and Ries, 1969) have shown that seed protein content might affect seedling vigor. For example, Lowe and Ries (Lowe and Ries, 1973) reported that small wheat seed (35 mg) with high protein content produced larger seedlings than large seeds (45 mg) of the same genetic constitution with low protein content. Lopez and Grabe (1973) worked with wheat and barley seeds and found a positive relationship between seed protein and plant performance.

Ries and Everson (1973) obtained wheat seed from different sources and determined the effects of protein content and seed size on subsequent seedling vigor. They observed that both environment and genotype affected the protein content of the seeds. They said that regardless of genotype or environment, seedling vigor was consistently

related to seed protein. Seedling vigor was also related to seed size, but when differences in seed size were eliminated, seed protein content and seedling vigor relationships were significant.

The rate of seedling growth or seedling vigor in cereals is reported to be influenced by seed size, seed protein content, germination resistance, and genotype.

Ries and associates (Lowe and Ries 1972, 1973; Lowe et al. 1972; Ries and Everson 1973) have shown seed vigor and final yield in wheat to be associated with seed size and seed protein content.

Barley cultivars containing high grain nitrogen germinated more rapidly and produced larger seedlings than cultivars with low nitrogen content (Metivier, 1977). Seedlings grown from seeds containing higher amounts of protein accumulate more dry matter than seedlings grown from seeds with lower amounts of protein (Schweizer and Ries, 1969; Lowe and Ries, 1972; Bulisiani and Warner, 1980). However, Bulisiani and Warner (1980) have shown that, if exogenous N is supplied with the seed at the time of planting, the differences in seedling shoot dry weight between seeds of high and low protein content disappear. McDaniel (1969) reported that superior seedling vigor of heavy seeds of barley, Hordeum vulgare L., is due to an increased quantity of mitochondrial protein and higher respiratory activity of mitochondria.

### SEED SOURCE

The source of seed affects seedling shoot dry weight (Quinby et al., 1962; DasGupta and Austenson, 1973a,b). The factors responsible for source effects are in part due to seed size and seed protein content effects, as well as germination resistance, a measure of the relative rate of germination (Gordon, 1971). LaFond and Baker (1986) found seed size effects on speed of germination and recommended that similar sizes be used when comparing cultivars as well as seed from a common source that is completely after-ripened to avoid the confounding effects of dormancy. Koller and Negbi (1959) suggested that the speed of germination at low temperatures, and the position of temperature minima for germination, may be correlated with the geographical distribution of different species of caryophyllaceae.

### SEEDLING AXIS DEVELOPMENT AND SOLUBLE PROTEINS

Assuncao (1979) studied moisture stress effect on seed quality of wheat seeds and reported from a field study that the embryo weight was reduced in the more stressed plants in proportion to the reduction in seed weight.

Ching and Rynd (1978) studied the patterns of embryos from high and low protein, wheat cultivar Yamhill, grain produced under varied fertilizer conditions. High protein grain produced seedlings 25% heavier after four days of germination. This increased growth rate apparently is not directly related with seed weight, nor with genetic capability as the two groups are the same cultivar. The



difference may be attributed to the efficiency of metabolic activity and substrate transfer from the endosperm to seedling axis in the high protein seeds. The soluble protein content was consistently higher in the embryo and seedling axis of the high protein seeds. Significant differences were found after four days of germination; and an increased divergence was shown after nine days of germination, resulting in an 80% higher soluble protein content in the seedling axis of the high protein seeds. The larger increase in size and soluble protein in high protein seeds indicates a higher protein synthesizing ability which probably is attributed to more available substrate and energy (ATP), more active enzymes, and/or more machinery for protein synthesis.

Downes (1978) studied two wheat cultivars, Hyslop and Wanser, under mild water stress and found that the water potential, water content, fresh weight, dry weight, and soluble protein content of the seedling axis were progressively decreased with increasing stress. Shah and Loomis (1965) observed decreases in soluble and total protein in water stressed sugar beet leaves. Barnett and Naylor (1966) reported that soluble protein in two bermuda grass varieties, Common and Coastal, was decreased 31% and 36%, respectively, as shoots were stressed to -10.0 to 37.0 bars leaf water potentials.

Stutte and Todd (1969) found protein content decreased to 58% of the control in wheat leaves as relative water

content reached 60% or greater. He postulated that changes in protein content of wheat seedlings under water stress were due either to an inhibition of protein synthesis or an acceleration of protein degradation.

Based on the close relationship of water potential and soluble protein content in seedling axis, protein synthesis probably is the most sensitive system in plants to be affected by water stress. Under continuous mild stresses adaptive mechanism and genetic ability of adjustment seems to take affect and allow plants to cope with adverse conditions (Downes, 1978).

#### ALPHA-AMYLASE ACTIVITY

Alpha-amylase is an important starch degrading enzyme in the endosperm of cereal grains. It degrades starch by hydrolyzing the alpha-1,4-glucosodic linkages that produce dextrans and very small amounts of maltose and glucose. The maltose and dextrans are further degraded by glucosidases, beta-amylase, and phosphorylase to glucose and glucose-6-phosphate (Briggs 1972). The reaction products provide substrates and an energy source for the embryo during germination.

Wheat kernel alpha-amylase is found during development and germination (Kruger 1972a, 1972b). Environmental factors influence the synthesis and activity of all enzymes. Alpha-amylase synthesis, in particular, has been found to be temperature dependent (Groat and Briggs 1969). Lowered alpha-amylase activity was observed in germinating

crimson clover seeds at sub- or super-optimal temperatures of germinations. (Ching 1975).

Morilla et al. (1973) observed that in dessicated corn seedlings (water potential = -15.0 bars) RNase activity increased 50% over that of control plants (water potential = -3.0 bars). Tvorus (1970) indicated increases in RNase activity in response to water stress was due to de novo synthesis of the enzyme, since the response to dessication could be prevented by chcloheximide. Maranville and Paulsen (1970) observed a 63% increase in alpha-amylase activity in corn seedlings subject to severe water stress. They concluded that the observed decline in leaf starch content of water stressed corn seedlings was due indirectly to the stimulation of alpha-amylase activity. In contrast, Wilson (1971) observed that in crested wheatgrass a water potential of 20 atmospheres resulted in an 80% inhibition of alpha-amylase activity in germinating seeds. He postulated that alpha-amylase synthesis in crested wheatgrass was relatively drought intolerant process. Jones (1969) reported that in germinating barley seed, 0.6 M concentrations of polyethyleneglycol and mannitol inhibited GA-induced alpha-amylase activity by 80%. Jones and Armstrong (1971) postulated that inhibition of alpha-amylase production by sugars is mediated through the osmotic modulation of hydrolytic products from the starchy endosperm.

Reddy et al (1984) found that the enzyme activity varied with ripening temperatures. The enzyme activity was

higher at 15.5 C than that at 26.6 C. or under field conditions. The lower enzyme activity at 26.6 C and field conditions may result either from a lower synthesis, a higher rate of inactivation or degradation of the enzyme, or both. Since alpha-amylase degrades starch, a possible consequence of lower enzyme activity could be a greater net starch deposition, resulting in higher kernel weight when kernels are grown at higher temperatures. Cultivars varied quantitatively, but a general trend persisted. An inverse relationship between alpha-amylase and kernel weight was observed within and among cultivars.

Ching and Rynd (1978) reported that the activity of alpha-amylase was consistently and substantially higher in the endosperms of high protein wheat seeds. Since the quantity of substrate (starch) was equal in situ in the high and low protein seeds, the difference in activity indicates the amount of enzyme present in the endosperm. The increased alpha-amylase activity in high protein seeds was not the result of different gene products because the same 8 isozyme bands were observed in both groups of seeds.

Among the enzymes whose activities are increased under moderate to severe water stress (water potential = -10.0 bars to -15 bars) are ribonuclease and alpha-amylase in leaves (Todd, 1972).

Low alpha-amylase production is associated by linkage or pleiotropism with the dwarfing gene Rht3 in wheat (Flintham and Gale 1980).

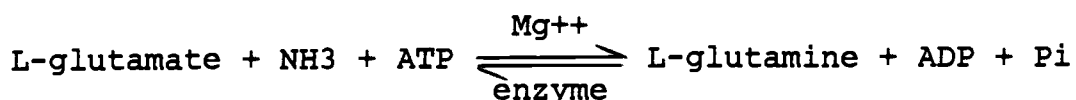
Hard red winter wheat cultivars differed markedly in sprouting and alpha-amylase synthesis in sprouted grain, which increased as time between maturity and exposure to simulated rain was increased. Hard white winter wheat lines were generally more susceptible than were hard red winter wheat cultivars, but exceptions occurred and differences were more quantitative than qualitative. Basal alpha-amylase activity differed more between years than among cultivars (McCrate et al. 1981).

