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The objective of this research was to identify the optimum cultural practices for the production of the highest quality wheat seed in Oregon. The production methods included locations, irrigation, N levels and seeding rates. The seed quality factors studied were seed weight, bushel weight, protein content and seedling vigor.

Foundation seed of Hyslop and Yamhill cultivars of soft white winter wheat was planted at Hyslop Farm (40 inches rainfall), Pendleton (18 inches rainfall), and Moro (10 inches rainfall). Three N levels were applied at Hyslop Farm and Moro and two N levels at Pendleton. Four seeding rates were used at each location. The effects of supplemental irrigation were also studied at Hyslop Farm. Components of seed yield were studied at all locations to help explain the effects of production methods on seed quality.

Of the four production practices, locations had the greatest effect on seed quality. Irrigation had more

effect on seed quality than N or seeding rates. Little or no effect on seed yield was obtained with irrigation; however, irrigation should be used to improve seed quality.

At Hyslop Farm, the highest seed quality and seed yield were both obtained with an application of 280 kg N/ha and a seeding rate of 112 kg/ha.

At Moro production methods had no effect on seed quality. A combination of 56 kg N/ha and 43 kg seed/ha produced the highest seed yield so this was considered the best production practice.

At Pendleton, 76 kg N and 14 kg seeding rate was the optimum cultural practice for highest seed quality in Hyslop. This optimum, however, involved a seed loss. In Yamhill, 188 kg N was the optimum for highest seed quality. The highest seed yield was obtained at 28 kg seed/ha within this N level; seeding rates, in Yamhill, had no effect on seed quality at the optimum N level.

Effect of Production Methods on Quality of Wheat Seed

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Felix Njeruh Mathenge

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in charge of major

Redacted for Privacy

Head of Department of Crop Science

Redacted for Privacy

Dean of Graduate School

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DEDICATION

To my wife, Mary, I dedicate this thesis for her companionship and consistent support throughout my M.S. programme.

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EFFECT OF PRODUCTION METHODS ON QUALITY OF WHEAT SEED

INTRODUCTION

With the ever rising demand for food supply to feed a hungry world, increasing yields of wheat, the most widely cultivated of all cereals, will be desirable. Such increases will be achieved through a combination of improved production technologies. One of the many aspects of management that will need to be improved is seed quality.

Several researchers have shown that certain seed attributes such as seed size, protein content and bushel weight are correlated with seedling vigor, plant growth and yield. Recent reports indicate that large seeds or seeds with high protein content develop into larger seedlings which in turn produce higher yields. Consequently, these important components of seed quality have attracted considerable interest.

This research was initiated to determine the effect of production methods on these seed quality attributes so as to be able to identify the production practices suitable for producing the highest quality wheat seed in Oregon.

Since the management practices commonly used for grain production may not be the same as those that result in the highest quality seed, it was necessary to undertake this research.

Three major wheat producing areas in the State of Oregon were used to study environmental effects on seed quality. Within locations, irrigation, nitrogen fertilization and seeding rates were the cultural practices investigated. Two winter wheat varieties were included to find out if varietal responses to cultural practices would be similar in the production of high quality wheat seed.

LITERATURE REVIEW

Influence of Seeding Rates on Yield and Seed Size

Seed Yield

Percival (1921), in Australia, summarized that optimum seeding rate varied considerably with the climatic conditions. In countries of low rainfall, short growing season and necessarily low yields, the amount of seed sown often is less than 1 bu/A. In England and Western Europe under high rainfall conditions, rates of seeding varied from 201.6 to 268.8 kg/ha (180-240 lb/A) of wheat per acre.

After reviewing the seeding rate data at several stations in the Great Plains and in the Great Basin area, Martin (1926) concluded that 33.6-50 4 kg/ha (30-45 lb/A) was an adequate amount of seed in terms of number of plants per unit area. However, to overcome the effects of adverse field conditions, higher seeding rates were more practical.

In yield trials on wheat in irrigated fields, Woodward (1956) found that the same yield was produced by 67.2, 100.8 and 134.4 kg/ha (60,90 and 120 lb/A) of seed, while a 33.6 kg/ha (30 lb/A) rate resulted in lower yields. He concluded that with a firm, moist seedbed, a farmer using irrigation might obtain maximum yields by sowing high grade certified seed at 44.8 kg/ha (40 lb/A).

Pendleton (1960) observed that the highest yields were produced by intermediate 100.8 and 151.2 kg/ha (90 and 135 lb/A) rates, but he recommended the use of 100.8 kg/ha (90 lb/A) because of the resultant lodging with higher seeding rates.

Results similar to Pendleton's were found by several other workers. In Australia, Puckridge and Donald (1967) reported that the yield of grain per unit area showed a peak value at intermediate densities (35 and 184 plants per m^2). They postulated that the reason for low yield at low densities was the uneven pattern of light interception at the soil surface owing to the wide spacing of plants. The reason for low yield at high densities was the leaf and tiller senescence as controlling factors of yield.

Several workers reported that highest yields had been produced by higher seeding rates. Kinra et al. (1963), working on wheat at two locations, found that under adversely dry conditions the 100.8 kg/ha (90 lb/A) rate out-yielded 67.2 kg/ha (60 lb/A) rate. At the other location, which had almost normal conditions, there was no difference in yield due to seeding rate.

Syme (1972) observed a 9% increase in yield of Robin wheat by increasing the seeding rate from 56 to 112 kg/ha (50-100 lb/A) in South Wales.

It has been reported by many workers in different parts of the world that it was possible to obtain the highest yields from lower seeding rates. In Canada, Guitard et al. (1961) pointed out that at the lower seeding rates, there were significant increases in yield with increases in seeding rate, but there was no increase in yield at highest rates. They also observed that the influence of seeding rate on yield was not altered by variety.

Larter (1971) reported that he observed the highest yields of wheat at the two lowest seeding rates, 25 and 50 kg/ha (22.3-44.6 lb/A). Significantly reduced yields were obtained at highest rates, 100 kg/ha (89.3 lb/A), and above. He suggested that the use of 68 to 102 kg/ha (60.7-91 lb/A) seeding rates by the farmers would be satisfactory, for those rates provide a margin of safety for adverse field conditions.

In England, Willey and Holliday (1971), working with wheat, noted that a significant decrease in yield occurred at high populations which was attributed to the decrease in grains per unit area which was highly correlated (0.94) with yield per unit area.

Khalifa (1970), in Sudan, in summarizing his data, reported that 187 and 125 kg/ha (166.9-111.6 lb/A) produced significantly lower seed yields than 62 kg/ha (55.3 lb/A). He concluded that the reduction in seed yield with the highest rates was due to decrease in the number of seeds/head.

Many researchers, under a wide range of conditions, have found that the differences in seeding rates produced very little or no difference in seed yield. Working with barley, Middleton (1964) found no difference in yields with three seeding rates, 100.8, 50.4 and 25.2 kg/ha (90, 45 and 22.5 lb/A), and suggested the use of the low seeding rates under optimum conditions to save seed.

Working on wheat in dryland areas of Turkey, Bolton (1973) reported that at four locations the response to seeding rates was about the same. The 60 and 90 kg/ha (53.6 and 80.3 lb/A) rates appeared too low and there was little or no difference between 120 and 150 kg/ha (107.1 and 133.9 lb/A).

Seed Size

Pendleton (1960), working on wheat with six seeding rates between 50.4 and 302.4 kg/ha (45 and 270 lb/A) obtained data indicating a slight but continuous decrease in seed weight as the seeding rate increased.

Middleton (1964) reported that, in his experiments with barley, no significant difference in seed weight was recorded between different densities, although highly significant differences were obtained between varieties.

Severson and Rasmusson (1968) observed that the average weight per 1000 seeds of barley increased significantly when spacing was increased from 2.5 to 7.5 cm. Additional spacing increments resulted in smaller but not significant increments in seed weight.

In Canada, Guitard *et al*. (1961) noted that the response of 1000-seed weight to seeding rate was not greatly influenced by yield. Increase in seeding rate caused a small linear decrease in 1000-seed weight.

In Australia, Puckridge and Donald (1967) observed the lowest 1000-seed weight in the lower rates and concluded that the lower 1000-seed weight value at lowest seeding rate might be a real effect due to extreme intertiller competition within plants at very low densities or it might be due to small seed size in very late tillers.

In Russia, Simonyan and Babayan (1973) noted that the length of ear, its seed content, seed weight and protein percentage decreased with denser seeding.

Khalifa (1970), in Sudan, demonstrated that the effect of seeding rate on the 1000-seed weight was insignificant.

Relationships of N Fertilization, Yield and Protein Content

Nitrogen is one of the basic elements in wheat nutrition and is usually the most limiting factor. Several investigators have reported increased yields in spring and winter wheat under different conditions.

Williams and Smith (1954) attributed the increase in winter wheat yields at four locations to the use of nitrogen fertilizer. By increasing the rates of nitrogen from 28 to 56 and 112 kg/ha (25 to 50 and 100 lb/A), they found a corresponding increase in grain yields.

In the CIMMYT fertilizer report (1970-71), results from the 1969-70 season showed an increase in yield ranging from

0 to 23.4 quintals per hectare (equivalent to 308 percent) depending on the different levels of fertility. During the 1970-71 season, tests conducted with 0, 33, 67, 90 and 133 kg of nitrogen per hectare (0, 25.5, 59.8, 80.3 and 118.7 lb N/A) showed an increase in yield up to the 67 kg rate in areas of 300-500 mm rainfall. For areas of more than 500 mm, yield increased up to the 90 kg rate. These two levels of fertility were recommended as optimum for field use.

In Oregon, Pumphrey (1961) stated that in spite of variations in rainfall, soil and management, especially in the northeast, wheat required addition of nitrogen fertilizer for maximum yield. He further reported that 33.6 kg N/ha (30 lb N/A) increased yield by about 9 bushels/A, while 67.2 kg N/ha (60 lb N/A) yielded 17 additional bushels. Rates of 100.8 kg N/ha (90 lb N/A) and 134.4 kg N/ha (120 lb N/A) resulted in very little increase in yield over the 67.2 kg N/ha (60 lb N/A) level. In regions of low rainfall, increase in grain yield resulting from 33.6 kg N/ha (30 lb N/A) and 67.2 kg N/ha (60 lb N/A) was 3 and 4 bushels/A, respectively. Higher rates produced slightly less yields. He concluded that not all effects of nitrogen application are beneficial. As the rate increases past the optimum for grain yield, growth of straw becomes excessive especially if adequate moisture is available. Lodging, delayed maturity, reduced yield and test weight may also result.

Stickler and Ten Pas (1969) reported that the response of a wheat crop to nitrogen application is variable. On soils deficient in nitrogen, each 20 kg N/ha (17.9 lb N/A) produced 300 to 400 kg (267.8 to 357.1 lb) of additional yield until the 40 kg N/ha (35.7 lb N/A) level was reached. On some soils yield increases were noted up to 60 kg N/ha (53.6 lb N/A).

Woodward (1964), working with semi-dwarf spring wheat, reported varietal differences as a significant factor affecting response to nitrogen application. Due to their long vegetative cycle, winter wheat varieties need more than one application.

Terman et al. (1969), in an irrigation-nitrogen rate experiment on hard red winter wheat over a three-year period, found that the chief effect of applied N (one application) with adequate water supply was to increase yield, when water deficits were present, however, the entire effect was to increase protein content.

Other researchers have found an increase of both yield and protein as an effect of N fertilization. Hunter et al. (1958) working with pastry-type wheats, found that protein content was not raised to objectionably high levels until more N was applied than that needed to produce maximum yield. He noticed that when applied N increased the yields significantly, protein increased at a lower rate; however, for greater applications of N, protein content increased more rapidly than yield. In general, increased N increased test weights on farms where it also increased yields. Decrease in test weights occurred only on farms where increased N either decreased or had no effects on yield.

Several workers have reported no increase in yield or a negative relationship between yield and protein, when N was applied (Hojjati and Maleki, 1972; Lopez, 1972; and Solen, 1973). Hojjati and Maleki (1972) indicated that yield of grain was not affected by applications of 50 or 100 kg N/ha (44.6 or 89.3 lb N/A) but yield decreased at the 200 kg N (178.5 lb N) level. In their experiments, N stimulated vegetative growth much more than seed production. Under this condition, protein content of the grain was consistently increased by each additional increment of N at the rate of one percent for each addition of 50 kg/ha (44.6 lb/A) of N.

Solen (1973), working with four varieties of wheat, found a significant negative correlation between protein content and grain yield including some components of yield, in Pendlèton, Oregon. At the Pendleton site, where moisture became a limiting factor, the negative association resulted largely as the indirect effect of kernel weight on protein content. With the spring application of N, a delay in maturity for Hyslop and Yamhill was noted which, with the subsequent loss of moisture, resulted in shriveled grains. This resulted in Hyslop and Yamhill (low protein cultivars) having higher protein content than Atlas 66 and NB 68513 (high protein cultivars).

A large number of investigators have indicated that N fertilization increases the protein content of wheat grain. Chang and Robertson (1968) found that seeds fertilized with 90 kg N/ha (80.3 lb N/A) contained 1.1-1.3 times as much Kjeldahl-N as did those from parents receiving no N.

