RELATIONSHIP BETWEEN DATE OF PLANTING AND RATE AND METHOD OF FERTILIZER APPLICATIONS ON YIELD, TEST WEIGHT AND KERNEL SIZE OF HANNCHEN BARLEY

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Aldo Luis Norero

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APPROVED:

Redacted for Privacy

Associate Professor of Soils

In Charge of Major

Redacted for Privacy

Head of Department of Soils

Redacted for Privacy

Chairman of School Graduate Committee

Redacted for Privacy

Dean of Graduate School

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

RELATIONSHIP BETWEEN DATE OF PLANTING AND RATE AND METHOD OF FERTILIZER APPLICATIONS ON YIELD, TEST WEIGHT AND KERNEL SIZE OF HANNCHEN BARLEY

INTRODUCTION

The Willamette Valley is one of the principal barley growing areas in the Pacific Northwest. The barley acreage in the Willamette Valley has been relatively stable during recent years but the acreage in the Northwest has been expanding. One of the main causes of this increase is attributed to substitution of acreages alloted to wheat (22). Table 1 presents some statistics of barley production in Oregon (32).

Table 1

Barley statistics for Oregon. Acreages and production.

Willamette Valley Counties		State of Oregon	
1950-1954 average	1958	1950-1954 average	1958
total acreage			
143,780	153,300	335,600	585,000
production in 1000 bushel			
5,224	5,351	12,531	19,890

Barley is mostly grown for malting, seed and livestock feeding purposes. Maltsters use only the highest quality barley and premium prices are paid for it. Most of the malting barley produced in the

Northwest belongs to the two row type of which the Hannchen variety is the most important example.

The 1954 census showed that 581,180 acres were devoted to cereal crop production in the Willamette Valley with barley occupying 143,780 acres (38). Although these crops occupy an important place economically, the interactions between (a) methods of fertilizer applications, (b) rate of applications, and (c) time of planting on the yields of spring planted grain crops in the Willamette Valley have not been evaluated.

However, it has been observed that excessive rates of certain fertilizers elements have a detrimental effect on the malting quality of barley (3). Consequently, the net result of a fertilization program on yield and quality acquires a special significance when considering the most economical return from the production of malting barley.

The primary objectives of this study were to evaluate the influence of:

(a) time of planting, and

(b) rates of nitrogen and phosphorus fertilizers on the yield and quality of spring planted barley in the Willamette Valley.

Preliminary information was also sought on the early phosphorus uptake by plants as influenced by methods of applying phosphorus, sources of phosphorus fertilizers and of nitrogen associated with them. This information was considered particularly interesting in relation to growth of early seeded plants.

The increasing amount of yellow dwarf virus in the Willamette Valley during the past three years has aroused interest in the possibilities of early planting dates for spring grain crops. Observations made by staff members from the Plant Pathology, Entomology and Farm Crops Departments have indicated that the depression in yields from yellow dwarf virus infection are less severe when the barley is seeded early in the season[1/]. Chemical controls are not economically feasible at the present time and the varieties that do have genetic resistance to yellow dwarf virus are not suitable for malting. This means that early seeded spring barley with optimum fertilizer applications could offer the possibility for producing malting quality barley in the Willamette Valley with minimum damage from the yellow dwarf virus.

1/ Personal communication with staff members from these Departments.

LITERATURE REVIEW

Fertilization and Quality

Veblen (40) has summarized fertilizer trials on several barley varieties in various states in the Midwest and in the Willamette Valley. His own results in Western Oregon supported the generalized conclusion that nitrogen is the single element giving the most frequent responses and largest yields; phosphorus generally produces less marked effects but significant increases have often been obtained in combination with nitrogen. Responses to potassium have in general been rarely significant, and if so, yield increases have been relatively small (43).

Hill (21) and Foote and Batchelder (13) have pointed out the benefits derived from applications of nitrogen on yields of malting barley in the Willamette Valley. The latter, however, have called attention to the fact that responses to nitrogen by non-irrigated spring sown barley will be limited by the moisture regime during the growing season.

The assessment of the malting quality and the effects of fertilizers on the quality of barley have been reviewed and discussed elsewhere (40). It has been pointed out that as availability of nitrogen increases the following effects are usually noted: (a) the protein content in the grain increases, (b) the percent of thin kernels increases, (c) the total extractable material (starch) increases, (d) the number of plump kernels decreases, and (e) the test weight decreases. Lodging has been frequently observed associated with high nitrogen content (4). Phosphorus has on occasions been shown to minimize or counteract some of the undesirable effects of abundant nitrogen (25).

Methods of application of fertilizers

It has become fairly well established that under most conditions it is possible to increase the efficiency of fertilizers by proper placement methods. A large part of the experimental evidence indicates a superiority of band or localized placement over broadcast application of fertilizers.

Several investigators (45,42,31) have reported increased recovery of nitrogen and potassium fertilizers by small grains from localized placement as compared to broadcast applications. However, because recovery of nitrogen and potassium is usually higher (regardless of placement method) and banding of these fertilizers entails a greater danger of injury to seedlings than does phosphorus fertilizers, placement methods have been particularly emphasized for phosphorus.

Recent experimental results using radioactive phosphorus (28,35, 5 ,30) have given further support to earlier evidence (8 ,12,26) that crops usually obtain larger amounts of fertilizer phosphorus from localized placement than from broadcast applications. However, banding methods may not prove superior to broadcast methods for certain crops and under optimum conditions of soil moisture (20) and fertility (9).

Benefits derived from band placement of phosphorus has been attributed to reduced fixation, greater accesibility of applied phosphorus to plant roots and early growth stimulation (36). As a result, early developing plants may better withstand diseases and injurious insects. Duley (12) found greater tillering of small grains from drilled than from broadcast treatments. Also, results have been published (29) indicating a greater ability of wheat to compete with weeds when phosphorus was supplied in a band application than when it was broadcast.