Bingham and Whitmore (1966) and Derera et al (1977) noted significant cultivar differences in basal alpha-amylase activity in mature sound grain. Moss et al (1972) found difference in the rate of alpha-amylase germination among the wheat cultivars grown in Australia.

In wheat grain endosperm, alpha-amylase activity was decreased by the stress treatments while water potential was increased by stress. As the treatments continued, a differential reduction expressed by the two cultivars occurred with the drought resistant Wanser being less affected or able to produce relatively more enzyme under stressed conditions compared to Hyslop (Downes, 1978).

#### GLUTAMINE SYNTHETASE ACTIVITY

The amide glutamine is formed by the amination of glutamate catalysed by glutamine synthetase. The reaction is as follows:



No investigations have been instigated to elucidate the effect of water stress on glutamine synthetase activity in higher plants. Regulatory studies on glutamine synthetase activities reveal that this enzyme is subject feed back inhibition of glutamine metabolic end products and more importantly by energy charge of the cell.

The enzyme glutamine synthetase is believed to play a key role in the assimilation, storage, and translocation of ammonia in higher plants (Lignowski et al., 1971), and glutamine itself is known to participate in the synthesis of a variety of key metabolites (Greenberg, 1969).

Ching and Rynd (1978) reported that glutamine synthetase was synthesized mainly during the first three days of germination. Its activity was maintained for four days at a maximum level and then fell off. The glutamine synthetase activity was comparable between the high and low protein seeds during the first two days of germination, but thereafter was higher in high protein seeds.

Downes (1978) found that glutamine synthetase activity was reduced by the stress during first two days of germination, then adaptation processes occurred resulting in comparable glutamine synthetase activity in all treated materials. The adaptive mechanism apparently occurs at the transcriptional level in producing more efficient glutamine synthetase in compensating the mild environmental stress.

O'Neal and Joy (1973) reported that glutamine synthetase isolated from pea leaves was inhibited competitively by histidine and ornithine and non-competitively by alanine, glycine, and serine. However, this inhibition was significant only when  $Mn^{++}$  served as a co-factor in the reaction and the concentrations of metabolites required for 50% inhibition of enzyme activity were rather high, 1.7 to 6.5 mM for histidine, 7.8 mM for ornithine, and over 40 mM for glycine, serine, and alanine. They suggested most likely that glutamine synthetase activity in pea leaves is regulated by the energy charge of the cell. They showed with  $Mg^{++}$  serving as co-factor ADP, 5'-AMP and Pi were significantly inhibitory and the relative activity of glutamine synthetase was 53% and 20% at energy charges of 0.8 and 0.5.

Weissman (1976) reported that the activity of glutamine synthetase of sunflower roots after the roots were incubated in the following culture solutions: 9 days  $NO_3$ , 7 days  $NO_3$ , 2 days  $NH_4$ , 3 or 5 days zero N and 3 or 5 days darkness increased with increasing cellular energy charge. A significant correlation coefficient of 0.72 was obtained for all experimental data. Weissman postulated that the relationship between glutamine synthetase activity and energy charge provides the cell with a highly sensitive control mechanism under conditions of rapid consumption or limited supply of adenylate energy. He further showed that in the 3 or 5 day zero N and 3 or 5 days darkness treat-

ments, high concentrations of alanine modulated the glutamine synthetase activity-energy charge relationship.

Lignowski et al. (1971) studied the changes in glutamine synthetase activity in germinating pumpkin seeds. They observed low levels of activity during the first two days of germination, 0.4 umoles per minute per cotyledon pair. Enzyme activity increased rapidly thereafter and reached a maximum of 0.35 umoles. By the eighth day of germination, glutamine synthetase activity decreased 0.25 umoles. They reported no appreciable change in ATPase activity in the enzyme preparation during the germination period. ATPase activity from 2 to 8 days of germination was 4.5 to 5.0 umoles PO<sub>4</sub> released per glutamine synthetase assay. The observed maximum activity of glutamine synthetase activity at the sixth day of germination paralleled the period of greatest axis growth and nitrogen transport from the cotyledons of pumpkin seedlings (Lignowski and Splittstoesser, 1971; Splittstoesser and Steward, 1970).



## METHODS AND MATERIALS

Uniform seed lots of 26 wheat cultivars (Appendix I) including five different classes were produced at Corvallis and Moro, OR during the 1984-85 crop season. The locations represent two different growing environments in Oregon. Corvallis is wet (1000<sup>+</sup> mm) with a relatively mild winter, while Moro is dry (290 mm) with cold winters.

Seeds from both sources were sized to achieve uniformity by passing all the seedlots through a #8 (8/64" x 3/4" slot) screen and holding on a #7 (7/64"x 3/4" slot) screen. The sized seed lots were used for all further study.

All the seed lots were tested for germination potential in the laboratory following the procedure proposed by Association of Official Seed Analysts (1965). There were no differences among the seed lots in germination potential.

One-thousand-seed weights were determined for each of the sized seed lots.

Sized seed from both sources for each of the cultivars was planted at a uniform depth using a special precision planter. Individual seeds were placed at 5-cm distance within a row. The experiment was conducted at three locations (Hyslop, Moro, and Pendleton) during Fall of 1985 and Spring of 1986. Three replications were established at each location. Four rows, two meter long were planted for each plot in a split plot design with varieties as main plots and seed sources as sub plots.

Soil samples at 0-5 and 5-8 cm depth were taken at the

time of seeding. Soil samples were dried in the oven at 105°C for 24 hours and gravimetric soil moisture content was determined by using the formula:

$$\text{Gravimetric soil moisture content} = \frac{\text{wet soil} - \text{dry soil}}{\text{dry soil}} \times 100$$

#### EMERGENCE RATE INDEX

Daily counts were made, beginning with the first emergence, for total number of seedlings in the plot. The number of seedlings emerged for each day were determined by subtracting the total number of seedlings from the previous day.

Emergence rate index (ERI) was calculated using a modification of the method described by Maguire (1962). The number of seedlings emerged each day was divided by the days from first emergence. The values obtained for each day were summed to obtain the ERI for a plot.

$$\text{ERI} = x_1/y_1 + x_{ii}/y_{ii} + \dots + x_n/y_n$$

where x=Number of seedlings emerged for the day

y=Number of days from the first seedling emergence

#### GERMINATION RATE INDEX

Fifty seeds from each seed lot were germinated in plastic germination boxes for each of the fifteen combinations of the five constant temperatures (7, 10, 15, 20, and 25°C) and three water potentials (0, -7, and -14 bars) in the germinator. The treatments were replicated three times.

To create -7 and -14 bars water potentials, polyethy-

lene glycol 8000 was used with distilled water using the relationship suggested by Michel (1983). Three layers of brown germination towel paper were used in the germination boxes, two layers under the seed and one layer to cover the seed. The paper was soaked with 15 mL of the solution in each box.

The seeds were considered germinated when both radicle and plumule had appeared. Daily counts after first germination were made for all treatments.

Germination rate index for all the seed lots was calculated for all the temperature and water potential combinations using the same method as for the emergence rate index in the field study.

#### BASE TEMPERATURE

Time in days to reach 50 and 70% germination at 0 bars and 50% germination at -7 bars was calculated at all the temperatures. The reciprocal of time was regressed against the temperatures under study. The base temperature was determined by using the method as described by Arnold (1959).

#### PROTEIN ANALYSIS

Percent nitrogen content for the seed lots was determined using kjeldahl's method described by Schuman et al. (1973) with some modifications.

The samples were dried in the oven for 2 days at 70°C, and ground through a 20-mesh screen.

Samples were redried at 60°C for 1-2 hours prior to weighing. From each sample 0.4 g was weighed in a digestion tube. A tissue standard sample was also weighed. One gram of catalyst (mixture of 1000g anhydrous sodium sulfate, 25 g powdered copper sulfate, and 10g powdered selenium metal) and 8 mL of concentrated sulfuric acid was added to each sample tube and thoroughly mixed. The samples were digested at 120°C for 1 hour and 15 minutes followed by 350°C for 3 hours on a Technicon BD-40 Block digester.

After cooling, distilled water was added to each of the tubes to about one-third full and well mixed. Then distilled water was added to the calibration line of the tube and mixed well by inversion, and 4 mL aliquot was syringed into the sample cups, capped and stored at 4°C.