Some researchers showed a decrease in protein content after a low N fertilization. Fernandez and Laird (1959), working with soil moisture and N fertilization, found a decrease of protein content of whole grain with small applications of N, but protein increased with large applications. The lower protein content of the grain from wheat fertilized with 50 kg N/ha (44.6 lb N/A) than from unfertilized wheat was attributed to a greatly increased vegetative growth in the fertilized wheat. Protein content was lowest in the wettest treatment and highest in the driest treatment.

Roberts et al. (1972), in the Columbia Basin, found that added increments of fertilizer N in most cases produced increases in grain protein, although the initial small increments of applied N which resulted in marked yield increases caused a slight depression in the percentages of grain protein.

Effect of N Fertilization on Seed Size and Test Weight

Seed Size

Available evidence shows that increased nitrogen application may or may not result in increased seed size of the harvested crop.

Chang and Robertson (1967) working on barley found that nitrogen fertilizers significantly increased the proportion of large seeds produced at four of the five field locations. Wahhab and Hussain (1957) also observed increased 1000-seed weight in irrigated wheat on applications of nitrogen fertilizer, though in the same experiment spikes/plant and kernels/spike were unaffected.

Other researchers have reported a decrease in seed size associated with increasing nitrogen applications. Lopez (1972) reported that seed weight decreased progressively as the rate of nitrogen applied increased. The weight of 1000 seeds from the plots which received the highest level of nitrogen (216 kg N/ha or 192.8 lb N/A) was 9.9 gm or 24 percent lower than the seed from the control plots which received no nitrogen. The intermediate rates of 85 kg N/ha (75.9 lb N/A) and 131 kg N/ha (116.9 lb N/A) resulted in 11.9% and 17% reduction in 1000-seed weight, respectively. This decrease in size was nearly all at the expense of the endosperm, as embryo size was unaffected by nitrogen application. These findings are supported by Gupta and Singh (1970) who reported progressively lower 1000-seed weights with fertilizer applications beyond the 120 kg N/ha (107 lb N/A). Relative to the foregoing opposing reports, however, Zali et al. (1973) have reported an increase of both 1000-seed weight and protein content with increasing N applications.

Test Weight

Test weight is defined as the weight of grain that fills a given volume. It is the product of density and volume of grain occupying the container. The latter component when expressed as percentage of the volume of the container is referred to as packing efficiency and is a cultivar characteristic. Of the two components, packing efficiency has a greater effect on test weight when comparing soft winter wheats (Ghaderi et al., 1971). The same researchers pointed out that kernel widths were correlated more than length with kernel volume and also that test weights and kernel weight under different environments were correlated.

Hunter (1961) observed that the effects of N on test weights tended to parallel effects on yields. Generally, on sites where yields were increased by N, test weights were also increased. Largest decreases in test weights occurred on sites where increased N reduced yields.

On these sites, reduced yields were often accompanied by burning of foliage and shrivelling of grain resulting from the early exhaustion of soil moisture supply.

Yamada et al. (1972) working on wheat in California, found that fertilizer treatments containing phosphorus suppressed test weights appreciably, whereas nitrogen had less effect on test weight.

Yamazaki and Briggle (1969) reported that packing efficiency (the percent of bulk volume occupied by grain), one component of test weight, is associated with variety, whereas kernel density, the second component of test weight, is not associated with variety when considering soft wheats but seems to be related to environment. They thought that air spaces within the grain were a major factor in determining kernel density.

Effect of Supplemental Irrigation on Yield, Seed Protein, Seed Size and Test Weight

Some researchers have reported that nitrogen content and quality of grain is lower in years of high rainfall than in drier years, and from irrigated as compared with dry land.

Greaves and Carter (1923) found that a high rate of irrigation decreased the nitrogen content of wheat, barley and oats in Utah, but increased the phosphorus, potassium, calcium and magnesium content.

Shutt (1935) found that irrigation decreased the protein content of Red Fife wheat grain by 2.8 percent; the dry land controls containing 17.8 percent protein.

Russell and Voelcker (1936) used the results of 50 years' experiments at the Woburn Experiment Station, and the corresponding rainfall data, to deduce the effects of rainfall at various stages of growth of the barley crop on the nitrogen content of the harvested grain. Results showed that above average rainfall during May and June and early July reduced the nitrogen content, and that rainfall above the average in August increased, but only slightly, the nitrogen content.

Howell *et al*. (1959) attributed weight loss of soybeans in wet weather to high respiration rates persisting for longer than normal because of the slower drying of the seeds. Over the range 21-37°C the respiration losses at a moisture content of 55 percent (fresh weight basis) were equivalent to 0.03-0.05 percent of the seed dry weight per hour. Leaching of materials from the seeds while in the pods was an insignificant cause of weight loss.

Salter and Goode (1967) reviewed the moisture sensitive stages during the growth of crops. They concluded that for many cereals and other annual crops, the period when the floral organs are developing is particularly sensitive to drought. Cereals experiencing drought during the early stages of flower initiation produce abnormal and sterile pollen grains and although the gynoecia are little affected, fewer ovules are fertilized and grain number per ear is reduced. Mean seed weight can be reduced by drought experienced after fertilization.

The timing of irrigation seems to be the single most important factor when irrigating wheat. Kezer and Robertson (1927) examined the effect of irrigation on wheat for a period of 4 years on plots protected from rain. They noted that the highest yield from a single irrigation was obtained when water was applied either at jointing or heading. If water was withheld until heading was complete, slightly lower yields resulted, but grain quality was improved.

Smith (1920), in summarizing the work of several workers in Europe and America, found that most workers agreed the wheat plant must have an abundance of moisture at the heading stage. Some workers place the most critical stage just as the plants were beginning to head, others between the boot and the bloom period, and still others between the bloom and milk stage.

Working in the semi-humid climate of the Willamette Valley, Foote and Klock (1967) found that supplemental irrigation increased winter wheat yields only slightly even when irrigations were applied at the proper times. They found that nitrogen fertilizer application was a more efficient means of increasing yield than was irrigation.

Yamada *et al*. (1972) reported a significant increase in test weight influenced by heavy irrigation during early boot, late boot and milk stages of wheat. This contrasted with no change in test weights on plots irrigated at earlier stages of growth. In the same experiment, they found that protein concentration of grain was influenced primarily by nitrogen addition, but timely irrigation was of some benefit.

Effect of Seed Size on Seedling Vigor and Performance Potential

Several researchers have demonstrated that larger seeds in wheat produce more vigorous seedlings.

Kittock and Law (1968) reported that emergence, shoot weight and seed weight were positively correlated for 5 seed size classes.

Bremmer *et al*. (1963) reported that plant weight was reduced in plants from seeds with small endosperm but not from those with small embryos. During the first 6 days of growth, small embryos had a higher relative growth rate than large ones; thereafter until the exhaustion of reserves, growth was related to the amount of reserve material present.

Christian and Gray (1935) showed that plants grown from large seeds had an advantage when grown in competition with those grown from small seeds of the same variety.

Voronin *et al*. (1969) showed that large, medium, and small seeds of spring wheat produced 6, 5 and 4 seminal roots, respectively.

Chang and Robertson (1968) reported that large seeds produced taller plants with broader leaves.

Kaufmann and Guitard (1967) reported that in greenhouse tests with two varieties, large seeds were superior to those grown from small in rate of seedling growth, plant height and size of the first two leaves. Differences in rate of growth were more pronounced when plants were grown on vermiculite than when grown in soil, but even less difference was observed when grown in vermiculite with a complete nutrient solution. From this they concluded that increasing nutrient content of the substrate reduces dependence of the seedling on the nutrients available from the seed.

Parallel results have been demonstrated for other Gramineae species such as corn, sorghum and small seeded grasses. Cooper and McDonald (1970) reported that partial removal of the corn endosperm at seeding resulted in decreased growth of roots and shoots and decreased leaf area per seedling.

Beyer (1973) reported that no effect of seed size was evident in germination or emergence of sorghum, but small seeds had greatly reduced growth rate up to 17 days postemergence.

In blue panicgrass (*Panicum antidotale*), Abernethy *et al*. (1973) reported that heavy seed weight selections exhibited greater dry matter production. In other grasses, Kneebone and Cremer (1955) showed that the larger the seed within a lot, the more vigorous were the seedlings produced.

In berseem clover (*T. alexandrinum*), Radwan *et al*. (1972) showed that early seedling growth was significantly affected by seed size. They attributed the difference to an initial advantage in photosynthetic area maintained for 55 days from planting. At 55 days, seedlings from large seed had about 30 percent more leaf area than those from small seed.

Seed sizes also affect seedling vigor in horticultural crops. Ching and Danielson (1972) found a direct correlation between seed size and seedling vigor in lettuce. Scaife and Jones (1970), working with the same species under uniform conditions and in the absence of inter-plant competition, found a linear relationship between the fresh weight of the plant top at harvest and the weight of the seed sown.

Hanumaiah and Andrews (1973) reported that growth and vigor of seedlings of both cabbage and turnips increased as seed size increased. In cabbage, yield was not significantly increased as seed size increased, but large turnip seeds always produced superior plants, particularly through the first 80-103 days after planting.

Edward and Hartwig (1971) working with soybeans, demonstrated that in early seedling development, both the leaf area and dry weight were closely related to seed size. Taller plants were obtained from the larger seeds.

Effect of Seed Protein Content on Seedling Vigor and Performance Potential

Lopez (1972) reported that high protein seeds of wheat and barley developed into larger seedlings with higher dry matter content when grown in N deficient soil.

Lowe and Ries (1972) showed a significant positive correlation between wheat seed protein content and dry matter after 3 weeks of growth. They also reported that seedlings grown from high protein seeds were more advanced in morphological development than seedlings grown from low protein seeds. Lowe and Ries (1973) reported that seedling dry weight was positively related to the protein content of the aleurone layer and endosperm, but not of the embryo. This conclusion was reached because small (35 mg) high protein seeds (4.7 mg protein/seed) produced larger seedlings than large (45 mg) low protein seeds (4.3 mg protein/seed).

The same researchers transferred embryos from high protein seeds to low protein seeds and vice versa. They reported that high protein endosperm produced more vigorous seedlings regardless of the embryo type grown on it. This indicated that the factor(s) responsible for the greater growth of high protein seeds is/are in the endosperm.

Ries et al. (1970) reported that increases in seed protein due to both herbicide and N applications were reflected in higher yields the next generation. Yield was directly correlated with seed protein content, but not with seed size. In one test in Mexico, the effect of protein on the next generation was eliminated by 120 kg N/ha (107.1 lb N/A) applied at time of planting. On the average, seed from the high N plots yielded 12 percent more than that from the low N plots.

Ries and Everson (1973) reported that both environment and genotype affected the protein content of wheat seed, but regardless of genotype or environment, seedling vigor (dry weight of shoots) was consistently related to seed protein content. In this study, seedling vigor was also related to seed size, but when seed size was eliminated as a factor by using uniformly sized seed, the seed protein content and vigor relationships were significant.

Ries (1971) reported that seedling size, yield and number of fruits were more highly correlated with protein per seed than with seed size in beans.

MATERIALS AND METHODS

Varieties and Seed Sources

Foundation seed of Hyslop and Yamhill wheat, produced in the Willamette Valley, was used in these studies. Both are soft white winter wheat varieties. Hyslop is semi-dwarf and is stiff-strawed, tillers more than Yamhill, and has a reported protein content of about 8.2%. Yamhill is mid-tall and stiff-strawed, and has a reported protein content of about 8.7%. Both are high-yielding.

Seed Production Methods

Experimental Design and Statistical Analysis

A split-plot design was used to study the effects of N fertilization and seeding rates on quality of seed produced at each of three locations: Hyslop Crop Science Field Laboratory near Corvallis (Hyslop Farm), Sherman Agricultural Experiment Station (Moro) and Quinten Ruggs Farm (Pendleton). The three locations are in major wheat growing areas of the state of Oregon. N rates were main plots and seeding rates were sub-plots. In addition, duplicate experiments were established at Hyslop Farm to study the effects of irrigation. Plots were 6.1 m (20 ft) long with six rows per plot. Row spacings were .23 m (9 in) at Hyslop Farm and Pendleton and .30 m (12 in) at Moro.

Treatments were replicated four times.

All data were subjected to standard analysis of variance procedures, and the 0.05 probability level was the confidence used for all significant comparisons, unless stated otherwise. Least significant difference (LSD) was the test criterion. Adjusted error variance values were used for testing irrigation and varietal interactions with cultural practices (see Appendix tables).

Locations

Hyslop Farm - The soil type is a fertile Woodburn silt clay loam. The average rainfall is 39.15 inches a year and the average temperature is 51°F. (Details of weather data in Appendix Table 1.)

