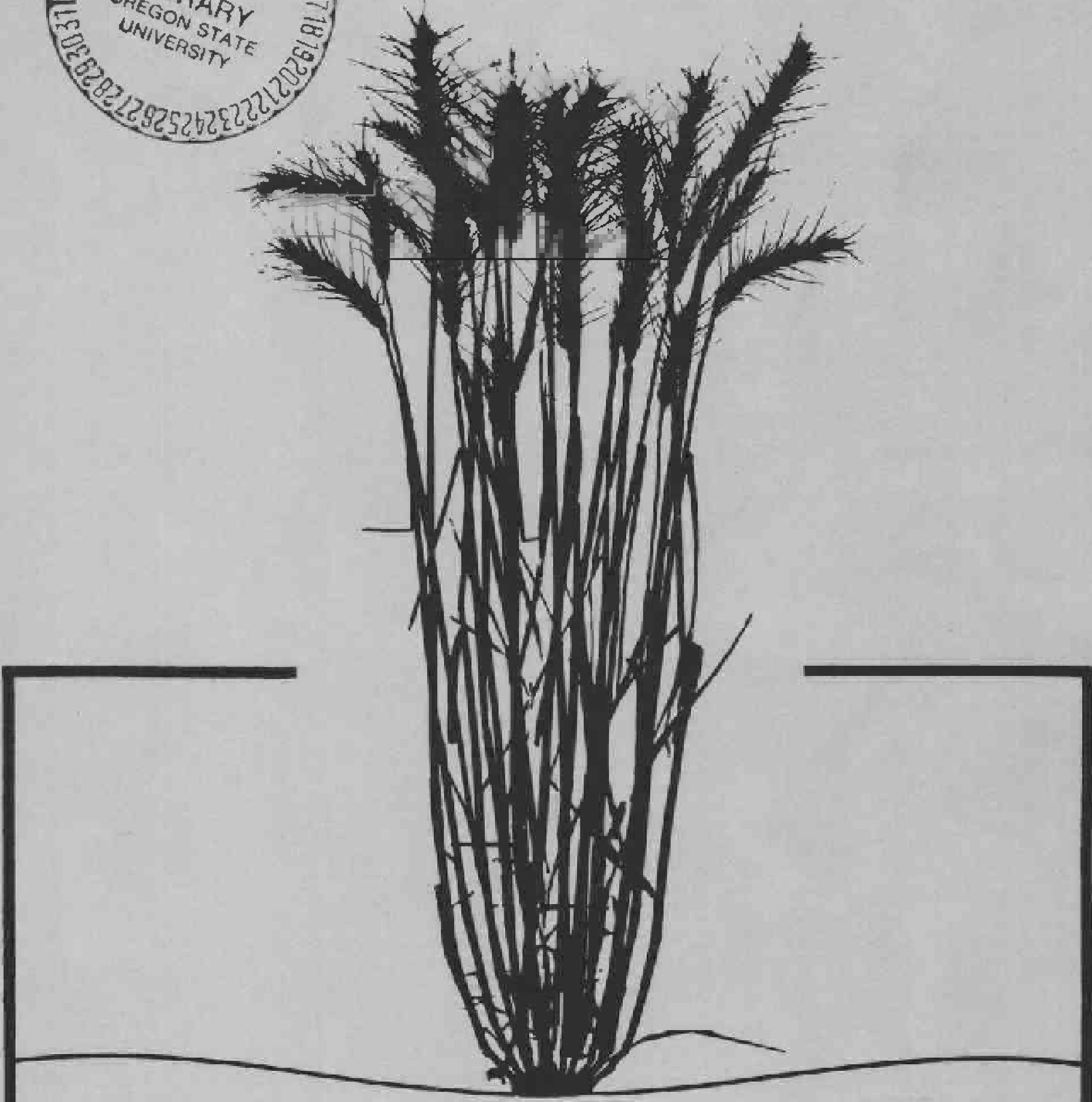


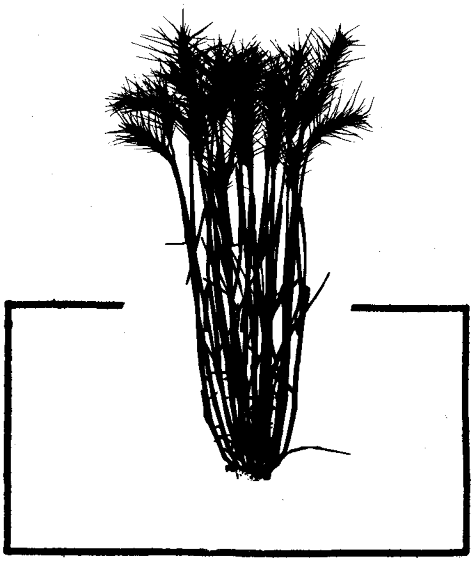
COLUMBIA BASIN AGRICULTURAL RESEARCH

ecial Report 661
June, 1982

Agricultural Experiment Station • Oregon State University
in cooperation with Agricultural Research Service USDA

COLUMBIA BASIN AGRICULTURAL RESEARCH

SPECIAL REPORT 661, JUNE 1982



EDITORIAL COMMITTEE

Dale E. Wilkins, chairman
Ron W. Rickman
Don J. Rydrych

Acknowledgement is made to Carol Brehaut, for typing and to Gordon Fischbacher, for graphic preparation.

CONTENTS

DESCRIPTION OF NEW CEREAL VARIETIES

Charles R. Rohde[1]

WINTER WHEAT

Crew

Crew is a multiline variety of club wheat made up of a blend of 10 components which have resistant or intermediate resistant reactions to the prevalent races of stripe rust. It is heterogeneous for plant height, chaff color, and heading date because of inherent differences among its components. Crew equaled or exceeded Faro for stand establishment, cold hardiness, and lodging resistance. In tests at Moro and Pendleton, the yield and test weight of Crew have been about equal to the yield and test weight of Faro. Most of the components head about two days later than Faro. The milling and baking quality of Crew is similar to that of Faro. Crew was developed cooperatively by Agricultural Research Service, U. S. Department of Agriculture, the Washington Agricultural Research Center, and the Oregon Agricultural Experiment Station. Crew was released in 1981.

Hill 81

Hill 81 is a bearded, white-chaffed, semi-dwarf winter wheat released in 1982. Its grain test weight is about the same as that of Stephens. Hill 81 is more winterhardy than Stephens, and it is recommended for those areas where the winter hardiness of Stephens has not been adequate. This variety is usually one to two inches taller than Stephens. Hill 81 matures about four days later than