The digested samples were analysed using an Autoanalyzer. The proportioning pump was started and distilled water was pumped through all the tubes for 10 minutes. Then a NaOH mixture (1000g sodium potassium tartarate and 7000g reagent grade NaOH dissolved in 20L of water), alkaline phenol and 5% sodium hypochlorite was started. Samples were remixed by inversion in sample cups and placed in order in sample tray with set of chemical standards. Cups were removed and tray was placed on sampler. The analysis was started after steady reagent base line was established on the recorder.

After all the samples were run, peak %T readings were converted to optical density using a chart. Percent nitro-

gen was calculated using standard concentrations and optical density readings.

Percent nitrogen values were multiplied with a factor of 5.7 to convert them to protein percentage values. Protein percentage values were converted to protein quantity per 1000 kernels using 1000-kernel weights for each seed lot.

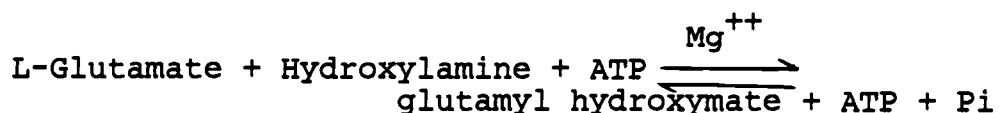
### Enzyme Analysis

Thirty seeds from each seed lot were germinated for 2 days at 20°C constant temperature.

Ten germinating seeds were selected at random from each treatment. Axis and endosperm were separated on a moist filter paper. The axis fresh weight was recorded.

The endosperms were placed into tubes containing 6 mL of cold grinding buffer of Ca-acetate 10 mM, pH 6.0 and stored in an ice bath for alpha-amylase determination.

Glutamine synthetase activity in embryos was determined by the method of O'Neal and Joy (1973). The assay reaction is:



The reaction product glutamyl hydroxymate yields a characteristic brown color with ferric chloride and is determined spectrophotometrically.

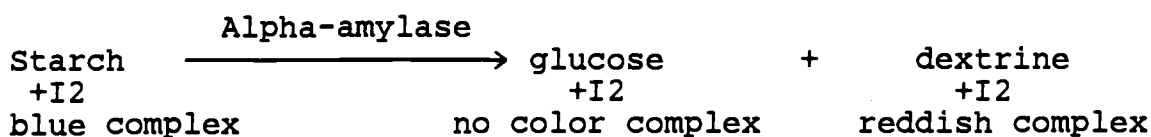
The dissected embryos were ground in 10 mL of grinding buffer containing 0.1 M N-2 hydroxyethylpiperazine, N'-alpha-ethanesulfonic acid (HEPES), 4 mM MgAc<sub>2</sub>, 0.1 M

sucrose, and 10 mM 2-mercaptoethanol pH 7.5, in a cooled mortar and pestle. The homogenate was centrifuged at 20,000 g for 10 minutes. The supernatant was collected and assayed for glutamine synthetase activity.

The reaction mixture consisted of 0.4 mL of enzyme extract and 0.5 mL of reaction buffer containing 0.1 M HEPES, 0.04 M MgSO<sub>4</sub>, 0.16 M L-glutamic acid, pH 7.5 with or without 0.02 M ATP. The reaction mixtures were preincubated at 37°C for 2 minutes, then 0.1 mL of 0.2 M hydroxylamine, pH 7.5 was added. After a 10-minute incubation at 37°C, the reaction was stopped by an addition of 1 mL of color reagent (0.18 M FeCl<sub>3</sub>·6H<sub>2</sub>O dissolved in 0.67 M HCl and 5% TCA). After 10 minutes, 1 mL of glass-distilled H<sub>2</sub>O was added to bring the volume to 3 mL. The mixture was centrifuged at 5000 g for 1 minute to remove protein.

The amount of reaction product (glutamyl hydroxamate) formed in 10 minutes was determined colorimetrically at 540 nm against a blank of enzyme extract and all other assay components except ATP. The total activity was defined as nanomoles of product per minute per seed. The specific activity was defined as nanomoles of product per minute per milligram of extracted protein. Soluble protein in the extract was determined by the method of Bradford (1976).

Alpha-amylase activity in germinating wheat endosperms was determined by a modification of the Mitchell (1972) method as:



Ten dissected endosperms were ground in 10 mL of extracting buffer in a cooled mortar and pestle. The homogenate was transferred to a water bath and heated at 70°C for 20 minutes. After heating, the homogenate was centrifuged at 20,000xg for 10 minutes. The supernatant was collected and assayed for alpha-amylase activity.

Enzyme extract was added to an incubation mixture composed of 1 mL of reaction buffer (10 mM Ca-acetate, pH 4.8) and 1 mL of substrate starch solution (200 mg soluble starch in 100 mL of reaction buffer). The final incubation volume was 3 mL. After 0 and 5 minute incubation at 0°C, a 0.5 mL aliquot was taken from the reaction tube and combined with 0.5 ml of color reagent (60 mg KI and 60 mg I2 in 100 mL of 0.05 N HCL). Five mL of glass-distilled water was added to the mixture. The optical density was read at 620 nm against a blank of 0.5 mL color reagent, 0.5 mL reaction buffer and 5.0 mL glass-distilled H<sub>2</sub>O. The total activity was defined as milligrams starch hydrolyzed per minute per seed. The specific activity was defined as milligram starch hydrolyzed per minute per milligrams extracted protein. Soluble protein in the extract was determined by the method of Bradford (1976).

## RESULTS AND DISCUSSION

Seeds of 26 wheat varieties, produced at two locations were compared for several seed characteristics and for field emergence at three locations. The seed characteristics studied were:

One-thousand-seed weight, protein quantity per 1000 seeds, base temperature for 50 and 70% germination at 0 bars and 50% germination at -7 bars. Embryo fresh weight, alpha-amylase total activity, alpha-amylase specific activity, glutamine synthetase total activity, glutamine synthetase specific activity, embryo soluble protein, and endosperm soluble protein were also determined after germinating the seeds at 20°C constant temperature for two days.

The seed characteristics which showed significant relationships with field emergence for different locations and for different classes of wheat were 1000 seed weight, protein quantity per 1000 seeds, base temperature, embryo weight, glutamine synthetase activity, embryo soluble protein, and endosperm soluble protein.

EMERGENCE RATE INDEX

Wheat varieties from five classes compared for their emergence rate index in the field showed different behavior among the classes and in some cases were different within a class at three different locations.

The soft white winter (SWW) class had no significant differences within the class at Hyslop and Moro location



(Table I).

At the Pendleton location the results were similar with the exception of the varieties Malcolm and Oveson. This is surprising since these two varieties are the most recent releases in the cereal improvement program in Oregon. However, during the final five years (1980-84) of selection and testing before release the climatic conditions for germination and emergence have been unusually favorable. The emergence potential of these two new varieties may be somewhat limited since they were not subjected to stress conditions during the final selection period.

Seed source had an effect on the field emergence of the SWW class at Hyslop and Moro locations. Moro seed source had higher ERI at both the locations while seed source differences were not significant at Pendleton.

The hard red winter (HRW) class showed no differences at the Hyslop location but the varieties showed significant differences at the Moro and Pendleton locations (Table I). The Hyslop location had more favorable moisture and temperature conditions than the other locations. Weston performed the best followed by Wanser, while Kharkof and Bezostaya were the poorest. The latter two varieties are national and international standard check lines out of their area of adaptation, whereas the former are lines developed in the local region.

In this class (HRW) the Hyslop seed performed better compared to Moro seed and were significant at Moro loca-

Table 1: Means of emergence rate index for soft white and hard red winter wheat varieties and seed sources at three locations

<u>Varieties</u>	<u>Locations</u>		
	<u>Hyslop</u>	<u>Moro</u>	<u>Pendleton</u>
<u>Soft White Winter</u>			
Stephens	81.18	53.73	72.27
Hill-81	83.67	54.94	65.68
Lewjain	80.62	54.21	76.99
Nugaines	78.04	48.01	62.47
Daws	72.47	46.43	64.51
Luke	80.00	55.75	68.03
Sprague	87.84	63.95	67.21
Dusty	85.89	59.81	65.08
Oveson	64.12	36.96	50.36
Malcolm	85.59	41.64	57.93
LSD <sub>0.05</sub>	NS	NS	11.98
<u>Seed Sources</u>			
Hyslop	75.98	49.43	65.87
Moro	83.91	53.66	64.23
LSD <sub>0.05</sub>	5.32	2.64	NS
<u>Hard Red Winter</u>			
Kharkof	85.15	48.36	60.42
Wanser	85.82	58.78	66.14
Hatton	75.65	50.27	65.52
Weston	102.27	66.93	77.03
Bezostaya	75.88	49.74	51.10
LSD <sub>0.05</sub>	NS	8.83	15.57
<u>Seed Sources</u>			
Hyslop	86.65	56.52	66.92
Moro	83.26	53.11	61.16
LSD <sub>0.05</sub>	NS	2.97	NS

tion. The seed source differences were not significant at the Hyslop location. It appears that the seed source differences are more conspicuous under stress situation for this class.