The field used for this experiment was in wheat the previous cropping season. It was disc-plowed in summer and harrowed twice early in fall. For weed control, Karmex (Diuron) was sprayed on November 3, 1975 at the rate of 2 lb/A in 30 gallons of water. Fertilizer schedule for the plots was as follows:

N level	Time of Application	Kg N/ha	Source of N
Low	Fall (October)[1]	56	16:20:0
Medium	Fall (October)	56	16:20:0
	Spring (late March)[2]	112	Urea (46% N)
High	Fall (October)	56	16:20:0
	Spring (late March)	112	Urea (46% N)
	Spring (late May)[3]	112	Urea (46% N)

[1]Seeding time; [2]flower initiation; [3]Anthesis/beginning of seed filling

Seeding was effected on October 16, 1975 at the rates of 14, 28, 56 and 112 kg/ha (12.5, 25, 50 and 100 lb/A) with a six-row planter.

Supplemental water was supplied to one set of plots by sprinkler irrigation twice -- during late anthesis (1.3 in) and at the seed filling stage (1.3 in). Soil moisture during this period was monitored by burying concentric gypsum blocks about 6 in deep between rows within a random sample of the irrigated plots. The soil moisture content was estimated by the current (in microamperes) registered on a soil moisture meter via the electrodes attached to the buried gypsum blocks. By use of a standard curve, the readings were converted to bars tension, a measure of water potential. The objective of these measurements was to help keep the soil water potential, by irrigation, above 2 bars tension at one-half the root depth (approximately 6 in for the varieties used) as recommended. Readings were taken approximately every 3 days.

Abundant rainfall in the preceeding months did not warrant an earlier irrigation. The irrigated set of plots was compared with the non-irrigated control plots. Heavier irrigation was preferred during the dry month of June, but the threat of lodging made further application prohibitive.

Before harvesting, the ends of the plots were trimmed to remove border effect and then the plot length was measured. All six rows per plot were harvested with a Hege combine on August 2, 1976. Yield per plot was converted to yield in kg/ha.

Moro - The soil is a Walla Walla silt loam type. The average rainfall and temperature are 10.56 inches and 49°F, respectively. (Details of weather data in Appendix Table 1.)

The area used for this research was fallow the previous season. It was mold board-plowed in the Spring, then spring-tooth harrowed and rod-weeded before planting on September 29, 1975.

The herbicide bronate (Bromoxonyl + MCPA) at 1.5 lb/A in 25 gallons of water was sprayed in March 1976.

N fertilizers were applied as follows:

N level	Time of application	Kg N/ha	Source of N
Low	Fall (October)	56	Aqua Ammonia
Medium	Fall (October) Spring (early April)[1]	56 112	Aqua Ammonia Urea (46% N)
High	Fall (October) Spring (early April)[2]	56 224	Aqua Ammonia Urea 46% N)

[1]Flower initiation; [2]The 3rd split application was also made at flower initiation because of lack of rainfall later on.

A six-row deep furrow drill was used for seeding on September 29, 1975 at the rate of 10, 21, 43 and 84 kg/ha (9, 19, 38 and 75 lb/A).

The ends of the plots were trimmed and the plot length measured at harvest time. Unlike Hyslop Farm and Pendleton only five of the six rows in a plot were harvested (August 23, 1976) because only that many fit the width of the Hege combine. Yield per plot was converted to yield in kg/ha.

Pendleton - The soil type in this area is moist Walla Walla silt loam. The average rainfall is 13.17 inches/year and temperatures average 52°F. (Additional weather data in Appendix Table 1.)

In this farmer's field, the preceeding crop was bush beans. The field was rototilled and harrowed before planting wheat. The herbicide bronate (Bromoxonyl + MCPA) at the rate of 1.5 lb/A of material was sprayed on March 10, 1976.

The application of N fertilizers was as follows:

N level	Time of application	Kg N/ha	Source of N
Medium	Fall[1]	0	--
	Late Winter (March)[2]	24	Ammonium Sulfate (21:24:0)
	Late Winter (March)[2]	52	Urea (46% N)
High	Fall	0	--
	Late Winter (March)[2]	24	Ammonium Sulfate (21:24:0)
	Late Winter (March)[2]	52	Urea (46% N)
	Early Spring (April)[3]	112	Urea (46% N)

[1]Carry over of N from bush bean crop was a substitute for N application.

[2]A blanket application over all plots causing a loss of low N plots.

[3]Flower initiation.

Planting was carried out on October 3, 1975 with the same planter used at Hyslop Farm and at the same seeding rate of 14, 28, 56, 112 kg/ha (12.5, 25, 50 and 100 lb/A).

The crop was harvested on August 21, 1976 with a Hege combine after trimming the edges and measuring plot lengths. As in other locations, yields were recorded in kg/ha after conversion.

To help in the interpretation of seed quality evaluations, components of yield were determined at each location, as follows:

Plants/meter - A representative sample of 1 meter of plants within any of the inner four rows per plot (four replications per treatment) was uprooted and the individual plants carefully separated and total count made as plants/meter.

Heads/plant - The total number of heads from the 1 meter of plants was divided by the total number of plants to give the heads/plant component.

Seeds/head - After counting the total number of heads, the heads were thrashed with an experimental plot thresher, the seeds were collected and cleaned by slotted screens on an electric vibrator. Due to a high proportion of seeds damaged by the thresher, a 5 1/2/64" x 3/4" bottom slot sieve was used instead of the usual 5/64" x 3/4". An electric seed counter determined the total number of seeds. This number divided by the number of heads per meter of row provided the seeds/head component.

1000-seed weight - Weights were taken of two manually counted sub-samples of 500 seeds each, for all the replications per treatment. A summation of the two weights provided the 1000-seed weight. If the weights of the sub-samples per replication varied by more than .5 g, a repeat count was made.

Seed Quality Evaluation

The quality of the seed harvested from each of the treatments and locations was evaluated as follows:

1000-seed weight. In the determination of 1000-seed weight, two sub-samples of 500 seeds per replication were counted manually and weighed. The combined weight represented 1000-seed weight. Where the sub-samples differed by more than 0.5 g in weight, the count was repeated.

Seed size distribution. Seed size distribution (sizing) was done with slotted sieves which separated seeds into 3 seed sizes -- large, medium and small. Large seeds were held on top of a 7/64" x 3/4" slotted sieve; medium sized seeds went through the 7/64" x 3/4" sieve but were held on the 6/64" x 3/4" sieve, and small seeds went through the above two sieves but were held on a 5/64" x 3/4" sieve. A representative seed sample of 100 g from each replication was shaked on an electric vibrator, and the resultant three portions by weight represented the percentage distribution of seed sizes within each replication.

Weight per bushel. Using the Boerner weight per bushel apparatus, bushel weights in lbs/bu were determined for each replication.

Protein determination. For each treatment, equal weights of seeds from each replication were mixed and ground. Two replicates from the composite sample were used for protein determination.

The determination of total nitrogen in plant material by the tube digestion method, procedure B, was used as outlined by Nelson *et al*. (1973). The ammonium was separated by steam distillation, collected in boric acid indicator solution and determined by titration with standard acid as described by Bremmer *et al*. (1965).

The percent of nitrogen per sample was calculated by the following equation.

$$\%N = \frac{\text{ml } H_2SO_4 \text{ in sample - ml in blank) x 0.01 x 14 x 100}}{\text{weight sample (mg)}}$$

The percentage protein content was determined by multiplying the %N times 6.25.

Seedling dry weight. For seedling vigor determination, 25 seeds from each replication were germinated in rolled towels at 20°C for 7 days.

Determination of normal and abnormal seedlings and dead (or dormant) seeds was done at the 7th day. All normal seedlings per towel were oven-dried in bottles for 1 hour at 100°C and 23 hours at 80°C, then cooled in desiccators and weighed. The total weight divided by the number of seedlings gave the dry weight per seedling.

RESULTS

Hyslop Farm - Non-irrigated

1000-Seed Weight

Hyslop - As Table 1 indicates, 1000-seed weights ranged from 43.07 g to 45.86 g, the heaviest seeds being produced with 280 kg N at the 112 kg seeding rate.

Seed weight was not affected by rate of N application but was reduced at the lowest seeding rate. The proportion of large seeds decreased progressively as seeding rates decreased (Table 3).

Yamhill - As with Hyslop, seed weight was unaffected by N levels. The heaviest seeds were produced at the highest seeding rate. Seed weights ranged from 45.86 to 50.05 g/1000, with the heaviest seeds produced with an application of 56 kg/ha of N and a seeding rate of 112 kg/ha.

Bushel Weight

Hyslop - Bushel weight was positively correlated (.95) with 1000-seed weight (Table 4). As with seed weight, bushel weight was unaffected by N levels and increased bushel weights were obtained at higher seeding rates. The range in bushel weights was 57.84 to 61.04 lbs/bu.

Yamhill - While N levels had no effect on bushel weight in Hyslop, bushel weights of Yamhill were greater at the high N level. Bushel weights generally increased with increase in seeding rates. Bushel weight was positively correlated (.52) with 1000-seed weight (Table 4).

Seed Protein Content

Hyslop - Protein content increased with each increment of N (Table 1). Within N levels, the highest protein content was associated with the lowest seeding rates. Seed protein ranged from 8.16% to 12.22%, with the highest protein found in seeds produced with 280 kg N and 14 kg seed/ha.

Yamhill - Each additional increment of N produced an increase in protein content. Within N levels, the highest protein content occurred at the lowest seeding rates. As in Hyslop, the highest protein content (14.19%) was obtained from the 280 kg N rate and 14 kg seeding rate.

Seedling Dry Weight

Hyslop - Seedling dry weight was correlated (.89) with seed protein content but not with seed weight (Table 4).

Yamhill - No differences were measured in the dry weights of seedlings grown from the seeds produced at any of the 12 N rate-seeding rate combinations. Higher protein content and heavier weight of seeds had no effect on seedling dry weight.

Seed Yield

Hyslop - When averaged over N levels, each increase in seeding rate resulted in higher seed yield. At the low N level, however, the 112 kg seeding rate did not yield more than the 56 kg rate, an indication that there was not enough N available for the increased plant population. Seed yield ranged from 4,746 to 10,619 kg/ha with the highest yield from the 280 kg N rate and 112 kg seeding rate.

Yamhill - Successive increases in seeding rates produced higher seed yield in each N level. As in Hyslop, the highest yield (8,888 kg/ha) was produced from the 280 kg N level and 112 kg seeding rate. Seed yield and bushel weight were positively correlated as in Hyslop (Table 4).

Hyslop Farm - Irrigated

1000-Seed Weight

Hyslop - Irrigation increased 1000-seed weight over the non-irrigated control at the 280 kg N rate and also increased seed weight at all seeding rates except at 56 kg/ha. Table 3 shows the increases in the proportion of large seed size due to irrigation. The range of seed weights under irrigation was 43.47 to 47.09 g, both occurring at the same N rate-seeding rate combinations as in the control.

Yamhill - Unlike Hyslop, Yamhill responded to irrigation with an increase in 1000-seed weight at each N level and seeding rate. Seed weights ranged from 47.65 to 52.28 g with the heaviest seeds produced at the 280 kg N rate and 112 kg seeding rate.

Bushel Weight

Hyslop - The same general trends and correlations were maintained in the irrigated plots as in the control (Tables 1 and 4). Irrigation did not affect bushel weight except for a small increase at the medium N level.

Yamhill - As in the control, bushel weight was positively correlated (.65) with 1000-seed weight. Irrigation decreased bushel weight at the highest seeding rate.

Seed Protein Content

Hyslop - Protein content ranged from 8.41% to 13.60%, the latter being produced from the 280 kg N rate and 28 kg seeding rate. As in the control, the highest protein content within each N level was found in seeds produced at lower seeding rates.

Protein content was increased by irrigation at the medium and high N levels and also at each seeding rate when averaged over N rates.

Yamhill - Irrigation reduced protein contents at the low and medium N levels but increased protein at the high N rate. Furthermore, a decrease in protein content occurred at each seeding rate, when averaged over the N levels, as a result of irrigation. The range of protein content was 7.72% to 15.00%, the highest resulting from the 280 kg N rate and 14 kg seeding rate.

Seedling Dry Weight

Hyslop - Irrigation improved performance of seeds from the medium and high N rates as indicated by the increased seedling dry weights at these levels. As in the control, seedling dry weight was correlated (.75) with seed protein but not with seed weight.

Yamhill - An increase in seedling dry weight occurred at the 280 kg N rate due to irrigation.

Seed Yield

Hyslop - Relative to the control, irrigation reduced seed yield to a small extent at the high N rate. As in the control, each successive increase in seeding rate resulted in a seed yield increase. Seed yields ranged from 4,746 to 10,308 kg/ha, with the highest seed yield resulting from the 280 kg N and 112 kg seeding rate.

Yamhill - Substantial increases in seed yield were obtained from irrigation at lower seeding rates, when averaged over the N levels. These increases were greater at the 168 kg N level than at other N applications. The

Table 1. Seed quality factors of non-irrigated and irrigated Hyslop and Yamhill wheat produced at Hyslop Farm, 1975-76.