Stephens. The milling and baking quality and resistance to lodging of Hill 81 are similar to these qualities of Stephens. Hill 81 is resistant to stripe rust, leaf rust, and most races of common bunt. This variety has yielded slightly less than Stephens in eastern Oregon except when winter injury occurs, then it yields higher than Stephens. Hill 81 was developed by the Oregon Agricultural Experiment Station.

Lewjain

Lewjain is a bearded, white-chaffed, semi-dwarf winter wheat released in 1982. This variety is similar to Luke in maturity (late), straw strength, winterhardiness (moderate), and milling and baking quality (excellent). Lewjain is resistant to the local races of common and dwarf bunt. It is resistant to stripe rust, but susceptible to leaf rust and *Cercosporella* foot rot. Lewjain is moderately resistant to *Cephlasporium* stripe. This variety has yielded slightly higher than Luke, and it is recommended in areas where

---

[1]Professor of agronomy, Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, Oregon 97801.

dwarf bunt is a problem. Lewjain was developed cooperatively by the Agricultural Research Service, U. S. Department of Agriculture, and the Washington Agricultural Research Center.

SPRING WHEAT

Owens

Owens is a bearded, white-chaffed, semi-dwarf soft white spring wheat released in 1981. The test weight of the grain is similar to that of Fieldwin. Owens matures about two days earlier, and its plant height is slightly taller than Fieldwin. This variety is resistant to stripe rust, and moderately resistant to leaf rust. Owens, slightly less resistant to lodging than Fieldwin, has not yielded as high as Twin and Dirkwin in eastern Oregon. Owens has good milling and baking quality. It was developed cooperatively by the Agricultural Research Service, U. S. Department of Agriculture, and the Idaho Agricultural Experiment Station.