Club type (CT) varieties showed no significant differences at any location (Table II). Club type wheat varieties are known to generally have wider adaptability which may account for equal performance under distinctly different climatic conditions.

The Moro seed source performed better than Hyslop seed source at Hyslop location for club type wheat varieties but not at other two locations. Since the Moro seed exhibits a lower base temperature requirement than the Hyslop seed source, it is likely that the emergence time was reduced accordingly (Table IV).

Varieties in the soft white spring (SWS) class exhibited no differences at any of the three locations (Table II). Relative performance of the varieties at different locations changed but the differences among the varieties were not significant. These varieties have been developed for the same area, so it can be speculated that there were not any basic differences among the varieties.

The Hyslop seed source performed significantly better than the Moro seed source for SWS at Hyslop and Moro locations. Seed source effects are similar at the least and most stressful locations but seems to disappear at inter-

Table 2: Means of emergence rate index for club type, soft white spring, and hard red spring wheat varieties and seed sources at three locations

<u>Varieties</u>	<u>Locations</u>		
	<u>Hyslop</u>	<u>Moro</u>	<u>Pendleton</u>
<u>Club Type</u>			
Moro	93.34	62.63	61.49
Faro	87.60	57.39	73.02
Tres	75.54	38.41	58.43
LSD <sub>0.05</sub>	NS	NS	NS
<u>Seed Sources</u>			
Hyslop	80.35	52.71	64.47
Moro	90.64	52.91	64.15
LSD <sub>0.05</sub>	8.69	NS	NS
<u>Soft White Spring</u>			
Dirkwin	77.19	63.45	74.60
Urquie	68.07	63.84	75.83
Owens	71.08	60.13	79.50
Waverly	63.49	62.91	75.28
LSD <sub>0.05</sub>	NS	NS	NS
<u>Seed Sources</u>			
Hyslop	73.19	64.17	75.71
Moro	66.73	61.00	76.89
LSD <sub>0.05</sub>	5.38	2.97	NS
<u>Hard Red Spring</u>			
Wared	45.36	53.37	66.79
Borah	61.57	61.94	69.12
Wampum	72.05	65.81	80.78
McKay	55.79	53.50	70.72
LSD 0.05	9.50	NS	9.17
<u>Seed Sources</u>			
Hyslop	63.03	60.79	70.86
Moro	54.36	56.25	72.85
LSD <sub>0.05</sub>	4.15	4.14	NS

mediate location. It seems that the seed source has a role to play at extreme climatic conditions for this class of wheat.

Among the hard red spring (HRS) varieties, Wampum was superior for field emergence at the Hyslop and Pendleton locations (Table II), but the other varieties showed no difference at either of these locations. At the Moro location all the varieties performed similarly for field emergence.

Seed source effects of the HRS types were similar to that of SWS wheat class. Seed from the Hyslop source performed better at the Hyslop and Moro locations, but were not different at the Pendleton location. Again the intermediate stress location masked the effects seen at the environmental extremes.

The varieties may or may not differ from each other in a particular environmental setting, because the genetic make up may not be distinctly different. Another reason may be that varieties may behave differently from each other at a narrow range of climatic conditions beyond which they all perform similarly. Many variables are involved in the field emergence and the varieties may or may not have their same requirements. If one factor is unfavorable for emergence, another factor may compensate. Another possibility is that varietal performance may be similar in the field, but the factor(s) responsible may be different for different varieties.

SEED DENSITY

Although the seed lots used were of uniform size, there were large differences in 1000-seed weight among the wheat varieties in all the classes within a seed source. 1000-seed weight is higher for Hyslop grown seed compared to Moro grown seed in all the varieties (Table III). In the absence of size difference among the seed lots, the 1000-seed weight variability are essentially differences in seed density.

At the Hyslop location, seed density did not show significant relationship with field emergence for the Hyslop seed source. For the Moro seed source there are significant negative correlations ( $P=0.05$ ) for club types and significant positive correlations ( $P=0.1$ ) for soft white spring wheat types with field emergence. The correlation coefficients are -99.83 and 90.74% respectively. The 1000-seed weight for soft white spring wheat varieties from Moro seed source are the lowest compared to the rest of the classes, indicating that the seed density of soft white spring wheat varieties from Moro seed source is relatively less than the rest of the seed lots under study.

1000-seed weight has significant negative correlations with field emergence for soft white winter and club types ( $P=0.05$ ) from both the seed sources when planted at Moro location. The correlation coefficients are -68.45 and -99.79 respectively. At this location, soil moisture availability in the seed zone at planting was lower than

Table 3: 1000 seed weight (grams) of uniform size seed for all the varieties from two seed sources

<u>Varieties</u>	<u>Seed Sources</u>	
	<u>Hyslop</u>	<u>Moro</u>
<u>Soft White Winter</u>		
Stephens	46.63	43.04
Hill-81	38.21	34.61
Lewjain	41.81	38.64
Nugaines	42.92	38.41
Daws	44.00	41.43
Luke	41.36	35.02
Sprague	38.58	30.30
Dusty	36.70	37.30
Oveson	47.34	40.88
Malcolm	48.60	44.18
<u>Hard Red Winter</u>		
Kharkof	43.79	32.80
Wanser	43.55	35.56
Hatton	39.65	36.14
Weston	50.90	44.41
Bezostaya	48.43	40.78
<u>Club Type</u>		
Moro	36.93	31.52
Faro	36.71	33.35
Tres	41.85	38.03
<u>Soft White Spring</u>		
Dirkwin	52.00	37.62
Urquie	49.70	35.07
Owens	48.70	34.54
Waverly	49.21	31.66
<u>Hard Red Spring</u>		
Wared	44.15	28.89
Borah	46.06	32.50
Wampum	48.65	34.22
McKay	50.14	34.93

the two other locations. Soft white winter and club type wheats are developed for the same area and selected under similar climatic conditions. Therefore, similar responses would be expected for germination and emergence rates. At the Moro location they showed similar behavior for the both seed sources.

Seed density exhibited no significant relationship with field emergence at the Pendleton location. It is likely that the influence of seed density was masked by other factors with greater influence on field emergence under these climatic conditions.

Seeds require a certain definite percentage of water before the germination process begins. Dense seeds require a greater quantity of water to attain the threshold water percentage. Therefore, the more dense the seed, the longer it requires to germinate and emerge.

These results are in agreement with the findings of Hunter and Erickson (1952) who reported that in order for the seeds to germinate, each species has to attain a specific moisture content. They reported that the minimum moisture content is approximately 30.5% for corn, 26.5 for rice, 50% for soybeans, and 31.0% for sugar beet seeds.

Ashraf and Abu-Shakra (1978) studied four wheat varieties for their germination at low moisture and temperature stress. They found that the seeds of the varieties germinated when they attained 50% moisture content on a fresh weight basis. They also reported that



there were varietal differences for the time to germinate and the time to germinate increased with decrease in moisture availability. They did not report the 1000-seed weights for the uniformly sized seed lots but it is speculated that there were differences among the varieties for 1000-seed weight. Therefore, it is possible that the differences in the germination time in their study could have been due to differences in seed density because it required more time to attain the required moisture percentage for germination.

#### BASE TEMPERATURE

Base temperature requirements for 26 wheat varieties of five different classes from two seed sources are given in table IV. Regression coefficients for all the base temperature values are highly significant ( $P=0.01$ ). Varieties differed considerably in the base temperature requirement.

The data clearly shows that source of seed has a significant effect on the base temperature requirement. When a variety is produced under two different climatic conditions, the base temperature requirement changes. Moro seed source has a lower base temperature as compared with Hyslop seed source for most of the varieties.