Nitrogen level kg/ha	Seeding rate kg/ha	1000-seed weight (g)				Bushel weight (lbs/bu)				Seed protein (%)			
		Hyslop		Yamhill		Hyslop		Yamhill		Hyslop		Yamhill	
		Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.
56	14	44.86	46.32	46.79	51.39	59.44	59.60	56.95	57.46	9.41	9.29	11.94	8.66
	28	45.58	45.98	48.53	51.54	59.93	59.96	58.08	57.76	9.10	9.19	10.91	8.44
	56	45.74	45.56	45.59	51.51	60.39	60.14	58.33	57.54	8.56	8.69	9.94	7.72
	112	44.58	45.32	50.05	50.20	59.88	60.28	58.70	58.18	8.16	8.41	10.07	7.75
	mean	45.19	45.80	48.74	51.16	59.91	60.00	58.02	57.74	8.81	8.80	10.72	8.14
168	14	43.07	43.47	46.83	47.65	57.84	58.35	57.20	56.83	11.47	11.66	13.60	11.31
	28	44.14	44.45	45.86	49.38	59.34	59.23	58.15	58.33	10.47	10.85	13.26	10.44
	56	44.78	44.87	48.04	51.24	59.56	59.89	58.88	59.11	10.16	10.54	12.97	10.32
	112	44.78	46.10	48.54	50.56	59.73	60.61	59.71	59.33	10.19	9.63	12.31	10.60
	mean	44.19	44.72	47.32	49.71	59.12	59.52	58.49	58.40	10.57	10.87	13.04	10.67
280	14	43.66	45.18	46.11	48.35	58.55	58.59	57.35	57.54	12.22	13.50	14.19	15.00
	28	44.50	46.03	48.02	49.97	59.31	60.10	58.89	58.39	12.19	13.60	14.16	14.75
	56	45.72	46.30	48.88	50.62	60.33	60.46	59.36	59.55	12.10	13.47	13.85	14.38
	112	45.86	47.09	49.36	52.28	61.04	60.85	60.18	60.13	12.00	13.41	13.63	14.44
	mean	44.94	46.15	48.09	50.31	59.81	60.00	58.95	58.90	12.13	13.50	13.96	14.64
$LSD_{0.05}$ (seed rates)		1.19	1.14	1.41	1.43	.74	.51	.42	.45	.20	.45	.38	.31
$LSD_{0.05}$ (N levels)		1.30	.59	1.53	1.66	.82	.31	.61	.49	.60	.37	.22	.59
$LSD_{0.05}$ (paired seed rates between irrigations)		1.24		1.68		.70		.54		.34		.34	
$LSD_{0.05}$ (paired N levels between irrigations)		.62		.84		.35		.27		.18		.17	
Seed rate means	14	43.86	44.99	46.58	49.13	58.61	58.85	57.17	57.28	11.03	11.66	13.24	11.66
	28	44.74	45.49	47.47	50.30	59.53	59.76	58.37	58.16	10.59	11.12	12.78	11.21
	56	45.41	45.58	48.84	51.12	60.09	60.16	58.86	58.73	10.27	10.88	12.25	10.81
	112	45.07	46.17	49.32	51.01	60.22	60.58	59.53	59.21	10.12	10.55	12.00	10.93
$LSD_{0.05}$ (seed rates)		.69	.66	.82	.83	.43	.29	.24	.26	.12	.26	.22	.18
$LSD_{0.05}$ (paired seed rates between irrigations)		.72		.97		.41		.31		.20		.20	

Table 1 (continued)

Nitrogen level kg/ha	Seeding rate kg/ha	Seedling dry weight (mg) Hyslop Non-irrig.	Hyslop Irrig.	Yamhill Non-irrig.	Yamhill Irrig.	Germination (%) Hyslop Non-irrig.	Hyslop Irrig.	Yamhill Non-irrig.	Yamhill Irrig.
56	14	13.25	13.96	15.63	16.24	93	97	93	95
	28	12.95	13.42	16.17	16.48	85	89	90	96
	56	13.37	13.48	16.13	15.36	88	91	91	95
	112	12.98	13.22	15.05	15.11	91	90	86	98
	mean	13.14	13.52	15.75	15.80	89	92	90	96
168	14	14.00	13.96	16.31	17.07	94	95	80	95
	28	13.48	14.32	15.60	16.46	95	96	89	90
	56	13.72	15.18	15.76	16.33	88	97	88	97
	112	13.53	14.86	16.04	16.35	91	92	91	91
	mean	13.68	14.58	15.93	16.55	92	95	87	93
280	14	14.33	15.27	16.07	17.20	86	89	95	93
	28	13.66	15.53	16.22	17.11	95	95	85	95
	56	14.00	14.42	16.65	16.76	89	98	84	96
	112	14.18	15.26	15.83	17.06	85	92	89	98
	mean	14.04	15.12	16.19	17.03	89	94	88	96
$LSD_{0.05}$(seed rates)		1.28	1.25	1.52	1.31	12	9	9	7
$LSD_{0.05}$(N levels)		.66	.71	1.29	.90	5	4	8	3
$LSD_{0.05}$(paired seed rates between irrigations)		1.21		1.48		10		8	
$LSD_{0.05}$(paired N levels between irrigations)		.61		.74		5		4	
Seed rate means	14	13.86	14.40	16.00	16.84	91	94	89	94
	28	13.36	14.42	16.00	16.68	92	93	88	94
	56	13.70	14.36	16.18	16.15	88	95	88	96
	112	13.56	14.04	15.64	16.17	89	91	89	96
$LSD_{0.05}$(seed rates)		.74	.72	.88	.76	7	5	5	4
$LSD_{0.05}$(paired seed rates between irrigations)		.70		.85		6		6	

Table 2. Seed yield and components of seed yield of non-irrigated and irrigated Hyslop and Yamhill wheat produced at Hyslop Farm, 1975-76.

Nitrogen level kg/ha	Seeding rate kg/ha	Seed yield (kg/ha) Hyslop Non-irrig.	Seed yield (kg/ha) Hyslop Irrig.	Seed yield (kg/ha) Yamhill Non-irrig.	Seed yield (kg/ha) Yamhill Irrig.	Plants/meter Hyslop Non-irrig.	Plants/meter Hyslop Irrig.	Plants/meter Yamhill Non-irrig.	Plants/meter Yamhill Irrig.	Heads/plant Hyslop Non-irrig.	Heads/plant Hyslop Irrig.	Heads/plant Yamhill Non-irrig.	Heads/plant Yamhill Irrig.
56	14	4746	4746	4243	4402	8	7	7	7	10	11	8	10
	28	6178	6055	5689	5825	13	14	12	17	6	5	5	4
	56	7297	6710	6676	6378	17	24	16	23	4	4	4	3
	112	7296	7322	7220	6250	22	29	22	32	5	3	4	2
	mean	6379	6208	5957	5714	15	19	14	20	6	6	5	5
168	14	6192	5991	5033	6239	9	10	9	7	11	10	9	10
	28	7772	7541	6530	7731	13	15	15	12	7	6	6	7
	56	8613	9246	8028	8625	17	17	18	19	5	5	4	4
	112	9720	10134	8777	8841	24	29	26	35	4	4	4	2
	mean	8074	8228	7092	7859	16	18	17	18	7	6	6	6
280	14	6958	6240	5409	5958	11	9	8	9	10	12	10	9
	28	8265	8132	7542	7644	14	11	15	14	7	9	6	6
	56	9744	9305	8173	8176	16	22	16	23	6	4	5	4
	112	10619	10308	8888	9219	28	29	28	33	4	4	4	3
	mean	8896	8496	7503	7749	17	18	17	20	7	7	6	6
$LSD_{0.05}$ (seed rates)		642	607	598	476								
$LSD_{0.05}$ (N levels)		863	424	590	393								
$LSD_{0.05}$ (paired seed rates between irrigations)		762		590									
$LSD_{0.05}$ (paired N levels between irrigations)		363		295									
Seed rate means	14	5965	5659	4895	5533	9	9	8	8	10	11	9	10
	28	7405	7243	6587	7066	13	13	14	14	7	7	6	6
	56	8551	8420	7626	7726	17	21	17	22	5	4	4	4
	112	9211	9255	8295	8103	25	29	25	33	4	4	4	2
$LSD_{0.05}$ (seed rates)		370	350	345	275								
$LSD_{0.05}$ (paired seed rates between irrigations)		419		341									

Table 2 (continued)

Nitrogen level kg/ha	Seeding rate kg/ha	Seeds/head Hyslop Non-irrig.	Seeds/head Hyslop Irrig.	Seeds/head Yamhill Non-irrig.	Seeds/head Yamhill Irrig.	1000-seed weight (g) Hyslop Non-irrig.	1000-seed weight (g) Hyslop Irrig.	1000-seed weight (g) Yamhill Non-irrig.	1000-seed weight (g) Yamhill Irrig.
	14	49	48	55	48	44.86	46.32	46.79	51.39
	28	45	43	46	43	45.58	45.98	48.53	51.54
56	56	44	41	46	40	45.74	45.56	49.59	51.51
	112	36	35	39	36	44.58	45.32	50.05	50.20
	mean	44	42	47	42	45.19	45.80	48.74	51.16
	14	45	46	54	48	43.07	43.47	46.83	47.65
	28	51	50	44	46	44.14	44.45	45.86	49.38
168	56	44	48	46	46	44.78	44.87	48.04	51.24
	112	44	47	42	41	44.78	46.10	48.54	50.56
	mean	46	48	47	45	44.19	44.72	47.32	49.71
	14	49	52	51	49	43.66	45.18	46.11	48.35
	28	50	50	46	45	44.50	46.03	48.02	49.97
280	56	50	51	43	45	45.72	46.30	48.88	50.62
	112	44	47	41	41	45.86	47.09	49.36	52.28
	mean	48	50	45	45	44.94	46.15	48.09	50.31
$LSD_{0.05}$ (seed rates)						1.19	1.14	1.41	1.43
$LSD_{0.05}$ (N levels)						1.30	.59	1.53	1.66
$LSD_{0.05}$ (paired seed rates between irrigations)						1.24			
$LSD_{0.05}$ (paired N levels between irrigations)						.62			
	14	48	49	53	48	43.86	44.99	46.58	49.13
Seed rate means	28	49	48	45	45	44.74	45.49	47.47	50.30
	56	46	47	45	44	45.41	45.58	48.84	51.12
	112	41	43	41	39	45.07	46.17	49.32	51.01
$LSD_{0.05}$ (seed rates)						.69	.66	.82	.83
$LSD_{0.05}$ (paired seed rates between irrigations)						.72		.97	

Table 3. Distribution of three seed sizes within seedlots of Hyslop and Yamhill wheat produced at Hyslop Farm, 1975-76.

Nitrogen level kg/ha	Seeding rate kg/ha	Large - over 7*				Medium - over 6*				Small - over 5*			
		Hyslop		Yamhill		Hyslop		Yamhill		Hyslop		Yamhill	
		Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.
56	14	53.51	61.34	54.75	75.83	40.07	32.94	37.55	21.02	9.41	5.58	7.61	3.07
	28	57.25	64.80	60.97	78.27	35.72	30.29	33.49	18.98	7.02	4.75	4.79	2.64
	56	60.62	66.43	65.64	80.56	33.19	29.09	30.47	17.40	6.16	4.40	3.80	1.98
	112	61.68	68.79	70.14	83.05	33.10	27.58	26.83	15.17	6.01	3.53	2.92	1.87
	mean	58.27	65.34	62.88	79.43	35.53	29.98	32.09	18.14	7.15	4.57	4.78	2.39
168	14	35.54	42.95	47.39	54.41	50.32	46.21	44.96	38.67	14.05	10.76	7.46	6.93
	28	43.25	48.45	47.49	62.38	45.56	42.69	45.83	33.08	11.08	8.89	6.61	4.45
	56	42.94	49.78	53.85	68.47	47.78	42.81	41.66	28.63	9.26	7.32	4.44	2.82
	112	45.47	54.43	60.08	67.52	46.17	39.71	36.52	29.51	8.33	5.78	3.36	2.88
	mean	41.80	48.90	52.20	63.20	47.46	42.86	42.24	32.47	10.68	8.19	5.47	4.27
280	14	39.14	51.00	48.97	58.96	47.41	40.25	43.30	35.64	13.43	8.67	7.68	5.29
	28	45.52	58.25	57.03	65.23	43.34	34.95	38.44	30.44	11.24	6.74	4.58	4.24
	56	51.80	60.67	62.13	70.70	40.33	33.69	34.21	26.46	7.93	5.66	3.69	2.90
	112	50.62	62.07	65.15	75.79	41.71	32.83	31.77	22.12	7.74	5.11	3.09	1.99
	mean	46.77	58.00	58.32	67.67	43.20	35.43	36.93	28.67	10.09	6.55	4.76	3.61
Seeding rate means	14	42.73	51.76	50.37	63.07	45.93	39.80	41.94	31.78	12.30	8.34	7.58	5.10
	28	48.67	57.17	55.16	68.63	41.54	35.98	39.25	27.50	9.78	6.79	5.33	3.78
	56	51.79	58.96	60.54	73.24	40.43	35.20	35.45	24.16	7.78	5.79	3.98	2.57
	112	52.59	61.76	65.12	75.45	40.33	33.37	31.71	22.27	7.36	4.81	3.12	2.25

*Over 7/64" x 3/4" (large), through 7/64" x 3/4" but held over 6/64" x 3/4" (medium) through 7/64" x 3/4" and 6/64" x 3/4" but held over 5/64" x 3/4" (small) slotted screens, respectively.