Stanford and Pierre (36) have emphasized the fact that the results of fertilizer placements are very much dependent on other factors and interactions play a role in the benefit derived therefrom.

Effect of nitrogen on phosphorus uptake

Grunes prepared a comprehensive review and discussion on the effects that additions of nitrogen have on the uptake of soil and fertilizer phosphorus (17). Among the factors influencing this effect, placement of one nutrient relative to the other and forms of applied nitrogen received the most attention. A large part of the studies show ammonium nitrogen to be relatively more efficient in encouraging phosphorus uptake by plants than nitrate nitrogen (2, 6, 34). It has recently been pointed out that ammonium nitrogen tended to be more effective than nitrate nitrogen in increasing phosphorus uptake by corn growing in soil, but that the reverse was true for plants growing in sand-resin where no nitrification took place. An intimate association of nitrogen and phosphorus fertilizers has usually been found necessary to produce the most marked effects (17). Factors such as soil reaction (48), nature of the complementary ion (24) and temperature (11, 46) have been reported to also influence the effect of nitrogen on phosphorus uptake.

Dates of seeding

The advantages of early seeding of spring grains have been generally recognized by farmers and agronomists. Late seeding usually result in reduced yields and increased weather, weeds and disease hazards (47, 41, 44, 15). Wiggans (44) observed that the differences between sowing dates of spring oats were more marked in years of heavy stem rust and crown rust infestation. He also reported a consistent reduction in test weight and height of plants with postponement of seeding dates. Woodward (47) and Wahhab (41) have observed the trend of lower yields with later planting dates even under irrigation of spring grains.

PROCEDURE

Locations

The experiment was carried out at three locations that gave a range in fertility levels and soil drainage conditions. These locations were:

(a) Fuller farm (Polk Co.), on Melbourne soil series;

(b) Hyslop farm (Benton Co.), on Willamette soil series and

(c) East farm (Linn Co.), on Chehalis soil series.

Melbourne is an old residual soil derived from the weathering of sandstones and shales. The soil is characterized by a brown, moderately fine textured, moderately acid surface horizon, and a brownish yellow, somewhat dense subsoil. Drainage restrictions are moderate to severeon this soil. Agriculturally this soil is adapted to prune orchards, and general grain and forage crop production (37).

Willamette soil occurs on old valley filling and is derived from the weathering of old water laid deposits. The soil is characterized by a very dark brown, medium textured, moderately acid surface horizon, and a dark brown, moderately textured, firmer subsoil. Drainage is moderately good. The soil is particularly suited for small grains, fruits, clover, alfalfa and grasses. It is the soil on which cereals are most extensively cultivated in the Willamette Valley (7).

Chehalis is a soil derived from recent alluvium along the present floodplains in the Willamette Valley. It lacks distinct textural B horizon and it is less acid, less fine textured and more friable, permeable and of better tilth than the Willamette soil. Chehalis soil has excellent drainage. It is one of the most intensively cultivated soils of the Willamette Valley. Small fruits, orchards and vegetables are some of the most important crops produced (23).

Chehalis and Willamette soils are highly productive soils for cereals; the former ranking somewhat higher than the latter. Melbourne soil is judged to be of much lower productivity (33).

Chemical analysis were made by the Oregon State College Soil Testing Laboratory (1) of composite samples taken from each replication a week before the beginning of the experiment. The results are presented in Table 2.

The experimental site at the East farm was planted to Ladino clover in 1957 and 1958; it was fallow during 1959.

The experimental site at the Hyslop farm was planted to fall seeded rye during 1959; previously it had grown alta fescue for seed production for several years.

The experimental site at the Fuller farm has been used in the production of cereal crops for a number of years.

Table 2

Chemical analysis of soils from the experimental sites

Location	Rep.	Soil reaction pH	Tons/acre Lime Req't	p.p.m. phosphorus	Milliequivalents per 100 gr. potassium	calcium	magnesium
East	I	6.3	1	12.5	0.59	9.20	4.15
farm	II	6.2	1	12.5	0.42	9.50	5.05
	III	6.2	1	12.5	0.50	8.90	5.20
Hyslop	I	5.6	2	23.0	0.34	5.60	1.30
farm	II	5.5	2	23.5	0.38	5.20	1.30
	III	5.6	2 1/2	22.0	0.44	6.00	1.45
Fuller	I	5.7	2	6.5	0.23	6.00	2.25
farm	II	5.6	2	7.0	0.25	6.20	2.35
	III	5.7	2 1/2	6.5	0.23	7.10	2.40

Experimental design

The experiment was laid out as a split-plot design in which three consecutive planting dates represented the main plots and the fertility treatments represented the subplots. There were three replications.

The size of each subplot was 6 by 30 feet. Eight rows of Hannchen barley, seven inches apart, were sown per subplot and two guard rows were seeded between subplots. Spaces four feet wide were left and seeded between the main plots and replications.

Treatments

Dates of planting. At the East farm, seeding was made April 5, April 25 and May 10.

At the Hyslop farm seeding was made April 1, April 30 and May 10.

At the Fuller farm seeding was made April 8 and June 4.

Restricted soil drainage and somewhat heavier precipitation did not permit the establishment of an intermediate seeding date at the Fuller location.

Fertilizer treatments. A set of fifteen fertilizer treatments was tested at each location and planting date. These are considered the main treatments of the experiment. In addition and for preliminary comparisons five extra treatments were included in the early planting date.

Table 3 lists the main fertilizer treatments which were designed to test the effects of rates, combinations and method of placement of fertilizers.