For 70% germination at 0 bars water potential the base temperature ranged from  $0.47-3.56^{\circ}\text{C}$ ,  $0.66-4.04^{\circ}\text{C}$ ,  $1.23-2.95^{\circ}\text{C}$ ,  $0.82-3.18$ , and  $1.39-4.60^{\circ}\text{C}$  for SWW, HRW, CT, SWS, and HRS respectively, for the Hyslop seed source. The

Table 4: Base temperature ( $^{\circ}\text{C}$ ) of five wheat classes from two seed sources for 70 and 50% germination at 0 bars and 50% germination at -7 bars water potential

Germ. (%) Pot. (Bars)	HYSLOP SOURCE			MORO SOURCE		
	70 0	50 0	50 -7	70 0	50 0	50 -7
<u>Variety</u>	<u>SOFT WHITE WINTER WHEAT</u>					
Stephens	3.23	5.16	3.28	0.03	2.38	1.97
Hill-81	0.47	2.98	3.23	2.51	4.72	2.55
Lewjain	1.66	4.16	2.90	0.89	4.22	1.14
Nugaines	2.59	4.82	3.63	0.01	2.21	2.80
Daws	3.56	5.32	3.54	1.41	3.81	2.40
Luke	0.62	4.42	4.04	2.50	4.02	2.25
Sprague	3.31	5.14	3.90	3.73	5.38	3.01
Dusty	0.50	3.56	4.14	2.69	5.04	1.99
Oveson	2.36	4.06	2.34	0.66	3.21	1.41
Malcolm	2.74	4.22	4.71	0.86	3.88	3.12
	<u>HARD RED WINTER WHEAT</u>					
Kharkof	4.04	5.68	4.36	0.87	1.4	2.43
Wanser	1.79	4.19	4.21	-0.04	2.05	2.04
Hatton	2.53	4.80	5.19	0.37	3.30	1.40
Weston	0.87	2.70	3.34	0.16	0.56	0.28
Bezostaya	0.66	2.55	3.65	-0.64	0.03	0.55
	<u>SOFT WHITE WINTER CLUB WHEAT</u>					
Moro	2.95	4.38	4.66	3.05	3.95	1.99
Faro	1.23	3.36	2.91	1.40	1.88	-1.43
Tres	1.92	4.02	3.99	-0.92	-0.61	-0.23
	<u>SOFT WHITE SPRING WHEAT</u>					
Dirkwin	0.82	1.94	1.76	-0.28	1.77	1.05
Urquie	3.18	5.17	3.57	1.44	3.10	1.34
Owens	1.08	2.43	1.49	0.48	3.22	2.02
Waverly	2.15	4.30	2.96	1.76	3.54	2.19
	<u>HARD RED SPRING WHEAT</u>					
Wared	2.02	3.94	3.51	1.89	3.13	1.34
Borah	4.60	5.59	3.88	-	3.93	1.97
Wampum	2.57	4.48	4.38	1.61	4.77	2.86
McKay	1.39	2.00	3.97	0.33	3.17	1.74

range for the base temperature requirement for the same varieties and for the same development stage is relatively lower for the Moro seed source. The range for the Moro seed source is 0.01-3.73°C, -0.04-0.87°C, -0.92-3.05°C, -0.28-1.76, and 0.33-1.89°C respectively for the same five classes.

There are also differences among the five classes within a seed source. Hard red wheats have a wider range of base temperatures as compared to Soft white wheats in both the winter and spring types. This indicates that the hard red wheats, in general, can be planted over a wider range of temperature conditions.

The lower end of the base temperature range for winter types is lower than spring types. Therefore, winter types should germinate more rapidly at lower temperatures than spring types under relatively cool conditions.

The base temperature requirement for 50% germination at 0 bars water potential was higher for all the varieties and in both seed sources as compared to 70% germination at 0 bars water potential. Base temperature requirement is reduced with the advancement of the development stage. These results agree with Russelle and Bolton (1980), as they found that the minimum temperature requirement decreases as more time is allowed between planting and emergence of wheat and barley.

Base temperature requirement for 50% germination at -7 bars water potential is lower than at 0 bars water poten-

tial in all the varieties and in both the seed sources with a few exceptions. It seems that wheat can germinate even at a lower temperature when the water potential is reduced. The data seem to indicate that wheat varieties adapt to the effects of water stress by lowering the temperature requirement.

These results are in agreement with DeJong and Best (1979) who reported that the minimum temperature for wheat emergence dropped as the soil water potential was lowered. It was suggested that the seedlings compensated for the increased water stress by lowering their minimum temperature requirements.

Base temperature is also variety specific but the relative change for different development stage or water availability is almost the same for all the varieties.

Base temperature for 50% germination at -7 bars water potential is positively correlated with field emergence rate index for SWW ( $P=0.05$ ) and HRS ( $P=0.1$ ) at the Hyslop location for the Hyslop seed source. The correlation coefficients are 69.77 and 92.11% respectively.

Base temperature for 70 and 50% germination at 0 bars were positively correlated with field emergence rate index of SWW ( $P=0.05$ ) and CT ( $P=0.1$ ) at Moro location for the Moro seed source. The correlation coefficients are 65.45, 67.05, 99.63, and 99.16% respectively.

At the Hyslop location base temperature for 50 and 70% germination at 0 bars is positively correlated with the

field emergence rate index of CT but is negatively correlated for SWS types (Table V) for the Moro seed source.

Base temperature for 50% germination at -7 bars was significantly correlated with field emergence for hard red spring wheat ( $P=0.1$ ) at the Moro and Pendleton locations.

The results are in agreement with the past experience that varieties having high base temperature requirement emerge faster at relatively warmer temperatures but their emergence rate drops rapidly at the cooler temperatures (Personal communication with Dr. Floyd E. Bolton).

#### PROTEIN

Protein quantity per 1000 seed is negatively correlated with field emergence for soft white winter wheat from Hyslop seed source at the Hyslop and Moro locations ( $P=0.05$ ). The correlation coefficients are -65.06 and -69.28 respectively. Protein quantity per 1000 seed had no significant relationship with field emergence in any other case.

Several investigators (Lowe et al., 1972; Lowe and Ries, 1972, 1973; Ries et al., 1970; Ries and Everson, 1973; Schweizer and Ries, 1969) have shown that seed protein content might affect seedling vigor. Their results are based on the effect of percent protein in the seed on the seedling dry weight and mostly in the laboratory.

In the present study the approach is different. The effect of quantity of protein in the seed available to the emerging seedling is related to the speed of seedling

Table 5: Correlation coefficients (%) for base temperature (BT) with field emergence at three locations for Moro seed source of five wheat classes soft white winter (SWW), hard red winter (HRW), club type (CLUB), soft white spring (SWS), and hard red spring (HRS)

<u>Wheat Classes</u>	<u>Locations</u>		
	<u>Hyslop</u>	<u>Moro</u>	<u>Pendleton</u>
<u>BT for 70% Germination at 0 Bars</u>			
SWW	40.37	65.45**	32.07
HRW	12.02*	-32.15*	23.09
CLUB	99.58**	99.63*	80.03
SWS	-98.32	-03.42	-73.98
HRS	-30.32	11.56	-22.47
<u>BT for 50% Germination at 0 Bars</u>			
SWW	52.85	67.05**	44.63
HRW	-16.52*	-24.67*	32.63
CLUB	99.08*	99.16*	77.32
SWS	-93.43	-11.57**	-45.94
HRS	79.31	96.54	72.56
<u>BT for 50% Germination at -7 Bars</u>			
SWW	31.10	04.10	-11.09
HRW	-34.13	-47.39	-06.65
CLUB	48.38	48.93	-04.60
SWS	-68.87	28.01*	06.86*
HRS	85.11	94.85	90.69*

\*, \*\* = significant at 0.1 and 0.05 probability level, respectively

emergence in the field. This approach is similar to the study conducted by Bulisiani and Warner (1980) who reported that, under field conditions, seed protein content had no effect upon seedling vigor as measured by emergence rate because the experiments were conducted under high nitrogen fertility regime which explained the the lack of response to seed protein content.

In the present study emergence rate was measured in the fields where adequate nitrogen had been supplied. It is speculated that adequate supply of nitrogen at the time of seeding has suppressed the protein differences in the seed to show up in the emergence rate except in a couple of cases mentioned above. The significant relationships are probably due to the interactive effect of another factor.

Embryo soluble protein is positively correlated with field emergence for soft white spring ( $P=0.05$ ) and for hard red spring wheat at the Hyslop ( $P=0.1$ ) and the Pendleton ( $P=0.05$ ) location from Hyslop seed source. The correlation coefficients are 95.16, 93.55, and 98.54% respectively.

Hyslop seed has a higher quantity of total protein per seed and when combined with an adequate supply of soil moisture and appropriate temperature, the ability of the cultivars to synthesize protein will be increased. At time of spring planting more moisture was available at Hyslop and Pendleton locations and also the temperature was probably more suitable at Hyslop location. As a result, the cultivars having a higher total protein per seed responded

to these climatic conditions.