Table 4. Correlation coefficients among seed yield and seed quality factors for non-irrigated and irrigated Hyslop and Yamhill wheat produced at Hyslop Farm, 1975-76.

			1000-seed weight	Bushel weight	Seed protein	Seedling dry weight
Seed yield	Hyslop	Non-irrigated	.40	.55*	.43	.44
		Irrigated	.37	.67**	.34	.55*
	Yamhill	Non-irrigated	.22	.87**	.45	.25
		Irrigated	.59*	.98**	.14	.05
1000-seed weight	Hyslop	Non-irrigated		.95**	-.25	-.25
		Irrigated		.79**	.12	.21
	Yamhill	Non-irrigated		.52*	-.27	-.35
		Irrigated		.65**	-.54	-.07
Bushel weight	Hyslop	Non-irrigated			-.23	-.21
		Irrigated			-.12	-.06
	Yamhill	Non-irrigated			.40	.14
		Irrigated			.09	.06
Seed Protein	Hyslop	Non-irrigated				.89**
		Irrigated				.75**
	Yamhill	Non-irrigated				.83**
		Irrigated				.43
Seedling dry weight	Hyslop	Non-irrigated				
		Irrigated				
	Yamhill	Non-irrigated				
		Irrigated				

*,**Significant correlations at the 0.05 and 0.01 levels, respectively.

range of seed yields was 4,402 to 9,219 kg/ha; both extreme yields were obtained from the same N rate-seeding rate combination as in the control.

Under irrigated conditions, Hyslop and Yamhill were about equal in seed yield at lower seeding rates, when averaged over N rates, but at higher seeding rates Hyslop outyielded Yamhill by a wide margin. Seed yield was positively correlated with bushel weight for both varieties under non-irrigated and irrigated regimes (Table 4).

Sherman Agricultural Experiment Station (Moro)

1000-Seed Weight

Hyslop - The response to seeding rate was opposite to that at Hyslop Farm, with heavier seed weights produced at the lower seeding rates at Moro. When averaged over seeding rates, N rates did not influence 1000-seed weights. The range of seed weights was 29.69 to 34.73 g, the latter resulting from seeds produced with 56 kg N and 10 kg seeding rate (Table 5).

Table 7 indicates higher percentages of large seeds in seed lots produced at the lower seeding rates.

Yamhill - As in Hyslop, the largest seed size was produced at the lowest seeding rate. Similarly, N rates did not produce important differences in seed weights. The lowest and highest seed weights were 37.47 and 39.99 g, respectively, occurring at the same N rate-seeding rate combinations as in Hyslop.

Bushel Weight

Hyslop - Neither N rates nor seeding rates had any influence on bushel weight (Table 5).

Yamhill - The N levels had little or no effect on bushel weights, but lower seeding rates produced slightly lower bushel weights.

Seed Protein Content

Hyslop - Seed protein content was increased only 1% by application of the high N rate. Increased seeding rates lowered protein content 1.82% and 2.56% at the 56 and 168 kg levels, respectively. Seeding rates had only a small effect at the high N rate. The highest protein content (15.41%) was obtained with 168 kg N and 10 kg seed/ha (Table 5).

Yamhill - As in Hyslop, seeding rates had a greater effect on protein content than did N levels, particularly at the two lower N levels. The highest protein content (16.47%) was obtained with 168 kg N and 10 kg seed/ha, as in Hyslop. Seed protein and bushel weight were also negatively correlated as in Hyslop (Table 8).

Seedling Dry Weight

N rates and seeding rates had no significant effect on seedling dry weights of either variety (Table 5).

Seed Yield

Hyslop - When averaged over N levels, increases in seeding rate up to 43 kg seed/ha increased seed yield. N rates had a negligible effect on yields. Seed yield ranged from 2,350 to 3,426 kg/ha, the latter coming from 168 kg N and 84 kg seed/ha.

Seed yield and 1000-seed weight were negatively correlated (-.66) as were seed yield and protein content (-.76). Seed yield and bushel weight, however, were positively correlated (.67) (Table 8).

Yamhill - As in Hyslop, yields increased with higher seeding rates up to 43 kg/ha. Similarly, seed yield and bushel weight were positively correlated (.60) (Table 8).

Quinten Ruggs Farm (Pendleton)

1000-Seed Weight

Hyslop - Within the N rates, increasing seeding rates reduced seed weight as in Moro. This reduction from the lowest to the highest seeding rate was 2.05 g in the 76 kg N plots, but 6.45 g in the 188 kg N plots. Consequently, an overall reduction in seed weight with the 188 kg N

Table 5. Seed quality factors of Hyslop and Yamhill wheat produced at Moro, 1975-76.

Nitrogen level (kg/ha)	Seeding rate (kg/ha)	1000-seed weight (g)		Bushel weight (lbs/bu)		Seed protein (%)		Seedling dry weight (mg)		Germination (%)	
		Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill
56	10	34.73	39.99	54.80	55.40	14.32	15.03	11.66	14.65	81	76
	21	34.08	38.65	55.18	55.35	13.35	15.04	10.97	14.78	88	77
	43	32.52	38.18	55.45	55.50	13.19	14.79	11.22	15.00	84	80
	84	31.43	39.71	54.97	55.89	12.50	14.13	11.44	15.20	90	79
	mean	33.19	39.13	55.09	55.54	13.34	14.75	11.32	14.91	86	78
168	10	34.15	38.76	53.54	54.93	15.41	16.47	11.94	15.89	86	82
	21	33.56	39.44	55.03	55.22	13.54	16.41	11.61	14.86	88	84
	43	32.29	39.50	54.81	56.01	13.44	14.66	11.37	15.25	95	85
	84	31.16	38.34	55.10	55.86	12.85	14.85	11.52	14.70	93	86
	mean	32.79	39.01	54.62	55.51	13.81	15.60	11.61	15.18	91	84
280	10	33.37	39.17	54.03	54.81	14.85	15.35	11.20	15.49	89	80
	21	32.50	39.24	54.23	55.63	14.51	15.47	11.20	15.74	87	82
	43	30.53	38.68	54.68	55.64	14.19	15.82	11.06	14.78	91	85
	84	29.69	37.47	54.48	55.59	14.00	15.69	11.70	14.79	90	93
	mean	31.52	38.64	54.36	55.42	14.39	15.58	11.29	15.20	89	85
$LSD_{0.05}$ (seed rates)		1.55	1.14	.88	.56	.54	.53	1.02	1.18	8	11
$LSD_{0.05}$ (N levels)		1.75	1.31	.81	.36	.62	.30	.44	.66	4	4
$LSD_{0.05}$ (paired seed rates between vars.)		1.62		.80		.34		1.05		10	
$LSD_{0.05}$ (paired N levels between vars.)		.81		.40		.17		.52		5	
Seed rate means	10	34.08	39.31	54.41	55.05	14.86	15.62	11.60	15.34	85	79
	21	33.38	39.11	54.81	55.40	13.80	15.64	11.26	15.13	88	81
	43	31.80	38.79	54.98	55.72	13.61	15.09	11.22	15.01	90	83
	84	30.76	38.51	54.85	55.78	13.12	14.89	11.55	14.90	91	86
$LSD_{0.05}$ (seed rates)		.90	.66	.51	.33	.32	.30	.59	.68	3	6
$LSD_{0.05}$ (paired seed rates between vars.)		.93		.46		.20		.60		6	

Table 6. Seed yield and components of seed yield of Hyslop and Yamhill wheat produced at Moro, 1975-76.

Nitrogen level (kg/ha)	Seeding rate (kg/ha)	Seed yield (kg/ha) Hyslop	Seed yield (kg/ha) Yamhill	Plants/meter Hyslop	Plants/meter Yamhill	Heads/plant Hyslop	Heads/plant Yamhill	Seeds/head Hyslop	Seeds/head Yamhill	1000-seed weight (g) Hyslop	1000-seed weight (g) Yamhill
56	10	2350	2908	10	10	13	12	34	37	34.73	39.99
	21	2894	2620	16	13	10	9	28	32	34.08	38.65
	43	3245	3063	25	29	6	4	25	27	32.58	38.18
	84	3128	3055	26	49	6	3	23	20	31.43	39.71
	mean	2904	2912	19	25	9	7	28	29	33.21	39.13
168	10	2367	2595	7	8	16	14	32	36	34.15	38.76
	21	3130	3307	18	15	9	7	28	33	33.56	39.44
	43	3096	3202	19	21	8	5	27	27	32.29	39.50
	84	3426	3226	34	48	5	3	23	20	31.16	38.34
	mean	3005	3082	20	23	10	7	28	29	32.79	39.01
280	10	2563	2774	11	8	14	14	32	39	33.37	39.17
	21	2388	2867	11	15	13	6	29	33	32.50	39.24
	43	3253	3237	23	27	7	5	23	26	30.53	38.68
	84	3212	2999	35	36	5	4	21	21	26.69	37.47
	mean	2854	2969	20	22	10	7	26	30	31.52	38.64
$LSD_{0.05}$ (seed rates)		636	398							1.55	1.14
$LSD_{0.05}$ (N levels)		397	315							1.75	1.31
$LSD_{0.05}$ (paired seed rates between vars.)		530								1.62	
$LSD_{0.05}$ (paired N levels between vars.)		265								.81	
Seed rate means	10	2427	2759	9	9	14	13	33	37	34.08	39.31
	21	2804	2931	15	14	11	7	28	33	33.38	39.11
	43	3198	3167	22	26	7	5	25	27	31.80	38.79
	84	3255	3093	32	44	5	3	22	20	30.76	38.51
$LSD_{0.05}$ (seed rates)		367	230							.90	.66
$LSD_{0.05}$ (paired seed rates between vars.)		306								.93	

Table 7. Distribution of three seed sizes within seedlots of Hyslop and Yamhill wheat produced at Moro, 1975-76.

Nitrogen level (kg/ha)	Seeding rate (kg/ha)	Large - over 7* (%)		Medium - over 6* (%)		Small - over 5* (%)	
		Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill
56	10	17.21	23.78	56.23	70.11	26.49	6.11
	21	16.90	20.62	60.04	72.72	23.00	6.63
	43	12.71	25.49	60.27	69.50	26.95	4.99
	84	10.90	36.63	61.52	58.81	27.48	4.42
	mean	14.43	26.63	59.52	67.79	25.98	5.54
168	10	17.47	24.94	54.81	68.00	27.55	7.01
	21	13.93	24.99	60.08	70.79	25.81	4.19
	43	11.33	31.59	59.11	64.21	29.46	4.30
	84	9.98	32.34	60.93	63.29	28.97	4.37
	mean	13.18	28.47	58.73	66.57	27.95	4.97
280	10	14.76	19.44	55.50	73.34	29.64	7.23
	21	11.75	23.09	58.06	71.79	30.07	5.10
	43	6.68	29.94	58.78	68.81	34.65	4.25
	84	5.81	25.85	56.81	68.16	37.35	5.99
	mean	9.75	23.83	57.29	70.53	32.93	5.64
Seeding rate means	10	16.48	22.72	55.51	70.48	27.89	6.78
	21	14.19	22.90	59.39	71.77	26.29	5.31
	43	10.24	28.01	59.39	67.51	30.35	4.51
	84	8.90	31.61	59.75	63.42	31.27	4.93

*Over 7/64" x 3/4" (large), through 7/64" x 3/4" but held over 6/64" x 3/4" (medium), through 7/64" x 3/4" and 6/64" x 3/4" but held over 5/64" x 3/4" (small) slotted screens, respectively.

Table 8. Correlation coefficients among seed yield and seed quality factors for Hyslop and Yamhill wheat produced at Moro, 1975-76.

		1000-seed weight	Bushel weight	Seed protein	Seedling dry weight
Seed yield	Hyslop	-.66**	.67**	-.76**	-.19
	Yamhill	-.12	.60*	-.13	.49
1000-seed weight	Hyslop		-.16	.34	.05
	Yamhill		-.15	-.04	.37
Bushel weight	Hyslop			-.87**	-.38
	Yamhill			-.62*	-.34
Seed protein	Hyslop				.25
	Yamhill				.22
Seedling dry weight	Hyslop				
	Yamhill				

*,**Significant correlations at the 0.05 and 0.01 probability levels, respectively.

was observed. Seed weights ranged from 34.84 to 42.76 g/ 1000, with the heaviest being produced at the 76 kg N and 14 kg seed/ha (Table 9). The reduction in the proportion of large seeds with increasing seeding rates and high N rate are reflected in Table 11.

Yamhill - As in Hyslop, the heaviest 1000-seed weights were obtained at the lowest seeding rates, within each N level. The reduction in seed weight with increasing seeding rates was greater in the 188 kg N than in the 76 kg N, as in Hyslop. Seed weights ranged from 41.41 to 45.61 g.