McKay

McKay is a bearded, white-chaffed, semi-dwarf hard red spring wheat released in 1981. The test weight of its grain is about one pound per bushel heavier than that of Fieldwin. McKay matures about the same time as Fieldwin, and its plant height is slightly taller. This variety is resistant to both stripe and leaf rust. McKay is very resistant to lodging. It has not yielded as high as Twin and Dirkwin in most areas of eastern Oregon. McKay has good milling and baking quality. This variety was developed cooperatively by the Agricultural Research Service, U. S. Department of Agriculture, and the Idaho Agricultural Experiment Station.

WINTER BARLEY

Scio

Scio is a medium short, midseason, feed grain variety released in 1981. It is similar to Boyer in maturity, and about three inches shorter than Boyer. It is very stiff-strawed and well adapted to high rainfall areas and irrigated areas where severe winters are not a problem. The spike of Scio is mid-dense and the kernels have a white aleurone. Scio was developed by the Oregon Agricultural Experiment Station.

SPRING BARLEY

Gus

Gus is a short, late maturing, six-row spring barley. The test weight of its grain is very high, averaging more than two pounds per bushel heavier than Steptoe. Gus is very resistant to lodging, and very well adapted for growing under irrigation. This variety has not yielded as high as Kombar. Gus is a feed grain variety.

CEREAL BREEDING AND TESTING PROJECT

Charles R. Rohde and Debora A. Nason[1]

The cereal breeding program at Pendleton has the primary objective of developing high yielding, soft, white winter wheat varieties for the lower yielding areas of eastern Oregon. Varieties adapted for lower yielding areas must often be taller than semi-dwarf varieties such as "Stephens" and "Daws" and include club varieties such as "Moro" and "Faro."

Desired varietal characteristics for lower yielding areas are: (1) production of high yields of grain with excellent milling and baking quality; (2) resistance to smut, stripe rust, foot and root rots, and Cephalosporium stripe; (3) ability to establish quickly in a high residue seedbed; (4) ability to emerge when seeded deep or when soil moisture in the seeding zone is low; (5) resistance to shattering; (6) medium straw height; (7) resistance to lodging; and (8) moderate winterhardiness.

New varieties of spring and winter wheat, spring and winter barley, and spring oats, developed by public and private breeders, are compared in the variety testing program at the Columbia Basin Agricultural Research Center. Plot sites at Pendleton, Moro, and Hermiston stations and on farmers' fields that are representative of cereal-growing areas of northeastern Oregon, provide data of yield, agronomic quality, and disease reaction characteristics for comparison to commonly grown varieties.

Climatic and soil conditions are diverse in northeastern Oregon; consequently, it is necessary to test cereal varieties at many locations and for at least three years to get reliable information as to their adaptability for various areas of northeastern Oregon. Tables 1 through 9 give yield data obtained from these trials for new and old varieties of wheat and barley. Detailed variety descriptions of newly released varieties are included in another article in this progress report.

[1]Professor and research assistant, respectively, Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, Oregon 97801.

Table 1. Yield data of winter wheat varieties for the years each has been tested in lower yield areas of eastern Oregon

Variety	Moro	Pilot Rock	Echo	Lexington	Heppner	Arlington	Condon	Average
				(bushels per acre)				
Jacmar	49.3	37.3	31.8	32.5	29.8	35.3	34.1	35.7
Stephens	52.7	35.4	30.6	35.8	34.0	31.0	29.1	35.5
Tyee	43.2	36.1	25.8	32.9	38.1	31.5	31.7	34.2
Faro	46.4	31.8	31.1	33.3	32.1	32.0	28.9	33.7
Hill 81	45.1	37.7	26.4	29.6	34.5	32.6	27.6	33.4
Daws	41.7	36.2	28.7	29.9	32.3	27.5	32.0	32.6
Sprague	41.2	33.0	27.9	32.1	33.5	28.7	30.1	32.4
Hyslop	39.5	32.8	29.5	33.5	33.3	28.4	28.4	32.2
McDermid	37.4	33.2	29.1	32.8	33.8	27.6	31.0	32.1
Nugaines	38.5	28.0	29.4	31.0	31.4	28.3	32.3	31.3
Barbee	40.3	33.0	24.2	28.2	29.9	27.4	32.5	30.8