Table 3

Fertilizer treatments applied at three planting dates and at the three locations

Treatments[a]	method of application	rates of application
S		
N_1 S		
P_1 S	S broadcast	
N_1 P_1 S	N_1 banded;	
N_1 P_2 S	additional	S 40 lbs S/A
N_2 S	N broadcast	
N_2 P_1 S	P banded	N_1 40 lbs N/A
N_2 P_2 S		N_2 80 lbs N/A
N_2 P_2		N_3 120 lbs N/A
N_3 P_2 S		
P_1 S	S broadcast	P_1 30 lbs P_2O_5/A
N_1 P_1 S	N_1 banded;	P_2 60 lbs P_2O_5/A
N_1 P_2 S	additional	
N_2 P_1 S	N broadcast	
N_2 P_2 S	P broadcast	

a. S = gypsum, N = ammonium nitrate, and P = concentrated superphosphate.

Table 4 presents the explanation of five additional treatments which were included only in the first planting date and were designed to test other sources of fertilizer phosphorus and of potassium additions.

Table 4

Additional fertilizer treatments applied at the first planting date only

Treatments	Methods of application	Rates of application
N_1 P_1 S^a	P banded	S 40 lbs S/A
N_1 P_1	S broadcast	N_1 40 lbs N/A
N_1 P_2 S^a	N_1 banded; additional N broadcast	N_2 80 lbs N/A
N_2 P_1 S^a		P_1 30 lbs P_2O_5/A
		P_2 60 lbs P_2O_5/A
N_2 P_2 S K^b	K banded	K^2 60 lbs K_2O/A

a. S as gypsum. N and P as ammonium phosphate plus additional N as $NH4_2SO_4$; in N_1P_1, NH_4NO_3 instead of $NH4_2SO_4$.

b. S = gypsum; N = $NH4NO_3$; P = conc. super.; K = KCl.

Field operations

Nitrogen and phosphorus fertilizers were applied with an experimental plot seed drill equipped with a belt-fed distributor. For banded treatments the fertilizer drills were lowered so as to deposit the fertilizer in a continuous band slightly below and beside the seed. For broadcast treatments the fertilizer drills were raised so as to sprinkle the fertilizer on the soil; chains and a harrow dragging behind subsequently stirred the fertilizer into the soil. Predetermined rates of nitrogen and phosphorus were spread and mixed on the belt to ensure even distribution. Gypsum was broadcast by hand prior to planting.

Rate of seeding was 90 lbs. per acre. A Planet Junior seeder was used to sow the guard rows between subplots.

Before harvesting, three feet lengths at each end of the subplots were clipped and discarded at Hyslop and Fuller farms. Because growth and straw production were much greater at the East farm, an additional three feet length was clipped at one end of the subplots. The central six rows of the remaining plants were cut with an experimental plot harvester and later mechanically thrashed and cleaned. No irrigation was applied during the experiment.

Measurements taken

Grain yields were weighed and converted to pounds per acre.

Quality estimations were based on test weight (lbs. per bushel) and the percentage of thin kernels (thins) that would pass through a $\frac{5\ 1/2}{64}$ by $\frac{3}{4}$ inch screen.

Phosphorus content was determined in plants at their five to six leaf stage of development. Leaf samples were collected by compositing random pickings throughout the subplots. The samples were quickly dried at 60° - 70° C and later ground and stored in tightly closed boxes. The analysis was performed according to the procedure in use at the Soil Fertility-Chemistry Laboratory Oregon State College (19).

FIELD OBSERVATIONS

Satisfactory stands of barley were obtained at the Hyslop farm and at the East farm on all planting dates. At the Fuller farm poor soil drainage and ponding of rainwater soon after emergence caused considerable loss in the early seeded plots. The condition of these plots was further aggravated by the invasion of ryegrass and other weeds.

Greater vegetative growth was clearly manifested in the early seeded barley at all locations. Plants of the early seeded plots attained a final height nearly double that of plants of plots seeded later. The East farm location produced the tallest barley of all three places. Associated with this, lodging occurred more frequently on the East farm than on the Hyslop farm and it took place predominantly among the earliest seeded plots. An account of observations on lodging is presented in Table 5.

At the Hyslop location a clear and early effect from nitrogen applications was manifested by a comparatively greener color and faster development of seedlings. This effect was more apparent in the earliest seeded plots. Observations on phosphorus, sulfur or potassium effects were contradictory and inconsistent among various observers.

At the East farm location all seedlings appeared remarkably uniform in vigor and color, irrespective of fertilizer treatment. As a whole, they developed somewhat faster than comparable stands at Hyslop farm.

Table 5

Intensity and frequency of lodging at harvest time

Time of seeding	Causative treatments	East farm Replications I	II	III	Hyslop farm Replications I	II	III
Early	N_3 P_2 S	**	**	--	--	**	--
	N_2 P_2 S K	**	**	--	--	--	--
	N_2 P_2 S	*	*	--	--	--	--
	N_2 P_2	**	--	--	--	*	--
	N_2 P_1 S	*	*	--	--	--	--
Middle	N_3 P_2 S	*	*	--	--	--	--
	N_2 P_2 S	--	*	--	--	--	--
	N_2 P_2	--	*	--	--	--	--
	N_2 P_1 S	--	--	*	--	--	--
Late	none	--	--	--	--	--	--

* severe lodging interferred with harvest in parts of the plots.

** severe lodging interferred with harvest in the entire plot.

-- absent.

P banded phosphorus.

Yellow dwarf virus, so increasingly prominent in previous years (10), failed to appear during the 1960 season. Isolated symptoms of the disease were observed on a few isolated plants in the plots of the Hyslop farm. On the East farm site they were practically absent. Counts on aphid population were begun but were later interrupted because these insects became extremely scarce.[1] It was contemporarily noticed that ladybird beetles were comparatively more abundant than in past years. A widespread occurrence of powdery mildew was observed at Hyslop on all plants of the latest date of seeding. At the Fuller farm, most of the early seeded plots yielded grain that was stained with black mold. The excessive rain during April and May probably contributed to the development of the mold.