Bushel Weight

Hyslop - A high positive correlation (.90) was found between bushel weight and 1000-seed weight (Table 12). Bushel weights ranged from 52.68 to 54.59 lbs/bu (Table 9).

Yamhill - As in Hyslop, a high positive correlation (.84) between bushel weight and 1000-seed weight was observed (Table 12). The range of bushel weights was from 53.40 to 54.70 lbs/bu (Table 9).

Seed Protein Content

Hyslop - The 188 kg N increased protein content of seeds by an average of 2.41%. The reduction in protein content with increasing seeding rates was more evident in the 76 kg N than in the 188 kg N. The highest protein content (15.41%) was obtained from seeds produced with 188 kg N and 112 kg seeding rate. Protein content and bushel weight were negatively correlated (-.71) as shown in Table 12.

Yamhill - Unlike Hyslop, Yamhill did not respond with a higher seed protein content with application of the high N rate. The response range of protein content to seeding rates, however, was 1.54% in the high N rate and .78% in the medium N rate. The lowest and highest seed protein contents were 13.69% and 16.04%, with the latter being obtained from 188 kg N and 14 kg seed/ha.

Seedling Dry Weight

Hyslop - A positive correlation (.70) between seedling dry weight and 1000-seed weight was observed (Table 12).

Yamhill - An increase in seedling dry weight was obtained with the high N application. This contrasts with Hyslop in which the high N rate did not influence seedling dry weights.

Seed Yield

Hyslop - A sharp reduction in seed yield occurred at the lowest seeding rate within each N level. In general, seeding rates above 28 kg/ha did not result in yield increases. Yields ranged from 5,763 to 8,148 kg/ha with the highest yield obtained from the 76 kg N rate and 56 kg seeding rate.

Yamhill - The lowest seeding rate produced the lowest seed yield while seeding rates up to 56 kg/ha increased yield. The range of seed yields was from 5,663 to 7,476 kg/ha, the latter from the same N rate and seeding rate combination as in Hyslop.

Table 9. Seed quality factors of Hyslop and Yamhill wheat produced at Pendleton, 1975-76.

Nitrogen level (kg/ha)	Seeding rate (kg/ha)	1000-seed weight (g)		Bushel weight (lbs/bu)		Seed protein (%)		Seedling dry weight (mg)		Germination (%)	
		Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill
76	14	42.76	45.61	54.04	53.40	13.51	14.47	13.45	16.37	65	75
	28	41.98	45.16	54.31	54.01	12.97	14.28	12.89	16.21	70	72
	56	41.42	45.26	54.59	54.70	12.88	14.13	11.85	15.70	66	68
	112	40.71	44.32	54.10	54.54	11.44	13.69	12.06	14.71	74	73
	mean	41.72	45.09	54.26	54.16	12.70	14.14	12.56	15.75	69	72
188	14	41.29	43.83	53.78	53.63	14.75	16.04	12.54	16.07	66	81
	28	39.83	43.52	53.85	53.85	15.31	15.57	12.67	16.31	71	73
	56	37.87	44.72	53.39	54.48	14.97	14.50	12.00	16.69	69	71
	112	34.84	41.41	52.68	54.49	15.41	15.41	11.66	16.02	72	68
	mean	38.46	43.37	53.43	54.11	15.11	15.38	12.22	16.27	70	73
$LSD_{0.05}$(seed rates)		1.99	1.39	.77	.58	.57	.50	.95	1.50	16	10
$LSD_{0.05}$(N levels)		2.68	1.35	.72	.37	.11	1.96	.73	.16	4	6
$LSD_{0.05}$(paired seed rates between vars.)		1.83		.68		.41		1.15		12	
$LSD_{0.05}$(paired N levels between vars.)		.91		.33		.20		.57		6	
Seed rate means	14	42.03	44.72	53.91	53.52	14.13	15.26	13.00	16.22	66	78
	28	40.91	44.34	54.08	53.93	14.14	14.93	12.78	16.26	71	73
	56	39.65	44.99	53.99	54.59	13.93	14.32	11.93	16.20	68	70
	112	37.72	42.87	53.39	54.52	13.43	14.55	11.86	15.37	73	71
$LSD_{0.05}$(seed rates)		1.41	.99	.55	.41	.40	.35	.67	1.06	11	7
$LSD_{0.05}$(paired seed rates between vars.)		1.29		.47		.29		.81		8	

Table 10. Seed yield and components of seed yield of Hyslop and Yamhill wheat produced at Pendleton, 1975-76.

Nitrogen level (kg/ha)	Seeding rate (kg/ha)	Seed yield (kg/ha)		Plants/meter		Heads/plant		Seeds/head		1000-seed weight (g)	
		Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill
76	14	6010	5663	8	7	14	13	45	46	41.76	45.61
	28	7177	7124	11	11	9	8	40	44	41.98	45.16
	56	8148	7476	17	21	6	5	35	34	41.42	45.26
	112	8107	6875	28	22	5	5	31	27	40.71	44.32
	mean	7360	6784	16	15	9	8	38	38	41.72	45.09
188	14	5763	5826	7	9	17	12	45	42	41.29	43.83
	28	7565	6973	12	14	10	7	41	43	39.83	43.52
	56	7260	7337	13	18	9	5	36	37	37.87	44.72
	112	7569	6873	26	22	5	5	36	30	34.84	41.41
	mean	7039	6752	15	16	10	7	38	38	38.46	43.37
$LSD_{0.05}$(seed rates)		779	682							1.99	1.39
$LSD_{0.05}$(N levels)		389	334							2.68	1.35
$LSD_{0.05}$(paired seed rates between var.)		745								1.83	
$LSD_{0.05}$(paired N levels between vars.)		373								.91	
Seed rate means	14	5886	5745	8	8	16	13	45	44	42.03	44.72
	28	7371	7048	12	13	10	8	41	44	40.91	44.34
	56	7704	7406	15	20	8	5	36	36	39.65	44.99
	112	7838	6874	27	22	5	5	31	29	37.72	42.87
$LSD_{0.05}$(seed rates)		551	482							1.41	.99
$LSD_{0.05}$(paired seed rates between vars.)		372								1.29	

Table 11. Distribution of three seed sizes within seedlots of Hyslop and Yamhill wheat produced at Pendleton, 1975-76.

Nitrogen level (kg/ha)	Seeding rate (kg/ha)	Large - over 7* (%)		Medium - over 6* (%)		Small - over 5* (%)	
		Hyslop	Yamhill	Hyslop	Yamhill	Hyslop	Yamhill
76	14	43.75	39.19	46.13	51.77	10.13	9.10
	28	45.37	45.64	45.56	47.50	9.27	6.90
	56	45.80	48.20	45.00	47.22	9.37	5.83
	112	50.54	53.20	40.81	42.24	8.65	4.55
	mean	46.37	46.56	44.38	47.18	9.36	6.60
188	14	36.27	38.53	50.96	53.29	12.75	8.15
	28	33.13	34.55	53.48	58.82	13.42	6.87
	56	30.68	49.69	56.53	45.77	13.04	4.51
	112	18.59	32.06	58.89	62.31	22.48	5.62
	mean	29.68	38.71	54.97	55.05	15.42	6.29
Seeding rate means	14	40.01	38.86	48.20	52.53	11.44	8.63
	28	39.25	40.10	49.50	53.16	11.35	6.89
	56	38.24	48.95	50.77	46.50	11.21	5.17
	112	34.57	42.63	49.85	52.28	15.57	5.09

*Over 7/64" x 3/4" (large), through 7/64" x 3/4" but held over 6/64" x 3/4" (medium), through 7/64" x 3/4" and 6/64" x 3/4" but held over 5/64" x 3/4" (small) slotted screens, respectively.

Table 12. Correlation coefficients among seed yield and seed quality factors for Hyslop and Yamhill wheat produced at Pendleton, 1975-76.

		1000-seed weight	Bushel weight	Seed protein	Seedling dry weight
Seed yield	Hyslop	-.33	.09	-.32	-.67*
	Yamhill	-.02	-.04	-.41	-.10
1000-seed weight	Hyslop		.90**	-.59	.70*
	Yamhill		.84**	-.60	.07
Bushel weight	Hyslop			-.71*	.39
	Yamhill			-.33	-.02
Seed protein	Hyslop				-.09
	Yamhill				.45
Seedling dry weight	Hyslop				
	Yamhill				

*,**Significant correlations at the 0.05 and 0.01 probability levels, respectively.

DISCUSSION

Of the four production practices, location (environment) had the greatest effect on seed quality. This is illustrated by the great differences in the average 1000-seed weight for each variety at the three locations. For Hyslop variety, average seed weight from Hyslop Farm was 11.7% and 37.71% higher than in Pendleton and Moro, respectively. The same general trend was maintained for Yamhill variety. These differences were further expressed in seedling vigor. For Hyslop variety, seedling dry weight from seeds produced at Hyslop Farm averaged 9.93% and 19.37% higher than seeds grown in Pendleton and Moro, respectively.

Since the mean temperatures for the three wheat growing regions are about the same, differences in rainfall probably account for the environmental or location effects on seed quality. For the 1975-76 crop year, Moro and Pendleton received only 24.66% and 43.67%, respectively, of the total rainfall at Hyslop Farm.

Within locations, irrigation had more effect on seed quality than N levels and seeding rates. At Hyslop Farm, for example, the highest seed weight of non-irrigated Yamhill was increased by 5.92% with irrigation. The same trend was maintained in Hyslop variety. These differences were also measured in the subsequent dry weights of seedlings grown from the same seedlots.

Similar positive effect of irrigation over the N levels and seeding rates, in improving seed quality, was measured in seed protein content. The highest protein content under non-irrigation was increased by 1.41% and .81% in Hyslop and Yamhill, respectively, with irrigation. Evidently, the higher moisture availability in the irrigated plots improved the efficiency of utilization of available N. Considering that less than half of the normal rainfall fell in June (the seed filling stage), it is conceivable that a mild moisture stress condition may have developed in the non-irrigated plots and irrigation was, consequently, of benefit.

The optimum combination of N levels and seeding rates for the production of the best seed quality differed at the three locations. The heaviest seed weight, for instance, was obtained with the highest N level and seeding rate at Hyslop Farm. At Moro, however, the lowest N level and seeding rate produced the heaviest seeds, while the medium N level and lowest seeding rate produced the heaviest seeds at Pendleton.

Moisture availability differences, especially between Moro and Hyslop Farm, may have had much to do with these contrasting responses. Both at Moro and Hyslop Farm, fewer heads/plant and seeds/head were obtained at higher seeding rates. This meant that inter-plant competition was the primary source of competition for nutrients and water at the highest seeding rate. At Hyslop Farm, however, the reduced inter-tiller and inter-seed competition at the highest seeding rate resulted in larger seeds, while smaller seeds were produced at Moro. It would appear, therefore, that under the limited moisture conditions of Moro, successive increases in seeding rates imposed progressively higher moisture stress due to the higher inter-plant competition, resulting in the reduction of seed weight. Conversely, adequate moisture supply throughout the growing season at Hyslop Farm, coupled with sufficient N supply, facilitated the progressive increase in seed weight at higher seeding rates.

Since the seeds from Moro, though small-sized, were as well-filled as those from Hyslop Farm, it would appear that sink size (storage capacity) and not assimilate supply was the limiting factor. Water stress is generally known to have adverse effects on inflorescence formation and development. It is likely, therefore, that in Moro the process of cell division and enlargement in individual seeds after fertilization, particularly in the endosperm, might have been inhibited with the overall effect of reduced sink size. The higher the water stress, as at the highest seeding rate, the greater was the negative effect on sink size. Though ambient temperatures in the two locations were about similar, soil temperatures at Moro were probably higher due to the lower unit surface area of canopy cover. This factor, too, might have had a share in the effect of reduced seed weight at Moro.

Within locations, optimum combinations of N level and seeding rate for the highest seed weight and protein content were not the same. In Moro, the highest seed weight was obtained at the 56 kg N rate and 10 kg seeding rate, whereas the highest protein content was produced at the 168 kg N rate and the 10 kg seeding rate. Seedling vigor, a measure of performance potential, however, was unaffected by either of the two seed quality factors, suggesting that large seed of low protein content and small seed of high protein content were of equal quality.

In Pendleton, the choice of the optimum combination of the N levels and seeding rates was more critical. The heaviest seed weight was produced with the 76 kg N rate and 14 kg seeding rate, whereas the highest protein content was obtained with the 188 kg N rate and usually at the 14 kg seeding rate. The two seed quality factors, however, had different effects on seedling vigor. In Hyslop, for instance, the heavier seed weights were related to heavier seedling dry weights, but the higher protein content was not related to seedling vigor. In Yamhill, these relationships were reversed. In terms of performance potential, it would appear, therefore, that in Pendelton, unlike the situation in Moro, the choice of the optimum N rate-seeding rate combination for the highest seed quality was variety-related. The best combination for the largest seed size in Hyslop (that is 76 kg N-14 kg seeding/ha) was more important than the optimum combination for the highest protein content. At Pendleton, 76 kg N and 14 kg seeding rate was the optimum cultural practice for highest seed quality in Hyslop. This optimum, however, involved a seed loss. For Yamhill 188 kg N was the optimum for highest seed quality. The highest seed yield was obtained at 28 kg seed/ha within this N level, but seeding rates had no effect on seed quality.