Endosperm soluble protein is positively correlated with field emergence in hard red winter wheat class from Moro seed source when planted at Hyslop and Moro locations ( $P=0.05$ ). The correlation coefficients are 88.27 and 81.71% respectively. But the endosperm soluble protein is negatively correlated ( $P=0.1$ ) with field emergence at Hyslop and Moro locations for club type varieties for the Moro seed source. The correlation coefficients are -99.18 and -99.26% respectively. The relationship of endosperm soluble protein with the field emergence apparently differs between wheat class types.

#### GLUTAMINE SYNTHETASE ACTIVITY

Total activity of glutamine synthetase is negatively correlated with field emergence in case of soft white winter wheat and club type when grown at the Moro location, with correlation coefficients of -69.29 and -99.98% respectively, and for hard red winter wheat when grown at the Hyslop location from the Hyslop seed source with a correlation coefficient of -81.62%.

Total activity of glutamine synthetase is negatively correlated with field emergence in case of club type from the Moro seed source when planted at Hyslop and Moro. Correlation coefficients are -99.94 and -99.91% respectively.

Total activity of glutamine synthetase in soft white spring is positively correlated with field emergence when planted at Hyslop location from the Moro seed source. The



correlation coefficient is 91.23%.

Specific activity of glutamine synthetase is negatively correlated with field emergence for soft white winter wheat at Hyslop and Moro locations from Hyslop seed source and at Pendleton location from Moro seed source. The correlation coefficients are -57.10, -63.50, and -66.74 respectively.

Ching and Rynd (1978) studied a soft white winter wheat cultivar Yamhill with different protein percentage and reported that the glutamine synthetase activity was comparable between the high and low protein seeds during the first 2 days of germination, but thereafter was higher in high protein seeds.

In the present study, the cultivars are compared to each other for the relative enzyme activity after germinating them for 2 days. The absolute differences may be small but very important in relative terms. The cultivars having relatively lower enzyme activity emerged faster in the field in some cases. It is likely that at this stage the lower activity of glutamine synthetase is more suitable for fast germination and emergence.

#### EMBRYO WEIGHT

Embryo weight is positively correlated with field emergence for hard red spring wheat when planted at Hyslop and Pendleton from the Hyslop seed source and also for soft white spring wheat when planted at Hyslop from Moro seed source. The correlation coefficients are 99.40, 97.55,

and 98.41% respectively.

These results are not related with the seed weight or protein. The difference may be attributed to the efficiency of metabolic activity and substrate transfer from the endosperm to seedling axis.

#### RELATIONSHIP BETWEEN FIELD EMERGENCE RATE INDEX AND LABORATORY GERMINATION RATE INDEX

In order to estimate the emergence rate index (ERI) in the field, ERI at three locations is related with the laboratory germination rate indexes (GRI) at 15 different combinations of temperature and water potentials. Correlation coefficients are calculated for winter and spring seed lots, from both the Hyslop and Moro seed sources. The highest correlation coefficient is used to choose the GRI to be used for estimation of the field emergence for a particular location.

#### WINTER VARIETIES FROM THE HYSLOP SEED SOURCE

For this category, the ERI at the Hyslop and Pendleton location is best correlated with GRI at 10°C temperature and -7 bars water potential and the correlation coefficients are 52.28% and 54.78% (P=0.01) respectively. Therefore, ERI at the Hyslop and Pendleton locations for winter varieties from the Hyslop seed source can best be estimated by calculating the GRI at 10°C temperature and -7 bars water potential.

The GRI at 10°C temperature and -7 bars water poten-

tial is significantly correlated with three of the several seed parameters studied. The three seed parameters are seed density, protein quantity per seed and endosperm soluble protein per seed. All of these parameters are negatively correlated ( $P=0.01$ ,  $0.05$ , and  $P=0.1$  respectively) with GRI at  $10^{\circ}\text{C}$  temperature and  $-7$  bars water potential. Therefore, the major factors influencing the GRI are the seed density, protein quantity per seed, and endosperm soluble protein per seed.

Endosperm soluble protein per seed was also significantly ( $P=0.05$ ) negatively correlated with the ERI at the Pendleton location. Same relationship was not found at the Hyslop location.

The ERI at Moro location has the best correlation of  $35.80\%$  ( $P=0.01$ ) with GRI at  $20^{\circ}\text{C}$  temperature and  $-7$  bars water potential. This differs significantly compared to the other locations. The GRI at  $20^{\circ}\text{C}$  temperature and  $-7$  bars water potential is best correlated with endosperm soluble protein per seed. The correlation coefficient is  $-51.93\%$  ( $P=0.05$ ). For ERI estimation for the Hyslop seed source of winter varieties, GRI at  $20^{\circ}\text{C}$  temperature and  $-7$  bars water potential can be used. The seeds having low endosperm soluble proteins per seed will germinate and emerge faster at the Moro location.

Seed characteristics significantly related to GRI and ERI were not the same.

WINTER VARIETIES FROM THE MORO SEED SOURCE

For the winter varieties from Moro seed source, the ERI's at the Hyslop and Pendleton locations are best correlated with the GRI at 10°C and -7 bars water potential. The correlation coefficients are 48.40% and 46.67% (P=0.01) for the Hyslop and Pendleton locations, respectively.

Although the ERIxGRI relationships are the same as the Hyslop seed source the parameters are different. The GRI in this case is correlated with seed density, base temperature, protein quantity per seed, embryo weight, and endosperm soluble protein. The correlation coefficients are -59.73%, 62.05 (P=0.01), -46.16, -43.98, and -44.39 (P=0.1) respectively.

For the Moro location the ERI is best correlated with GRI at 25°C temperature and -7 bars (P=0.01) which is not significantly different from the GRI at 20°C temperature and -7 bars (P=0.01) water potential. Since 20°C is the standard temperature used in seed testing methods, it would be more practical to use GRI at 20°C temperature for ERI estimation.

The GRI at 20°C temperature and -7 bars water potential is significantly correlated with seed-density and base temperature. The correlation coefficients are -48.50%, and 40.90% (P=0.01) respectively. The base temperature is negatively correlated (P=0.01) with seed density which again indicates the influence this factor has on the GRI and ERI.

Base temperature was the common significant seed characteristic for the best related GRI and ERI at all the locations.

#### SPRING VARIETIES FROM THE HYSLOP SEED SOURCE

For this group, the ERI at the Hyslop location is best correlated with the GRI at 7°C temperature and 0 bars water potential. The correlation coefficient is 53.07% (P=0.01).

The GRI at 7°C temperature and 0 bars water potential is significantly correlated with embryo fresh weight and glutamine synthetase specific activity. The correlation coefficients are 66.98%, and -64.51% (P=0.1).

For the Moro location, the correlation of ERI is significant (P=0.01) with GRI at 15°C temperature and 0 bars water potential. The GRI at this level is best correlated with base temperature and glutamine synthetase specific activity. The correlation coefficients are 71.58% (P=0.05) and -69.66% (P=0.1). Therefore, the seed lot having high base temperature and low glutamine synthetase specific activity will emerge faster at the Moro location for the spring planting.

At the Pendleton location, the ERI is best correlated (P=0.05) with GRI at 20°C temperature and -7 bars water potential. The GRI at this combination of temperature and water potential has the best significant relationship with glutamine synthetase specific activity. The correlation coefficient is -72.89% (P=0.05). Therefore, the glutamine synthetase activity appears to be the controlling factor

for the ERI at the Pendleton location.

The ERI at the Hyslop location was significantly ( $P=0.1$ ) correlated with embryo fresh weight. Embryo fresh weight was the common seed characteristic, significantly related to the GRI and ERI at the Hyslop location. Same relationship was not found at the Moro and Pendleton locations.

#### SPRING VARIETIES FROM THE MORO SEED SOURCE

For these seed lots, the ERI at the Hyslop location is best correlated with the GRI at  $7^{\circ}\text{C}$  temperature and 0 bars water potential. The correlation coefficient is 44.00% ( $P=0.05$ ).

The GRI at  $7^{\circ}\text{C}$  temperature and 0 bars water potential has a negative significant ( $P=0.1$ ) correlation with base temperature and positive significant ( $P=0.05$ ) correlation with embryo fresh weight. The spring wheat seed with the low base temperature and high embryo fresh weight will perform best at this location.

For the Moro location the ERI is best correlated with GRI at  $25^{\circ}\text{C}$  temperature and -7 bars water potential but the correlation is not significant.

The GRI at  $25^{\circ}\text{C}$  and -7 bars is positively correlated ( $P=0.05$ ) with base temperature. Therefore, the seed lots with a high base temperature requirement will perform better at this location.

At the Pendleton location, the ERI is positively correlated ( $P=0.1$ ) with GRI at  $20^{\circ}\text{C}$  temperature and -7

bars.