1/ Aphid counts were made by Dr. E. A. Dickason, Entomology Department O.S.C.

RESULTS AND DISCUSSION

The results of the main fertilizer treatments and of seeding dates on grain yields, test weight, percentage of thin kernels and phosphorus content of seedlings are presented in Tables 7, 8, 9 and 10. Poor stands on the early seeded plots at the Fuller farm as a consequence of poor drainage, ponding of water and weeds have limited the information obtained from this location. Results involving the use of "11-48" ammonium phosphate and potassium fertilizers are shown separately to facilitate discussion and presentation. The details of statistical analysis have been omitted for the sake of brevity, but conclusions pertaining to the existance or absence of significance in differences tested are presented in Table 6.

Fertilizer treatments

East farm. The small increases in yield from application of nitrogen were not significant at this location. The reduction in yields observed when all plots receiving 80 lbs. of nitrogen per acre were compared with all plot receiving 40 lbs. of nitrogen per acre was statistically significant. Increasing nitrogen rates also reduced test weights. A tendency was likewise noticed for percent thins to increase, but no statistical significance was attached to this. Nitrogen interactions that proved significant are shown in Table 6. Severe lodging was associated with high nitrogen rates and appeared accentuated at the early seeded date when presumably soil moisture was under lower tensions.

Table 6

Levels of significance that were found for differences caused by specified factors on grain yields, test weights, percent thin kernels and phosphorus content of seedlings of Hannchen barley grown at the East and Hyslop farms

Factors studied	Grain yield		Test weights		Thin kernels		Phosphorus %	
	East	Hyslop	East	Hyslop	East	Hyslop	East	Hyslop
Planting dates (D)	**	**	**	**	**	**	**	**
Nitrogen rates (N)	*	**	*	**	--	**	--	--
Phosphorus rates (Pr)	--	**	--	--	--	--	**	**
Placement method (Pm)	--	**	--	--	--	--	**	--
D X N	--	--	--	*	--	**	--	--
D X Pm	--	*	--	--	--	--	**	**
D X Pr	--	--	--	--	--	--	--	--
N X Pm	--	--	--	--	--	--	--	**
N X Pr	--	--	*	--	*	*	--	--
Pm X Pr	--	*	--	*	--	--	**	--
D X N X Pm	--	**	--	**	*	**	**	**
D X N X Pr	--	**	*	**	**	**	--	--
N X Pm X Pr	--	**	*	*	*	*	*	--
D X Pm X Pr	--	**	*	**	*	*	**	**

* differences found significant at the 5% level.
** differences found significant at the 1% level.

Table 7

Effects of rates, combinations and methods of placement of fertilizers on grain yields of Hannchen barley planted at three different times at three locations

Fertilizer treatments[a]	Planting dates						
	East farm			Hyslop farm			Fuller farm
	4/5	4/25	5/10	4/1	4/30	5/10	6/4
	Yields in lbs. per acre						
S (Check)	4270	3730	3180	1600	1480	930	1380
P_1 S	4410	3630	3270	1720	1650	1030	1190
N_1 S	4680	3320	3180	2770	1960	1140	1330
N_1 P_1 S	4460	3700	3520	2800	2060	1190	1210
N_1 P_2 S	4470	3910	3050	2840	2330	1570	1320
N_2 S	4170	3330	3290	3170	2120	1130	1270
N_2 P_1 S	3890	3620	2050	2810	2360	1480	1170
N_2 P_2 S	4000	3820	3140	3290	2310	1620	1270
N_3 P_2 S	3690	3010	2890	2670	2070	1610	1440
P_1* S	4290	3460	2070	1650	1490	1010	1210
N_1 P_1* S	4420	3460	2990	2830	1920	1360	1190
N_1 P_2* S	4100	3540	3310	2750	2020	1220	930
N_2 P_1* S	4250	3170	3350	3020	1980	1270	1080
N_2 P_2* S	3710	3100	2960	3210	2090	1350	1320

a. P = banded phosphorus
P* = broadcast phosphorus

Table 8

Effects of rate, combination and method of placement of fertilizers on test weights of Hannchen barley planted at three different dates at three locations

Fertilizer treatments[a]	Planting dates							
	East farm			Hyslop farm			Fuller farm	
	4/5	4/25	5/10	4/1	4/30	5/10	4/8	6/4
	test weight in lbs./bu.							
S (Check)	52.8	51.7	49.8	54.3	52.2	51.4	48.2	48.6
P_1 S	52.9	52.6	50.0	54.0	52.1	52.4	48.5	49.1
N_1 S	52.5	50.4	40.1	53.4	50.8	51.2	46.7	46.6
N_1 P_1 S	52.7	50.0	49.7	54.2	51.3	51.1	49.4	47.4
N_1 P_2 S	51.9	51.6	49.2	53.9	51.2	50.0	46.1	47.5
N_2 S	51.6	50.0	48.9	52.7	50.5	50.5	47.0	47.3
N_2 P_1 S	51.0	50.3	40.9	52.7	50.1	50.7	47.3	46.4
N_2 P_2 S	51.3	50.1	48.8	52.7	49.9	50.6	47.8	47.7
N_3 P_2 S	50.4	49.3	48.2	51.6	49.4	49.9	49.5	47.2
P_1* S	52.5	51.9	50.2	54.0	51.9	51.6	49.1	49.4
N_1 P_1* S	51.3	50.6	49.7	53.5	51.0	50.9	46.7	47.1
N_1 P_2* S	52.6	50.9	49.8	54.0	51.3	51.0	46.9	47.5
N_2 P_2*S	51.8	50.4	49.9	52.7	50.0	50.2	49.0	47.4
N_2 P_2*S	51.6	49.3	49.6	52.9	50.2	50.6	50.0	47.6

a. P = banded phosphorus
P* = broadcast phosphorus

Table 9

Effects of rate, combination and method of placement of fertilizers on percent thin kernels of Hannchen barley planted at three different dates at three locations