In Hyslop Farm, both the heaviest seed weight and highest seed protein content were obtained with the 280 kg N rate but the former at the 112 kg seeding rate and the latter at the 14 kg seeding rate. But since the difference in protein content at the extreme seeding rates was less than the difference in seed weight at the extreme seeding rates within the same N level, it would appear that the 280 kg N rate and 112 kg seeding rate would be the best compromise as the optimum combination for the production of the highest seed quality at Hyslop Farm. Even though the advantage of heavier seed weight was not related to seedling vigor, highest seed protein content was related to higher seedling dry weights, hence the choice of the 280 kg N rate for maximum seed protein content.

The two varieties, Hyslop and Yamhill, were chosen for this research because of their basic genetic differences. It was, consequently, important to find out if they would respond similarly or differently to the production practices in question with regard to the seed quality factors studied. With few exceptions, their responses were essentially similar.

In Hyslop Farm, seed protein content responded differently to irrigation in the two varieties. While irrigation had no effect at the low N rate but increased protein content at the medium and high H rates in Hyslop, Yamhill responded by a substantial loss of protein in seeds produced at the low and medium N levels. In Moro, the response range of seed weight and protein content to seeding rates in Hyslop was at least twice that of Yamhill, though the trends were similar. Hyslop, with its higher tillering capacity, was more likely to have sustained greater competition at each seeding rate and, consequently, the wider response. Similar observations were made in Pendleton with regard to the response of seed weights to seeding rates between the two varieties. In the same manner, seed protein increased to a greater extent in Hyslop than in Yamhill on application of the high N rate in Pendleton.

Finally, it is important to relate optimum seed production methods to maximum seed yields in this research and make recommendations for seed production in the light of farmers general practices in grain production. Yields at

Hyslop Farm averaged 4.8% and 147.6% higher than at Pendleton and Moro, respectively. Within Hyslop Farm, the 280 kg N rate - 112 kg seeding rate combination resulted in the highest seed quality and also the highest seed yields. For commercial wheat production in the Willamette Valley, the seeding rates used by farmers range from 90-134 kg/ha (80-120 lb/A) and N levels applied on wheat following a grain crop average 190 kg N/ha (170 lb N/A). Yields of the two varieties in farmers' fields range from 4033 kg to 6721 kg/ha (60-100 bu/A). Seed protein content of grain produced by farmers range between 8 and 10% for the two varieties. For seed production purposes, it appears that farmers would need to increase N application, to boost both seed protein content and seed yield, but retain their usual seeding rates. As for irrigation, while making a significant contribution in the improvement of seed quality, it made little or no difference in seed yields. This corresponds with the findings of Foote and Klock (1967) on the effect of irrigation on winter wheat yields.

In Moro, seed quality was unaffected by production methods and, therefore, the cultural practice associated with the highest seed yield was the best for this region -- that is 56 kg N rate and 43 kg seed/ha. For commercial grain production, the seed rates used by farmers in this dryland wheat area range from 34 to 56 kg/ha (30-50 lb/A) and N levels range from 22-45 kg N/ha (20-40 lb N/A).

Farmer's grain yields range from 1344 kg/ha to 4033 kg/ha (20-60 bu/A). Comparing these practices and general yields with the findings of this research, it appears that farmers would need to increase the N fertilizer level slightly but retain their usual seeding rates for maximum seed yields.

In Pendleton, an increase in seed size in Hyslop variety was associated with a loss in seed yield. This relationship held because higher seed weight was obtained at lower seeding rates,while higher seed yield was produced at higher seeding rates. The range of grain yields in farmers' fields of this region is from 2688 to 6049 kg/ha (40-90 bu/A). Since farmers use seeding rates ranging from 67 to 90 kg/ha (60-80 lb/A) and N levels ranging from 67 to 100 kg N/ha (60-90 lb N/A), following a legume or row crop, for grain production, they would need to cut down on their seeding rates but retain their usual N fertilizer practices for seed production purposes. This recommendation is based on the finding that 76 kg N rate and 14 kg seeding rate was optimum for highest seed size in Hyslop. Farmers have to make a choice since this recommendation involves a sacrifice in yield. Since Yamhill is not recommended in this region, hence not grown extensively by farmers, on account of heavy susceptibility to diseases, the need for higher N levels to maximize seed protein content may not probably be as important as increased seed size in Hyslop. The increase in protein content at higher N levels in Yamhill, nevertheless, would not involve a loss in seed yield, because the optimum seeding rate (28 kg/ha) for highest seed yield would be used, without changing the level of seed quality.

For definite conclusions on the recommendations given, the results of field performance of seeds produced will be necessary.

Questions that derive from this work might be resolved by a detailed study to help understand location effects on seed quality. Perhaps studies of physiological differences in seed produced at the different locations might shed some light. The soil/moisture relations in these locations as they relate to wheat growth in the critical stages could be investigated.

Finally, the possibility of improving seed quality even further at Hyslop Farm might be investigated because the plateau of seed weight and protein content was not reached at the maximum N rate and seeding rate combination used in this research.

SUMMARY AND CONCLUSIONS

The objective of this research was to identify the optimum cultural practices for the production of the highest quality wheat seed in Oregon. The production methods included locations, irrigation, N levels and seeding rates. The seed quality factors studied were seed weight, bushel weight, protein content and seedling vigor.

Of the four production practices, location had the greatest effect on seed quality. Hyslop Farm, representing the fertile, semi-humid Willamette Valley, produced the best quality wheat seed in terms of seed weight and seedling vigor. Pendleton, representing the marginal rainfall areas of eastern Oregon, produced intermediate quality seed, and Moro, representing the dry land wheat production regions of eastern Oregon, produced the lowest quality seed.

Within Hyslop Farm, the only location in which irrigation was possible, irrigation had a more positive effect on seed quality than N or seeding rates.

The optimum N level and seeding rate combinations differed at the three locations as well as within locations. At Hyslop Farm the 280 kg N rate and 112 kg seeding rate was the optimum for both seed weight and protein content. At Moro, the 56 kg N rate and 10 kg seeding rate was optimum for the heaviest seed weight, and the 168 kg N rate and 10 kg seeding rate was optimum for the highest protein content. These seed quality factors, however, had no effect on seedling dry weights. In Pendleton, the optimum for Hyslop variety was 76 kg N and 14 kg seeding rate, whereas for Yamhill variety 188 kg N was optimum, though seeding rates had no effect on seed quality. Differences in soil moisture potential among the locations was considered a major environmental factor determining the optimum production practice.

In a few instances, the two varieties responded differently to the cultural practices. With irrigation, protein content was reduced in Yamhill at the low and medium N levels, whereas in Hyslop no change occurred at the low N level but an increase occurred at the medium and high N levels. In Moro and Pendleton, the increase in seed weight and protein content in response to seeding rates and N levels was greater in Hyslop than in Yamhill.

Higher yields were produced at Hyslop Farm than at Pendleton and Moro. In Hyslop Farm 280 kg N level - 112 kg seeding rate was the best combination for the highest seed quality as well as for maximum seed yield. For highest seed quality and maximum seed yields, farmers in the Willamette Valley would adjust their usual grain production methods by applying higher levels of N fertilizers.

In Moro, cultural practices had no effect on seed quality. Consequently, the production method that gave the highest seed yield was the best for this dry region --

that is 56 kg N rate and 43 kg seeding rate. Farmers could increase seed yields by increasing N fertilizer application over their normal levels but retain their usual seeding rates.

The highest seed quality in Pendleton was variety-related. The heaviest seed weight in Hyslop was more important than the highest protein content and was produced at the 76 kg N rate and 14 kg seeding rate. In Yamhill, however, the highest protein content was of greater significance than seed weight and resulted from the 188 kg N rate; seeding rates had a limited effect on protein content, but highest seed yield resulted from 28 kg seed/ha. To obtain the highest seed weight in Hyslop, farmers would reduce drastically, the normal rates used for grain production. If higher protein content in Yamhill is desirable, farmers would step up the N application above the levels normally used for grain production. The choice between seed quality and yields would have to be made in Hyslop but not in Yamhill.

In conclusion, the ultimate test of the significance of the seed quality differences found in this research and the accompanying recommendations will be field performance in yield trials presently underway.

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APPENDIX

Appendix Table 1. Rainfall and temperature data for Hyslop Farm, Moro and Pendleton for 1975/76 crop year and long-term averages.

	Hyslop Farm				Moro				Pendleton			
	Rainfall		Temperature		Rainfall		Temperature		Rainfall		Temperature	
	75/76 crop year in/ month	30 year Av. in/ month	75/76 crop year max/min/ av.	30 year average	75/76 crop year in/ month	10 year Av. in/ month	75/76 crop year max/min/ av.	10 year average	75/76 crop year in/ month	40 year Av. in/ month	75/76 crop year max/min/ av.	40 year average
Sep	0.00	1.31	93 38 64	62	0.00	.41	90 37 61	59	0.00	0.75	93 30 60	60
Oct	4.30	3.78	89 32 52	53	1.17	.78	80 31 49	49	2.16	1.15	85 26 51	53
Nov	5.51	6.04	72 28 44	45	1.34	1.82	71 17 39	40	1.47	1.52	76 13 40	41
Dec	6.47	6.83	58 25 42	41	1.26	1.94	59 16 37	33	3.40	1.59	64 13 37	36
Jan	6.59	7.06	57 25 41	39	1.25	1.44	61 16 36	32	2.13	1.55	66 17 37	32
Feb	6.71	4.63	61 24 41	43	.93	.91	52 8 35	38	1.09	1.37	64 8 37	38
Mar	4.45	4.20	65 26 44	46	.95	.81	61 16 38	41	1.69	1.25	71 16 41	45
Apr	1.98	2.05	71 31 48	50	1.06	.75	68 23 45	46	1.38	1.06	73 27 47	52
May	1.14	1.77	83 33 54	56	.14	.66	84 32 54	53	1.21	1.18	86 31 56	59
Jun	.47	1.15	88 33 57	61	.06	.57	93 27 60	62	0.58	1.04	95 31 59	65
Jul	.90	.33	92 39 65	66	.79	.13	95 43 70	68	0.04	.31	100 38 69	73
Aug	2.08	.55	89 43 64	66	1.17	.34	92 41 67	67	2.58	.40	94 41 66	71
Total	40.60	39.70	$\bar{x}$ 77 31 51	52	10.01	10.56	$\bar{x}$ 76 26 49	49	17.73	13.17	$\bar{x}$ 81 24 50	52

Appendix Table 2. Observed mean squares for seed yield and seed quality factors for non-irrigated Hyslop wheat at Hyslop Farm during 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	233653	6.50	2.05	.14	129
Nitrogen (N)	2	26354727**	4.28	2.97	3.33*	49
Error(a)	6	995783	2.26	.90	.59	31
Seed rate (SR)		24306249**	5.34**	6.42	.53	30
NxSR	6	420944	1.47	.99**	.10	70
Error(b)	27	195567	.68	.26	.78	70
Total	47					
c.v.%		6	1.84	0.86	6.48	9
Grand Mean		7783	44.77	59.61	13.62	90

Source of variation	Degrees of freedom	Protein content
Rep	1	0.04
Nitrogen (N)	2	22.09**
Error(a)	2	0.08
Seed rate (SR)	3	0.99**
NxSR	6	0.21**
Error(b)	9	0.01
Total	23	
c.v.%		0.85
Grand Mean		10.50

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate
Rep x Nitrogen x Seed rate}

Appendix Table 3. Observed mean squares for seed yield and seed quality factors for irrigated Hyslop wheat grown at Hyslop Farm during 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	212860	3.51*	0.73	0.51	24
Nitrogen (N)	2	24028933**	8.85**	1.22*	10.60**	30
Error(a)	6	240110	0.46	0.13	0.67	21
Seed rate (SR)	3	29192260**	2.80*	6.58**	0.07	35
NxSR	6	709601	2.62**	0.70**	1.25	6
Error(b)	27	174748	0.61	0.12	0.7444	38
Total	47					
c.v.%		5	1.72	.59	5.99	7
Grand Mean		7644	45.56	59.84	14.41	94

Source of variation	Degrees of freedom	Protein content
Rep	1	0.001
Nitrogen (N)	2	43.04**
Error(a)	2	0.03
Seed rate (SR)	3	1.11**
NxSR	6	0.33**
Error(b)	9	0.04
Total	23	
c.v.%		1.81
Grand Mean		11.06

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate
Rep x Nitrogen x Seed rate

Appendix Table 4. Observed mean squares for seed yield and seed quality factors for non-irrigated versus irrigated Hyslop wheat at Hyslop Farm, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Nitrogen (N)	2	50764336	11.97	3.98	12.89	72
Seed Rate (SR)	3	53374793	6.93	12.91	.22	34
NxSR	6	859768	3.72	1.32	.62	78
Irrigation(Irr)	1	463907	14.73**	1.25*	14.82**	308*
NxIrr	2	619323	1.13	.21	1.04	8
SR x Irr	3	123717	1.20	.09	.33	31
NxSRxIrr	6	270776	.36	.38	.73	27
(Rep) Irr	6	223257	5.01**	1.39	.32	77
(RepxN) Irr (RepxSR) Irr (RepxNxSR) Irr (error)	66	263846	.78	.25	.74	49
Total	95					