Table 2. Yield data of winter wheat varieties for the years each has been tested in higher yielding areas of eastern Oregon

Variety	Pendleton	Holdman	Weston	LaGrande	Flora	Baker	Average
			(bushels per acre)				
Hyslop	75.8	39.8	60.3	61.0	56.6	57.6	58.5
McDermid	75.6	37.7	62.8	59.7	57.5	56.3	58.3
Stephens	78.1	39.4	61.4	61.4	60.5	47.1	58.0
Luke	73.7	39.4	58.5	59.8	54.3	59.6	57.6
Hill 81	72.4	35.9	56.0	64.7	62.1	53.6	57.5
Nugaines	74.2	37.7	59.2	59.9	52.6	54.6	56.4
Tyee	75.7	39.5	56.2	57.4	44.7	55.4	54.8
Daws	73.6	38.1	58.7	58.9	50.2	46.3	54.3
Faro	74.2	44.5	55.9	56.8	49.0	41.9	53.7
Sprague	69.0	36.7	55.3	52.6	56.4	46.5	52.8
Jacmar	71.5	41.5	62.1	54.4	44.1	38.8	52.1
Barbee	63.5	38.1	50.3	49.6	47.0	49.7	49.7

Table 3. Yield data of winter wheat varieties for the years each has been tested under irrigation in eastern Oregon

Variety	Pendleton	Hermiston	Summerville	Average
		(bushels per acre)		
Stephens	101.0	66.0	76.7	81.2
Hill 81	93.3	61.5	77.5	77.4
Hyslop	90.7	60.7	79.7	77.0
Daws	87.7	60.8	74.0	74.2
McDermid	86.2	60.5	73.0	73.2
Nugaines	82.6	52.7	78.2	71.2
Jacmar	53.7	48.9	63.6	55.4

Table 4. Yield data of spring wheat varieties for the years each has been tested in lower yielding areas of eastern Oregon

Variety	Moro	Echo	Lexington	Heppner	Arlington	Condon	Average
				(bushels per acre)			
Dirkwin	34.3	24.4	27.7	20.9	30.1	23.8	26.9
Borah	31.4	22.8	24.6	24.2	26.1	24.3	25.6
Prospur	30.9	21.8	24.9	26.9	24.1	24.3	25.5
Shasta	32.1	21.8	26.7	23.1	24.2	24.8	25.4
Wared	32.5	23.3	25.9	20.4	26.2	24.1	25.4
Wampum	29.4	25.6	23.4	22.4	25.2	24.6	25.1
Twin	31.2	22.8	25.1	19.8	25.6	23.0	24.6
Walladay	35.0	25.0	21.2	16.1	24.7	21.4	23.9
Owens 1/	27.7	19.2	24.6	20.1	27.6	----	23.8
Urquie	29.9	20.5	24.0	19.2	26.1	23.0	23.8
Fieldwin	28.3	22.1	22.2	21.3	22.9	25.8	23.8
McKay	30.3	20.1	23.5	18.3	26.6	----	23.8
Fielder	28.1	21.6	23.4	20.2	24.3	24.1	23.6
Fortuna	25.5	23.0	22.3	20.1	22.5	20.3	22.3
Federation	25.0	18.5	20.1	17.4	19.6	19.8	20.1

1/ Tested in 1981 only.

Table 5. Yield data of spring wheat varieties for the years each has been tested in the higher yielding areas of eastern Oregon

Variety	Pendleton Irrigated	Pendleton Dryland	Weston	Hermiston	LaGrande	Joseph	Baker	Average
				(bushels per acre)				
Dirkwin	63.1	47.9	49.9	52.0	47.3	50.5	38.4	49.9
Prospur	65.8	42.2	51.7	47.1	45.7	47.5	43.0	49.0
Borah	66.6	40.7	44.0	52.4	43.1	48.4	36.7	47.4
Wampum	63.4	42.4	46.1	45.6	45.1	52.1	37.1	47.4
McKay	68.7	39.5	48.4	43.9	43.2	48.3	32.8	46.4
Twin	62.6	41.4	39.7	42.7	46.1	45.0	42.8	45.8
Fielder	57.1	37.4	40.7	53.7	40.3	38.6	35.0	43.3
Fieldwin	59.2	38.7	29.1	51.4	42.5	42.7	36.5	42.9
Wared	56.0	37.4	41.5	43.4	37.5	42.8	34.8	41.9
Owens 1/	55.3	41.6	29.6	----	43.2	----	39.6	41.9
Urquie	57.5	38.5	29.5	39.2	43.4	43.7	40.5	41.8
Walladay	52.6	36.6	40.6	41.5	32.8	42.4	33.7	40.0
Federation	41.8	31.1	32.6	35.9	34.2	36.0	34.5	35.2

1/ Tested in 1981 only.