Fertilizer treatments[a]	Planting dates							
	East farm			Hyslop farm			Fuller farm	
	4/5	4/25	5/10	4/1	4/30	5/10	4/8	6/4
	percent of thin kernels							
S (Check)	2	3	6	2	3	5	3	6
P_1 S	1	4	9	3	4	5	3	4
N_1 S	3	6	7	2	8	6	4	9
N_1 P_1 S	3	8	9	3	5	7	3	7
N_2 P_2 S	3	4	10	2	7	8	2	7
N_2 S	3	9	9	4	11	6	4	10
N_2 P_1 S	6	5	8	5	11	7	3	9
N_2 P_2 S	6	8	11	5	9	7	3	10
N_3 P_2 S	8	13	16	10	13	10	4	7
P_1* S	3	3	8	2	4	4	4	6
N_1 P_1* S	3	7	9	2	7	5	4	6
N_1 P_2* S	2	5	9	2	7	6	3	8
N_2 P_1* S	3	6	8	4	10	7	4	8
N_2 P_2* S	3	10	8	3	9	7	3	7

a. P = banded phosphorus
P* = broadcast phosphorus

Table 10

Effects of rate, combination and method of placement of fertilizers on phosphorus content of seedlings (5 leaf stage) of Hannchen barley planted at three different dates and at three locations.

Fertilizer treatments[a]	Planting dates							
	East farm			Hyslop farm			Fuller farm	
	4/5	4/25	5/10	4/1	4/30	5/10	4/8	6/4
	percent phosphorus							
S (Check)	.38	.28	.26	.31	.33	.38	.30	.38
P_1 S	.43	.30	.29	.38	.34	.36	.31	.36
N_1 S	.37	.27	.24	.32	.29	.33	.28	.39
N_1 P_1 S	.42	.32	.28	.35	.31	.33	.28	.37
N_1 P_2 S	.48	.36	.30	.36	.33	.33	.28	.39
N_2 S	.36	.26	.25	.32	.30	.35	.28	.35
N_2 P_1 S	.43	.30	.26	.36	.32	.33	.29	.36
N_2 P_2 S	.46	.39	.27	.38	.35	.33	.28	.38
N_3 P_2 S	.45	.38	.31	.36	.36	.30	.28	.39
P_1* S	.41	.27	.27	.35	.34	.36	.29	.37
N_1 P_1* S	.36	.31	.25	.33	.31	.34	.28	.37
N_1 P_2* S	.39	.31	.27	.38	.32	.36	.27	.35
N_2 P_1* S	.36	.29	.26	.34	.30	.33	.30	.39
N_2 P_2* S	.39	.32	.26	.34	.32	.36	.29	.38

a. P = banded
P* = broadcast phosphorus

Neither yields, test weights nor percent thins were significantly altered by rates or methods of applying phosphorus. It may be interesting to note that all cases of lodging (Table 5) were associated with higher rates of nitrogen and with banded phosphorus.

No lodging was observed for the same high rates of nitrogen in the absence of phosphorus or with broadcast phosphorus. This was interpreted as meaning that more vigorous growth was associated with those treatments receiving nitrogen and banded phosphorus. The presence of fertilizer nitrogen did not result in any detectable stimulation of phosphorus uptake by seedlings. It is possible that a high level of indegenous nitrogen in the soil may have masked any effect that fertilizer nitrogen may have induced. If such stimulative effect did occur (either due to the soil and/or fertilizer nitrogen) it could explain the comparatively greater uptake of phosphorus by seedlings at the East farm (first seeding date) than at the Hyslop farm despite the fact that soil phosphorus was at lower levels at the East farm (Table 2). Early planted seedlings took up more phosphorus when the fertilizer was banded than when broadcast. However, so far as this location was concerned this finding was irrelevant; phosphorus was not found to be a limiting factor in the soil and it proved to have no effect on the quality of the grain.

Hyslop farm. At this location increases in yields due to nitrogen were highly significant (Table 7). This effect reached its maximum at the 80 pounds per acre rate. Application of 120 pounds of nitrogen per acre always depressed yields and it was associated with lodging. In agreement with early field observations increases due to nitrogen were more marked in the early seeded plants than in plants of later seeding dates. These responses to nitrogen were accompanied by a decrease in test weight and an increase in percent thins (Tables 8, 9).

Phosphorus alone failed to appreciably increase yields (Table 7). However, in combination with nitrogen a response was noted. Rates of 60 pounds per acre were superior to 30 pounds per acre. This effect was more marked when phosphorus was banded and in the late seeded plots. No influence of phosphorus rates or placement methods was detected on test weight or percent thins (Tables 8, 9). Banding phosphorus resulted in greater uptake of this nutrient by seedlings at the first planting date only. For the early plants the average phosphorus content of all banded treatments was 0.36 percent, while the average of all broadcast treatments was 0.34 percent. For the late seeded plants all banded treatments averaged 0.33 percent whereas all broadcast treatments averaged 0.34 percent of phosphorus. At this location, a stimulative effect of nitrogen additions on phosphorus uptake by plants was observed when the fertilizer was banded. This effect was more pronounced in plants of the earliest seeding date. Active nitrification has been reported associated with the stimulative effect of ammonium salts on phosphorus uptake (11). It is possible that moisture conditions were more favorable for nitrification at the early planting dates.