Source of variation	Degrees of freedom	Protein content
Nitrogen (N)	2	62.97
Seed Rate (SR)	3	2.05
NxSR	6	.45
Irrigation(Irr)	1	3.20**
NxIrr	2	2.17**
SRxIrr	3	.05
NxSRxIrr	6	.09*
(Rep) Irr	2	.02
(RepxN) Irr (RepxSR) Irr (RepxNxSR) Irr (error)	22	.03
Total	95	

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 5. Observed mean squares for seed yield and seed quality factors for non-irrigated Yamhill wheat produced at Hyslop Farm during 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	1882436	5.14	.59	2.45	161
Nitrogen (N)	2	10263032**	8.14	3.47*	.81	36
Error(a)	6	464625	3.15	.49	2.24	80
Seed rate (SR)	3	26324489**	18.96**	11.91**	.62	7
NxSR	6	268742	1.75	.29*	.67	111
Error(b)	27	169986	.95	.08	1.10	40
Total	47					
c.v.%		6.02	2.03	.48	6.57	7
Grand Mean		6850	48.05	58.49	15.96	88

Source of variation	Degrees of freedom	Protein content
Rep	1	0.02
Nitrogen (N)	2	22.32**
Error(a)	2	0.01
Seed Rate (SR)	3	1.83**
NxSR	6	.30**
Error(b)	9	0.03
Total	23	
c.v.%		1.38
Grand Mean		12.57

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate; Rep x Nitrogen x Seed rate}

Appendix Table 6. Observed mean squares for seed yield and seed quality factors for irrigated Yamhill wheat produced at Hyslop Farm during 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	597805	2.63	.19	.06	78
Nitrogen (N)	2	23352922**	8.54	5.47**	6.19	34
Error(a)	6	206625	3.67	.33	1.09	10
Seed rate (SR)	3	15416322**	10.06**	8.30**	1.48	15
NxSR	6	432925*	6.02**	1.31**	.46	27
Error(b)	27	107656	.97	.10	.82	24
Total	47					
c.v.%		4.62	1.95	.54	5.39	5.16
Grand Mean		7107	50.39	58.35	16.79	95

Source of variation	Degrees of freedom	Protein content
Rep	1	.20
Nitrogen (N)	2	85.91**
Error(a)	2	.07
Seed rate (SR)	3	.86**
NxSR	6	.08*
Error(b)	9	.02
Total	23	
c.v.%		1.27
Grand Mean		11.15

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate
Rep x Nitrogen x Seed rate}

Appendix Table 7. Observed mean squares for seed yield and seed quality factors for non-irrigated versus irrigated Yamhill wheat at Hyslop Farm, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Nitrogen (N)	2	31575265	16.57	8.81	5.67	67
Seed rate (SR)	3	40899279	27.63	20.01	1.24	8
NxSR	6	482267	3.19	1.16	.90	36
Irrigation(Irr)	1	1582633**	131.46**	.45*	6.14*	1014**
NxIrr	2	2040688**	.10	.12	1.33	4
SRxIrr	3	841532**	1.39	.20	.86	13
NxSRxIrr	6	219400	4.59**	.44*	.24	102*
(Rep) Irr	6	1240121	3.89	.39	1.25	119
RepxN) Irr (RepxSR) Irr (RepxNxSR) Irr	error 66	174603	1.41	.15	1.09	34
Total	95					

Source of variation	Degrees of freedom	Protein content
Nitrogen (N)	2	94.89
Seed rate (SR)	3	2.52
NxSR	6	.23
Irrigation(Irr)	1	24.07**
NxIrr	2	13.33**
SRxIrr	3	.17**
NxSRxIrr	6	.16**
(Rep) Irr	2	.11
(RepxN) Irr (RepxSR) Irr (RepxNxSR) Irr	error 22	.03
Total	47	

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 8. Observed mean squares for seed yield and seed quality factors of non-irrigated Hyslop and Yamhill wheat produced at Hyslop Farm, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Nitrogen (N)	2	34718812	11.97	2.82	3.67	12
Seed rate (SR)	3	50565899	21.15	17.72	.71	23
NxSR	6	372767	1.35	.96	.42	51
Variety (Var)	1	20882883**	258.04**	30.60**	130.76**	60
NxVar	2	1898946**	.45	3.61**	.47	73
SRxVar	3	64839	3.15	.62	.43	14
NxSRxVar	6	316919	1.87	.33	.35	130*
(Rep) Var	6	1058045	5.82	1.32	1.29	145
(RepxN) Var						
(RepxSR) Var	error 66	282309	1.16	.27	1.03	55
(RepxNxSR) Var						
Total	95					

Source of variation	Degrees of freedom	Protein content
Nitrogen (N)	2	43.93
Seed rate (SR)	3	2.74
NxSR	6	.35
Variety (Var)	1	51.21**
NxVar	2	.48**
SRxVar	3	.07
NxSRxVar	6	.17**
(Rep) Var	2	.03
(RepxN) Var		
(RepxSR) Var	error 12	.02
(RepxNxSR) Var		
Total	47	

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 9. Observed mean squares for seed yield and seed quality factors of irrigated Hyslop and Yamhill wheats produced at Hyslop Farm, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Nitrogen (N)	2	48085448	14.33	3.17	16.48	2
Seed rate (SR)	3	43205657	10.90	14.81	.76	22
NxSR	6	973862	7.75	1.69	.93	41
Variety(Var)	1	6920292**	561.30**	53.55**	101.25**	43
NxVar	2	296407	3.05	3.52**	.31	63
SRxVar	3	1402926	1.96	.08	.74	27
NxSRxVar	6	168664	.89	.32*	.79	22
(Rep)Var	6	405333	3.07	.46	.28	51
(RepxN)Var						
(RepxSR)Var } error	66	192989	1.03	.13	.80	28
(RepxNxSR)Var						
Total	95					

Source of variation	Degrees of freedom	Protein content
Nitrogen (N)	2	125.28
Seed rate (SR)	3	1.80
NxSR	6	.24
Variety(Var)	1	.21*
NxVar	2	3.67**
SRxVar	3	.17
NxSRxVar	6	.17
(Rep)Var	1	.10
(RepxN)Var		
(RepxSR)Var } error	22	.03
(RepxNxSR)Var		

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 10. Observed mean squares for seed yield and seed quality factors for Hyslop wheat produced at Moro, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	36096	2.22	1.15	0.45	19
Nitrogen (N)	2	94060	10.02	1.90	0.49	97
Error(a)	6	211062	4.10	.87	0.26	21
Seed rate (SR)	3	1786682**	23.60**	.99	0.47	77
NxSR	6	220988	0.54	.48	0.22	35
Error(b)	27	191897	1.14	.37	0.49	31
Total	47					
c.v.%		15	3.28	1.11	6.13	6
Grand Mean		2921	32.51	54.69	11.41	89

Source of variation	Degrees of freedom	Protein content
Rep	1	0.00
Nitrogen (N)	2	2.20*
Error(a)	2	0.08
Seed rate (SR)	3	3.23**
NxSR	6	0.31*
Error(b)	9	0.06
Total	23	
c.v.%		1.77
Grand Mean		13.85

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate
Rep x Nitrogen x Seed rate

Appendix Table 11. Observed mean squares for seed yield and seed quality factors for Yamhill wheat produced at Moro, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	46842	2.39	.06	.73	95
Nitrogen (N)	2	120520	1.48	.06	.43	236
Error(a)	6	132821	2.30	.17	.58	167
Seed rate (SR)	3	395094**	2.45*	1.36**	.43	101
NxSR	6	183812	2.26**	.30	.95	27
Error(b)	27	75316	.62	.15	.66	58
Total	47					
c.v.%		9.18	2.02	.70	5.38	9.29
Grand Mean		2988	38.93	55.49	15.10	82

Source of variation	Degrees of freedom	Protein content
Rep	1	.004
Nitrogen (N)	2	1.90*
Error(a)	2	.02
Seed rate (SR)	3	.86**
NxSR	6	.76**
Error(b)	9	.05
Total		
c.v.%		1.46
Grand mean		15.31

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 12. Observed mean squares for seed yield and seed quality factors of Hyslop and Yamhill wheat produced at Moro, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Nitrogen (N)	2	190576	9.49	1.31	.62	309
Seed rate (SR)	3	1909489	20.29	2.36	.57	174
NxSR	6	273810	1.24	.29	.58	16
Variety(Var)	1	106431	1032.87**	13.76**	326.05**	888**
NxVar	2	24004	2.01	.90	.29	25
SRxVar	3	272287	5.76**	.12	.33	4
NxSRxVar	6	130991	1.56	.53	.58	47
(Rep) Var	6	41469	2.31	.44	.59	57
(RepxN) Var, (RepxSR) Var, (RepxNxSR) Var (error)	62	140576	1.30	.32	.55	54
Total	95					

Source of variation	Degrees of freedom	Protein content
Nitrogen (N)	2	3.74
Seed rate (SR)	3	3.35
NxSR	6	.82
Variety(Var)	1	25.71**
NxVar	2	.36**
SRxVar	3	.73**
NxSRxVar	6	.25**
(Rep) Var	2	.002
(RepxN) Var, (RepxSR) Var, (RepxNxSR) Var (error)	22	.06
Total		

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 13. Observed mean squares for seed yield and seed quality factors for Hyslop wheat produced at Pendleton, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Rep	3	711074	3.43	.62	.52	529**
Nitrogen (N)	1	823532	85.02*	5.61*	.95	5
Error(a)	3	807271	5.69	.40	.42	10
Seed rate (SR)	3	6442034**	26.57**	.77	2.72**	87
NxSR	3	584696	7.57*	.63	.39	9
Error(b)	18	274625	1.79	.27	.41	110
Total	31					
c.v.%		7	3.34	.96	5.17	15
Grand mean		7200	40.09	53.85	12.39	70

Source of variation	Degrees of freedom	Protein content
Rep	1	0.03
Nitrogen (N)	1	23.26**
Error(a)	1	.0003063
Seed rate (SR)	3	.45*
NxSR	3	1.30**
Error(b)	6	.05
Total	15	
c.v.%		1.61
Grand Mean		13.91

*,**Significant differences and interactions at 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate
Rep x Nitrogen x Seed rate

Appendix Table 14. Observed mean squares for seed yield and seed quality factors for Yamhill wheat produced at Pendleton, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination	Source of variation	Degrees of freedom	Protein content
Rep	3	122523	5.96	.05	4.52**	8	Rep	1	.14
Nitrogen (N)	1	8383	25.63*	.02	2.21**	14	Nitrogen (N)	1	6.11
Error(a)	3	88011	1.45	.11	.02	27	Error(a)	1	.19
Seed rate (SR)	3	4119257**	7.30**	2.07**	1.49	116	Seed rate (SR)	3	.69*
NxSR	3	42991	1.91	.08	1.12	48	NxSR	3	.36
Error(b)	18	210626	.88	.15	1.02	45	Error(b)	6	.08
Total	31						Total	15	
c.v.%		6.78	2.12	.72	6.31	9.19	c.v.%		1.92
Grand Mean		6768	44.23	54.14	16.01	73	Grand Mean		14.76

*,**Significant differences at the 0.05 and 0.01 probability levels, respectively.

Error(a): Rep x Nitrogen

Error(b): {Rep x Seed rate
Rep x Nitrogen x Seed rate

Appendix Table 15. Observed mean squares for seed yield and seed quality factors of Hyslop and Yamhill wheat produced in Pendleton, 1975-76.

Source of variation	Degrees of freedom	Seed yield	1000-seed weight	Bushel weight	Seedling dry weight	Germination
Nitrogen (N)	1	499047	102.01	3.17	.13	17
Seed rate (SR)	3	10031789	27.53	.90	3.39	43
NxSR	3	303400	6.36	.48	1.15	43
Variety(Var)	1	2978351**	279.48**	1.40*	209.85**	200
NxVar	1	332868	8.64*	2.46**	3.03*	1
SRxVar	3	529502	6.34*	1.94**	.82	160
NxSRxVar	3	324286	3.13	.24	.36	13
(Rep)Var	6	416799	4.70	.33	2.52	268
(RepxN)Var						
(RepxSR)Var	error 42	271914	1.63	.22	.64	69
(RepxNxSR)Var						
Total	63					

Source of variation	Degrees of freedom	Protein content
Nitrogen (N)	1	26.61
Seed rate (SR)	3	.89
NxSR	3	1.05
Variety(Var)	1	5.83**
NxVar	1	2.76**
SRxVar	3	.25*
NxSRxVar	3	.62
(Rep)Var	2	.09
(RepxN)Var		
(RepxSR)Var	error 14	.07
(RepxNxSR)Var		
Total		

*,**Significant differences and interactions at the 0.05 and 0.01 probability levels.