The GRI at this level is negatively correlated ( $P=0.05$ ) with glutamine synthetase specific activity.

Embryo fresh weight was a common seed characteristic related to the ERI at the Hyslop location and GRI. Such relationship was not found at the other two locations.

#### RELATIONSHIP OF EMERGENCE RATE INDEX AND YIELD

Table VI shows the relationship of emergence rate with the yield at three distinctly different locations for the Fall and Spring plantings. It is clear from these data that fast emergence is more important for the stressful climatic condition.

Final yield is significantly ( $P=0.05$ ) correlated with the emergence rate index (ERI) at most stressful location, Moro, for the Hyslop seed source for the winter varieties planted during the Fall 1985. This relationship is even more highly significant in case of the Moro seed source. This relationship of ERI with final yield is also significant ( $P=0.1$ ) at the Pendleton location for the Moro seed source.

For the Fall planting there was enough soil moisture and precipitation available to support the seedling till it was able to extend its root system to meet its water requirements from the deeper soil profiles. Therefore, there was a positive effect of higher ERI on yield.

For the spring planting, again the relationship of the yield is significant with the ERI for both the seed sources

at the Moro location but the trend is reversed. Spring, 1986 was exceptionally dry and there was not enough moisture available to support the early established seedlings so that they may be able to extend their root system to the deeper soil profiles to sustain growth. The earlier the seedling emerged, the more moisture it required to meet its needs and consequently the more rapidly the soil moisture was depleted. This rapid moisture depletion affected the yield.



Table 6: Correlation coefficients (%) of emergence rate index with yield for winter and spring wheats from two seed sources at three locations

<u>Wheat types</u>	<u>Seed sources</u>	<u>Locations</u>		
		<u>Hyslop</u>	<u>Moro</u>	<u>Pendleton</u>
Winter	Hyslop	0.94	29.27*	5.97
Winter	Moro	15.53	53.35**	22.96
Spring	Hyslop	-31.69	-51.92*	-0.99
Spring	Moro	1.04	-40.36	29.50

\* and \*\* = significant at 0.05, and 0.01 probability level, respectively

## SUMMARY AND CONCLUSIONS

The objective of the study was to determine the seed characteristics contributing to the stand establishment of wheat under varying climatic conditions.

Seeds of 26 wheat varieties, produced at two locations, were compared for several seed characteristics and for field emergence at three locations. The seed characteristics studied were: 1000-seed weight, protein quantity per 1000 seeds, base temperature for 50 and 70% germination at 0 bars and 50% germination at -7 bars. Embryo fresh weight, alpha-amylase total activity, alpha-amylase specific activity, glutamine synthetase total activity, glutamine synthetase specific activity, embryo soluble protein, and endosperm soluble protein were also determined after germinating the seeds at 20°C constant temperature for 2 days.

The seed characteristics which showed significant relationships with field emergence for different locations and for different classes of wheat were 1000-seed weight, protein quantity per 1000 seeds, base temperature, embryo weight, glutamine synthetase activity, embryo soluble protein, and endosperm soluble protein.

The seed lots produced at two different locations were different from each other for the seed characteristics. Seed produced at the Hyslop location had higher seed density and also the quantity of protein per seed was higher as compared to the Moro produced seeds.

Wheat varieties differed considerably for the base temperature requirement. Base temperature requirement at 0 bars water potential for 50% germination was higher as compared to 70% germination for all the varieties and in both the seed sources. Base temperature requirement is reduced with the advancement of the development stage. The base temperature requirement for all the varieties was reduced under moisture stress conditions. Base temperature requirement for 50% germination at -7 bars water potential was lower as compared with 50% germination at 0 bars water potential. The Moro seed source had a lower base temperature requirement when compared to the Hyslop seed source.

Wheat varieties from five classes were compared for the emergence rate index (ERI) at three locations. Varieties showed different behavior among the classes and in some cases were different within a class.

Seeds of all the varieties were germinated under controlled conditions at five constant temperatures (7, 10, 15, 20, and 25°C) and three water potentials (0, -7, and -14 bars). Daily germination counts were recorded and a germination rate index (GRI) was calculated.

Correlation coefficients were determined for the seed characteristics, GRI and ERI at three different locations for winter and spring wheats from the Hyslop and Moro seed sources. The most important seed characteristic(s) for best GRI and ERI were determined.

It appears that for winter wheat, the field emergence

rate can be best estimated by GRI at 10°C temperature and -7 bars water potential for the Hyslop and Pendleton locations and by GRI at 20°C temperature and -7 water potential for the Moro location for both the seed sources.

In winter wheat, endosperm soluble protein was the common seed characteristic significantly related to GRI and ERI at the Pendleton location for the Hyslop seed source. Base temperature was the common seed characteristic significantly related to the best related GRI and ERI for the Moro seed source at all the three locations.

The field emergence rate for spring varieties grown at the Hyslop location can be best estimated by the GRI at 7°C temperature and 0 bars water potential for both the seed sources. For the Moro location, the field emergence can best be estimated by GRI at 15°C temperature and 0 bars water potential for the Hyslop seed source and by GRI at 25°C temperature and -7 bars water potential for the Moro seed source. The GRI at 20°C temperature and -7 bars water potential is the best estimator for field emergence rate at the Pendleton location for spring wheat varieties grown from both seed sources.

Among the spring varieties the embryo fresh weight appears to be the most significant parameter for field emergence rate at the Hyslop location for both seed sources. Embryo fresh weight was a common significantly related seed characteristic to the best related ERI and GRI for both the seed sources at the Hyslop location. Such

relationship was not found at the other two locations.

Yield is positively correlated with the emergence rate index under moisture stress conditions provided enough soil moisture is available to sustain seedling growth after emergence. Even when seeds are planted under very dry soil conditions, the ability to rapidly germinate and emerge when adequate soil moisture becomes available is critical. The more quickly the stand becomes established, the more likely the crop is to produce its yield potential.

In this study, the seed characteristics such as seed density, base temperature showed significant relationships with ERI and GRI. These seed characteristics can be used as a guide to in the breeding program to breed for specific environments. These seed characteristics can also be used for seed vigor testing in the laboratory.

Seed source has a significant role in the field emergence, indicating the importance of selecting the best seed production area for a specific environment. Further investigations in this direction are suggested.

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## APPENDIX



Appendix I. Description of the wheat varieties used in the experiments.

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STEPHENS

Stephens is a bearded, white-chaffed, semi-dwarf wheat released by Oregon State University (OSU) in 1977. Heads are distinctly coarse in appearance with beards that tend to flare. Stephens has only a minimal level of winter-hardiness and is susceptible to Cephalosporium stripe. This variety is resistant to stripe rust and has some resistance to leaf rust. Stephens has a very wide adaptation and yields well in low rainfall areas, high rainfall areas, and under irrigation.

HILL 81

Hill 81 is bearded, white-chaffed medium height variety released by OSU in 1981. It is more winterhardy than Stephens and is recommended for those areas where the winterhardiness of Stephens has not been adequate. Hill 81 is more tolerant to Cephalosporium stripe than Stephens, therefore, it is recommended in those areas where this disease is a problem.

LEWJAIN

Lewjain is a bearded, white-chaffed, semi-dwarf variety released by Washington State University (WSU) in

1982. It is a late season variety with very good winter-hardiness. This variety is resistant to dwarf bunt, tolerant to Cephalosporium stripe, and is recommended especially in those areas where dwarf bunt is a problem. In most areas its yield potential is not equal to that of Stephans.

#### NUGAINES

Nugaines is a soft white semidwarf winter wheat with excellent test weight, milling, and baking properties. The variety has a bearded, common-type head with white chaff. Nugaines has good mature plant resistance to stripe rust but is susceptible to stripe rust in the seedling stage. It is also susceptible to leaf rust, dwarf bunt, snow mold, and Cercospora foot rot. Nugaines is resistant to most races of common bunt and has moderate resistance to flag smut and Cephalosporium stripe (fungus stripe). Nugaines was developed by USDA-ARS and Washington State University.

#### DAWS

Daws is a bearded, white-chaffed, semi-dwarf variety released by WSU in 1976. This variety is very winterhardy and is recommended in areas where winterkilling commonly occurs. Emergence is only adequate, therefore, it is not recommended where it is necessary to seed deep in moist soil.

#### LUKE

Luke is a bearded, white-chaffed, semi-dwarf wheat

released in 1970. Grain test weight is about 2 lb/bu lower than Nugaines. It emerges more quickly and vigorously than Nugaines. It is resistant to stripe rust, common smut, dwarf smut, and snow mold. Because of its rapid emergence, Luke is well adapted for early seeding and it is the best variety to use in areas where dwarf smut is a problem. Luke has good milling and baking quality.