Fuller farm. At this location, the results of the late seeding date indicated no influence of nitrogen additions or phosphorus rates and placement methods on yields, test weight or percent thin kernels (Tables 7, 8, 9). Yields and test weight were uniformly low; thin kernel percentages tended to increase as nitrogen rates were increased, but this tendency did not cause significant differences.

Comments on results of fertilizer treatments: The soil on which these experiments were carried out differed appreciably in productivity capacity. Yields were highest at the East farm (Chehalis soil), medium at the Hyslop farm (Willamette soil) and lowest at the Fuller farm (Melbourne soil). Lowest quality of grains was also obtained at the latter location. The soils of the Hyslop and East farms produced grain of the same quality.

On the East farm barley grew on a deep, friable, slightly acid soil of excellent drainage. In addition, previous legume growth and a fallow period preceding this years' crop probably left a comparatively higher level of available nitrogen. It is not surprising then, that at this location the average production of grain was much higher, responses of yield and quality to fertilization were less marked and less affected by placement methods or time of planting than at the Hyslop location. On the Hyslop farm barley grew on a more compact, more acid soil with only moderately good drainage. Also, previous cereal crops may have lowered the level of available nitrogen.

The soil at the Fuller farm had a much lower fertility level and a less favorable physical condition. However, no response to kinds, rate, combination or placement of fertilizer was obtained. Instead, check plots tended to produce higher yields. But in this case, planting could not be made until quite late in the season (June). There was practically no rainfall at any stage of the growing period; moisture must presumably have become the most severe limiting factor.

Effects of planting dates

At the East farm, delay of seeding resulted in progressive decreases in yields, test weights and in increases of percent thins.

At the Hyslop location, similar, but more marked results than at the East farm, were obtained. The earliest seeded barley yielded twice the amounts produced by the latest seeded barley. Highest values for test weights were found for the earliest planting date, while values for the middle and late planting dates were practically equal. Postponement of seeding resulted in progressive increases in the percentages of thin kernels.

No logically valid comparisons between planting dates are possible at the Fuller farm because of the irregular losses suffered by the early seeded plots.

Comments on effects of planting dates: It is apparent that the most outstanding results of the experiment were those pertaining to the effects of seeding dates. This can readily be observed when the fertilizer effects are averaged out, as in Table 11.

Table 11

Effects of dates of seeding on grain yields, test weight, percent thins and in the phosphorus content of seedlings at the three experimental sites.

Measurements taken	Planting dates							
	East farm			Hyslop farm			Fuller farm	
	4/5	4/25	5/10	4/1	4/30	5/10	4/8	6/4
Grain yields (lbs/A)	4138	3476	3153	2679	1997	1286	--	1218
Test weight (lbs/bu)	51.8	50.6	49.5	53.5	50.8	50.8	47.9	47.5
Thin kernels (%)	3.8	6.4	9.3	3.6	7.7	6.4	3.1	7.3
Phosphorus of seedlings (%)	.413	.317	.271	.349	.325	.346	.286	.374

Table 12 illustrates the main features by which the 1960 growing season differed from the "normal" growing season. Normal values for temperatures and rainfall are averages for the 1925-1954 series of records (39).

Table 12

Comparison between temperatures and precipitation averages for the normal and the 1960 growing seasons

Climatic factor	Months			
	April	May	June	July
Average temperatures (degrees F)				
Normal season[a]	52.4	57.5	62.1	67.1
1960 season	50.4	54.3	63.0	67.9
Average precipitation (inches)				
Normal season[a]	2.3	2.0	1.5	0.3
1960 season	3.3	4.2	0.3	0.0

a. Normal season is average of 30 years.

Total precipitation for April, May, June and July was practically the same for the 1960 as for the normal season, but the distribution was markedly different. Abnormally higher rainfalls occurred in April and May while practically none was recorded during June or July. Associated with this, average temperatures in 1960 were cooler than normal during April and May and warmer than normal during June and July.

The result of these circumstances was that plants sown late in the season grew in a drier, brighter and warmer envirnment (i.e., under higher evapo-transpiration conditions) than plants sown earlier in the season. Figure 1 illustrates some of the environmental conditions under which the experiment developed and the relationships of these with the final results.

Vegetative growth became less vigorous, cases of lodging gradually disappeared (Table 5), yields and test weights decreased and the

Fig I. CLIMATOLOGICAL DATA IN RELATION TO GROWTH, YIELD, TEST WEIGHT AND THIN KERNELS OF HANNCHEN BARLEY

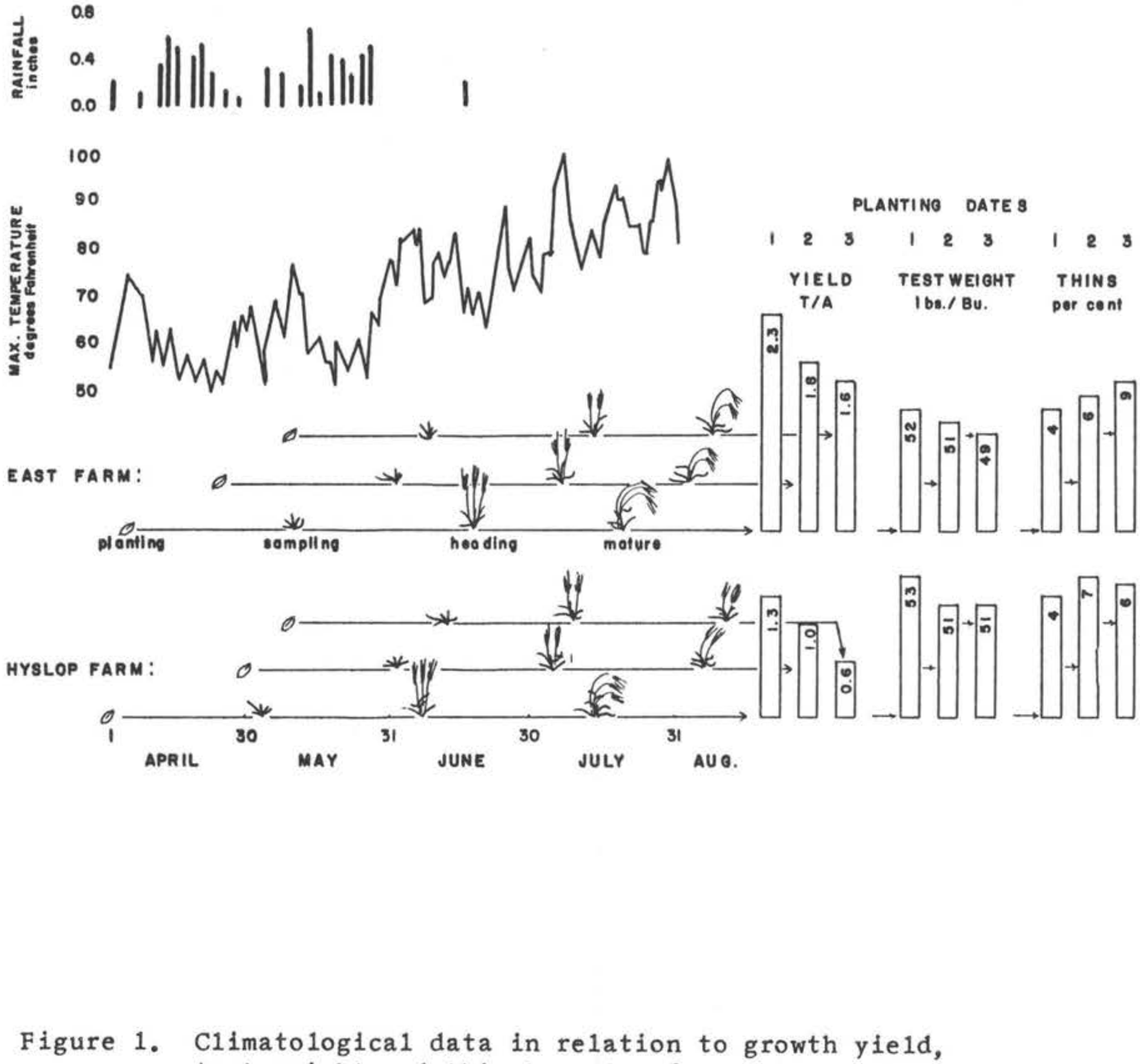

Figure 1. Climatological data in relation to growth yield, test weight and thin kernels of Hannchen barley.

number of defective grains increased as seeding was postponed (Table 11). These consequences could be attributed chiefly to higher soil moisture tensions as the season advanced. Fertilizer effects became less marked in late planting dates; this could also have been a manifestation of soil moisture becoming an increasingly important limiting factor to plant growth.

The extent to which planting dates affected the final results varied with locations. Since similar environmental conditions prevailed over the East and Hyslop farms these differences appear to be a function of differences in soil properties. On delayed seeding, growth and yields were reduced to a greater extent at the Hyslop farm where, as an average, plants of the latest seeding date produced less than half the amounts yielded by plants of the earliest seeding date. At the East farm, on the other hand, late seeded plots were still able to produce 3/4 of the quantities yielded by the early seeded plots. Better physical conditions and higher fertility levels may have permitted a more efficient use of the available moisture by plants growing on the East farm soil.

The influence that planting dates had on fertilizer effects could be better observed at the Hyslop location since responses to fertilization were more marked than at the East farm. Responses of barley to applications of nitrogen and phosphorus were greater at the earliest seeding date. These plants produced 75-100 % increases over the check plots, as compared to 25-50 % increases obtained by plants similarly fertilized but seeded later. Higher availability of soil moisture for plants of the early seeded plots was probably the cause of that difference. Progressive decreases in phosphorus content of seedlings were found at the East farm with postponement of planting (Table 10). Since it has been shown that phosphorus uptake is greater as soil moisture increases (27), the above finding would indicate that plants of the late seeding date suffered greater moisture stresses. At the Fuller farm, seedlings of the first planting date contained much less phosphorus than those of the late planting date (Table 10). However, at this location seedlings underwent a period of waterlogging conditions; poor aeration and cool temperatures could have slowed down phosphorus uptake by early seeded barley.

Under normal seasonal conditions the results of this experiment would have possibly shown less differences between extreme planting dates and a more marked effect of fertilization on late seeded plots in the less fertile soils. Although moisture regime may have played a decisive role in the differences observed between planting dates, other factors have undoubtedly intervened. As mentioned in the Literature Review, differences caused by planting at different times similar to the ones obtained in this experiment have been reported to occur under irrigation (47,41).

Additional comparisons

Sulfur and potassium effects. Statements concerning these nutrients are based on comparisons of treatments shown in Table 13.

Table 13

Effects of sulfur and potassium applications on grain yields, test weights and percentage of thin kernels (averages of three replications)

Fertilizer treatments	Planting dates: East farm 4/5	East farm 4/25	East farm 5/10	Hyslop farm 4/1	Hyslop farm 4/30	Hyslop farm 5/10	Fuller farm 4/8	Fuller farm 6/4
				grain yields (lbs./A)				
N_2P_2	3290	3341	3258	3067	2147	1384	--	1254
N_2P_2 S	4002	3822	3139	3293	2307	1624	--	1270
N_2P_2 S K	3693	--	--	3252	--	--	--	--
				test weights (lbs./bu.)				
N_2 P_2	50.4	50.7	49.5	52.7	50.7	50.9	47.6	47.1
N_2 P_2 S	51.3	50.1	48.8	52.7	49.9	40.6	47.8	47.7
N_2 P_2 S K	51.2	--	--	53.6	--	--	49.5	--
				thin kernels (%)				
N_2 P_2	9	6	13	5	7	8	3	6
N_2 P_2 S	6	8	11	5	9	8	3	10
N_2 P_2 S K	6	-	-	3	-	-	2	-

At the Hyslop location omission of sulfur always resulted in lower yields, but no statistical significance was attached to the differences. The same was true at the Fuller location and in the first two planting dates at the East farm, although again no statistical significance was found in the differences. However, because of the fact that localized places in the Willamette Valley have been reported deficient in sulfur (14), the above trend may be an indication of the advisability of adding this nutrient if it is not supplied as a component of other fertilizers. No effect of sulfur on test weight or percent thin kernels was detected at any location or planting time.