#### SPRAGUE

Sprague is a soft white common wheat developed for the snow mold areas. The chaff varies white to gray-brown; the heads are small and awned. Sprague has good resistance to snow mold and common bunt but is susceptible to dwarf bunt, stripe and leaf rust, and *Cercospora* foot rot.

It has excellent emergence and good winterhardness. Sprague was developed by USDA-ARS and Washington State University.

#### DUSTY

Dusty is a bearded, white-chaffed, semi-dwarf variety released by WSU in 1985. This variety has good winterhardness, is later in maturity than Stephens, but has yielded well at many locations in northeastern Oregon. Limited amounts of foundation and registered seed will be available this fall.

#### OVESON

Oveson is a soft white winter wheat. It is semi-dwarf white chaff wheat variety.

It is the recent release of Oregon State University.

#### MALCOLM

Malcolm is a soft white winter wheat. It is semi-dwarf with stiff white straw and awned nodding heads. It has had yields superior to those of Stephens. Malcolm is resistant to common bunt and mildew, but like Stephens, is susceptible to cephalosporium stripe and septoria. It is not recommended for the areas where extreme winter-hardiness is required. Malcolm has good milling and baking quality.

Malcolm was developed by Oregon State University.

#### KHARKOF

Kharkof is a hard red winter wheat variety. It is mid-tall, white stem variety. The kernels are dark red colored. It is winter-hardy and drought resistant. This variety was developed in Russia.

#### WANSER

Wanser is a hard red winter wheat developed for low rainfall areas of Washington. The variety yields well in areas that have less than 13 inches of annual rainfall. Wanser has a brown-chaffed head and bearded, lax spikes. It is resistant to common smut and most races of dwarf bunt.

Wanser has a good winterhardiness and it more winterhardy than Nugaines, Daws, or the club wheats. It is shatter resistant.

It was developed by USDA-ARS and Washington State University.

### HATTON

Hatton is a hard red winter wheat variety with a white-chaffed common type head. The variety has better stripe rust resistance than Wanser. It is susceptible to dwarf bunt, snow mold and Cercospora foot rot.

Straw strength, shatter resistance and emergence are equal to Wanser. Winterhardiness is slightly better than Wanser. Milling and baking qualities are similar to Wanser for bread baking.

Hatton was developed by USDA-ARS and Washington State University.

### WESTON

Weston is a hard red winter wheat. It is a semi-dwarf wheat variety with dark red kernel. It was developed in Idaho.

### BEZOSTAYA

Bezostaya is a hard red winter wheat variety. It is tall and beardless. Susceptible to Septoria, moderately susceptible to stripe rust and mildew. Good milling and baking quality. It was developed in Russia by L. Lukyenenko.

### MORO

Moro is a soft winter club wheat with brown chaff. Its chief advantages are resistance to stripe rust and excellent emergence. It is susceptible to leaf rust. Moro is resistant to most races of dwarf bunt and common bunt. Moro

is moderately resistant to Cephalosporium stripe (fungus stripe). Moro is a medium-tall club variety with white kernels. In the lower rainfall areas, Moro will germinate and emerge much better than other varieties from deep seedlings in dry, dusty seedbeds. Moro was developed by Oregon State university.

#### FARO

Faro is a beardless, brown-chaffed club variety released by OSU in 1976. It has good emergence and winterhardiness, is early to mid-season, and has adequate test weight. This variety is susceptible to stripe rust, and a grower should be prepared to apply a fungicide as soon as this disease appears.

#### TRES

Tres is a beardless, semi-dwarf, white-chaffed club variety released by WSU in 1984. Its name means three, signifying its resistance to three foliar diseases - stripe and leaf rust, and powdery mildew. Tres is one of the 10 components of Crew. It appears to have a similar yield potential to Crew, but has none of the heterogeneities found in Crew.

#### DIRKWIN

Dirkwin is a beardless, white-chaffed, soft white, semi-dwarf variety released by the University of Idaho in 1978. It is a very widely adapted variety, yielding well under both droughty and high-producing conditions. The

test weight of Dirkwin tends to be somewhat low. This variety is resistant to stripe rust, but is susceptible to leaf rust.

#### URQUIE

Urquie is semidwarf, awned, white-chaffed, soft white spring wheat. Urquie is resistant to lodging. The test weight of Urquie is Dirkwin. Urquie yields competitively in the irrigated areas of Washington with other soft white spring wheat varieties. Urquie has moderate high-temperature adult plant resistance to prevalent races of stripe rust but is susceptible to leaf rust, highly susceptible to stem rust and moderately susceptible to mildew. Milling and baking qualities are excellent.

Urquie was developed by Washington State University and USDA-ARS.

#### OWENS

Owens is a bearded, semi-dwarf, white-chaffed, soft white variety released by the U of I in 1981. It is resistant to stripe rust and moderately resistant to leaf rust. The test weight of Owens is significantly higher than Dirkwin, however, it usually does not yield as high as Dirkwin.

#### WAVERLY

Waverly is a bearded, semi-dwarf, white-chaffed, soft white variety released by WSU in 1981. This variety is moderately resistant to stripe rust and leaf rust. Its

test weight is superior to that of Dirkwin, however, it usually does not yield as high as Dirkwin.

#### WARED

Wared is a bearded, semi-dwarf, white-chaffed, hard red variety released by WSU in 1974. It is moderately resistant to both stripe and leaf rust. The test weight of Wared is quite high. Wared appears to be best adapted to lower yielding areas of northeastern Oregon.

#### BORAH

Borah is a bearded, white-chaffed, semidwarf wheat released in 1974. Compared to Wampum, maturity is two days earlier, and height is about 3 inches shorter. Borah is resistant to leaf rust and stem rust but moderately resistant to currently prevalent races of stripe rust. Borah has good milling and baking qualities.

#### WAMPUM

Wampum is bearded, mid-tall, white-chaffed, hard red variety released by WSU in 1978. This variety is resistant to stripe rust and moderately resistant to leaf rust. It is best adapted to the higher yielding areas of northeastern Oregon. Wampum has a special quality of being able to grow as a seedling when soil temperatures are quite low.

#### McKAY

McKay is a bearded, semi-dwarf, white-chaffed, hard red variety released by the University of Idaho in 1981.



This variety is resistant to both stripe and leaf rust.  
The test weight of its grain is usually very high.

Appendix II. Weather data from planting to emergence at three locations during fall 1985 and spring 1986.

	<u>Locations</u>		
	<u>Hyslop</u>	<u>Moro</u>	<u>Pendleton</u>
<u>At planting</u>	<u>Fall 1985 planting</u>		
Soil moisture (%)			
0-5 cm	12.24	7.23	12.65
5-8 cm	15.88	9.34	15.43
<u>Planting to emergence</u>			
Precipitation (mm)	88.00	nil	18.25
Mean temperature ( $^{\circ}\text{C}$ )	12.23	10.00	10.00
Minimum temperature ( $^{\circ}\text{C}$ )	5.00	-3.33	-6.67
Maximum temperature ( $^{\circ}\text{C}$ )	19.45	23.33	26.67
<u>At planting</u>	<u>Spring 1986 planting</u>		
Soil moisture (%)			
0-5 cm	19.46	9.91	20.90
5-8 cm	21.01	13.58	22.82
<u>Planting to emergence</u>			
Precipitation (mm)	33.75	2.75	10.50
Mean temperature ( $^{\circ}\text{C}$ )	14.25	8.34	9.17
Minimum temperature ( $^{\circ}\text{C}$ )	6.67	-3.89	-3.33
Maximum temperature ( $^{\circ}\text{C}$ )	21.67	20.56	21.67

Appendix III. Principal characteristics of the locations  
where experiments were established

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Corvallis

Lattitude	44 50 N
Longitude	125 21 W
Elevation	68 m
Soil type	Woodburn silty clay loam
Ave. annual rainfall	1,300 mm
Ave. max. temperature	27 °C
Ave. min. tempertutre	-1 °C

Moro

Lattitude	45 29 N
Longitude	120 44 W
Elevation	560 m
Soil type	Walla walla silt loam
Ave. annual rainfall	290 mm
Ave. max. temperature	16.17 °C
Ave. min. tempertutre	-6.33 °C

Pendleton

Lattitude	45 30 N
Longitude	120 45 W
Elevation	580 m
Soil type	Walla walla silt loam
Ave. annual rainfall	580 mm
Ave. max. temperature	32 °C
Ave. min. tempertutre	-9.8 °C

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