On both the Hyslop and East farms, application of potassium did not cause statistically significant differences in yields or test weights. Both soils contained a good supply of exchangeable potassium at the start of the experiment (Table 2). Also, it has been found that Willamette soil releases relatively high quantities of both "readily" and "slowly" available potassium (16). The reduction noted on yields following potassium applications at the East farm was associated with severe lodging on these plots (Table 5). Potassium showed no effect on percent thin kernels at the East farm, but significantly reduced the percent of thins at the Hyslop farm.

Information from potassium applications would have been of particular interest in connection with the Fuller location. This soil (Melbourne) gave lower values for exchangeable potassium (Table 2) and has been found to release potassium at a slower rate than the Willamette soil (16). Unfortunately, it was not possible to logically compare the appropriate treatments due to the complicating consequences of poor drainage.

Ammonium phosphate vs. concentrated superphosphate. Table 14 lists the results of comparable pairs of treatments. In each pair, one member provided the fertilizer elements as "11-48" ammonium phosphate plus sufficient $NH4_2SO_4$ to have rates of nitrogen and phosphorus equal to those provided by combining the simple fertilizer materials.

Table 14

Comparisons between "11-48" ammonium phosphate and single fertilizer combinations (first planting date only)

Treatments[a]	grain yield lbs./A		test weight lbs./bu.			thin kernels percent		
	East	Hyslop	East	Hyslop	Fuller	East	Hyslop	Fuller
N_1 P_1* S	4494	2602	52.5	53.6	47.4	2	2	3
N_1 P_1 S	4457	2795	52.7	54.2	49.4	3	3	6
N_1 P_2* S	4507	2607	51.7	54.0	46.8	2	2	2
N_1 P_2 S	4465	2839	51.9	53.9	46.1	3	2	4
N_2 P_1* S	4349	3157	51.4	53.1	48.8	3	4	2
N_2 P_2 S	3888	2806	51.0	52.7	47.3	6	5	5

a. P* = "11-48" ammonium phosphate
P = single fertilizer combinations

In most cases "11-48" treatments were practically equal or slightly more beneficial in their effects on yields, test weights or thin kernels than the combination of superphosphate and ammonium nitrate fertilizers. The differences were not statistically significant. For all practical purposes it can be concluded that ammonium phosphates and concentrated superphosphates are equally good sources of phosphorus.

SUMMARY AND CONCLUSIONS

The effects of rates, combinations and method of placement of fertilizers on yield and quality of grain and phosphorus uptake by seedlings of Hannchen barley were studied at three planting dates at three locations in the Willamette Valley, Oregon. Each location represented a soil of different fertility level and drainage, exemplifying some of the conditions under which Hannchen barley is grown in the Willamette Valley. These locations were:

East farm, with a soil of high productivity and excellent drainage;

Hyslop farm, with a soil of medium productivity and moderate drainage;

Fuller farm, with a soil of low productivity and restricted drainage.

The first planting was made during the first week of April; the second planting was made during the last week of April; the last planting was made the second week of May (East and Hyslop farms) and during the first week of June (Fuller farm).

Plants of early seeded plots at the East and Hyslop farms benefitted from rainfall in April (± 3.0 in.) and May (± 4.0 in.) but heavier precipitation and lower soil permeability at Fuller farm resulted in waterlogging of early seeded plots.

Plants from early seeding had completed the main parts of their vegetative growth before the driest period of summer set in. Plants of the middle and late seedings were overtaken by the dry months of the season at an early stage of development, before "heading" was complete.

The results obtained from the experiment have led to the following conclusions:

1. Planting early in the season resulted in greater yields, in higher test weights and in lower percentages of thin kernels.

2. At the East farm, fertilizer treatments had little effect on grain yields.

3. At the Hyslop farm, nitrogen and nitrogen in combination with phosphorus increased yields. Rates of 80 lbs. of nitrogen per acre and of 60 lbs. of phosphorus per acre produced the best responses.

4. At the Fuller farm, severe moisture deficiency probably impeded the manifestation of effects due to fertilizers.

5. Application of nitrogen resulted in lower test weights and in higher percentages of thin kernels.

6. Application of phosphorus did not influence test weights or percent thins nor did it counteract the above mentioned effects when combined with nitrogen.

7. Seedlings at their five leaf stage of growth contained more phosphorus when the fertilizer was banded than when it was broadcast only in the plots seeded early in the season.

8. Application of nitrogen at the Hyslop location resulted in greater phosphorus content of seedlings only when the fertilizer was banded and mainly in the early planted plots.

9. Sulfur and potassium applications did not cause any important yield effects.

10. Results were practically the same whether phosphorus was supplied as concentrated superphosphate or as "11-48" ammonium phosphate.

It should be emphasized that a different seasonal distribution of rainfall and temperature would undoubtedly alter the expression of the treatment effects evaluated in this study. The effects of different dates of planting and the interactions between planting dates, nitrogen rates and phosphorus application should be evaluated over a period of years so that the seasonal effects could be recognized.

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