Table 6. Yield data of winter barley varieties for the years each has been tested in lower yielding areas of eastern Oregon

Variety	Moro	Pilot Rock	Echo	Lexington	Heppner	Arlington	Condon	Average
					(pounds per acre)			
Steptoe (fall seeded)	2070	2970	2613	2476	2144	2302	2438	2430
Hesk	2316	3041	2402	2347	2165	2088	2144	2358
Mal	2180	2900	2091	2279	1963	2070	2443	2275
Wintermalt	2098	2422	2612	2497	2020	1940	1800	2198
Kamiak	2089	2466	2606	2186	1806	1927	1986	2152
Hudson	1968	2354	2517	2080	1869	1923	1644	2051

Table 7. Yield data of winter barley varieties for the years each has been tested in higher yielding areas of eastern Oregon

Variety	Pendleton	Holdman	Weston	Hermiston	LaGrande	Summerville	Baker	Flora	Average
					(pounds per acre)				
Hesk	5226	2465	4519	4362	4648	4167	2921	3018	3916
Scio[1/]	5157	3080	3215	4442	4732	3675	2714	4057	3884
Mal	5241	2418	4420	4136	4487	4490	2594	3158	3868
Boyer	5214	2460	4327	4367	4339	4176	2697	2935	3814
Schuyler	4942	2673	4137	3851	4338	4053	2940	3218	3769
Luther	4593	2339	4080	4047	3722	3722	2558	2913	3497
Kamiak	4824	2394	3650	3442	3814	3623	2599	3106	3432
Wintermalt	5031	2066	3431	3519	3883	3513	3128	2475	3387
Steptoe (fall seeded)	4933	2060	3881	3543	3639	3765	2259	2090	3271

[1]Tested in 1981 only.

Table 8. Yield data of spring barley varieties for the years each has been tested in the lower yielding areas of eastern Oregon

Variety	Moro	Echo	Lexington	Heppner	Arlington	Condon	Average
				(pounds per acre)			
Steptoe	2236	2108	2104	1776	1932	2253	2068
Advance	2116	2220	1980	1861	1872	2137	2031
Gem	2155	2019	2013	1745	1903	2148	1997
Hector	2238	2280	2014	1549	1834	1981	1983
Flynn 37	2089	2050	2037	1692	1798	1984	1941
Lud	2224	1955	1985	1587	1774	1871	1899
Summit	2190	2021	1997	1413	1736	1903	1877
Belford	1710	1771	1591	1279	1366	1325	1507

Table 9. Yield data of spring barley varieties for the years each has been tested in the higher yielding areas of eastern Oregon

	Pendleton							
Variety	Dryland	Irrigated	Weston	Hermiston	LaGrande	Joseph	Baker	Average
				(pounds per acre)				
Steptoe	3959	4322	3753	3702	4347	4259	3896	4034
Kombar	2421	4887	3752	3529	4450	3015	3155	3601
Advance	3682	4656	3045	3698	4445	3723	2901	3736
Lud	3623	4117	3254	3684	4201	3998	3162	3720
Summit	3455	4016	2948	3562	4110	3786	3154	3576
Gem	3494	3748	3091	3289	3525	3536	2836	3360
Kimberly	----	3366	2751	3473	3650	3453	3157	3308
Klages	3642	3478	2442	2998	3594	3666	3265	3298
Cayuse (Oats)	2632	3757	3006	2835	3217	3239	2736	3060
Morex[1/]	----	3371	----	2836	2808	----	2675	2922
Belford	2092	2860	2613	2718	2834	2919	2821	2694

1/ Tested in 1981 only.

TILLER AND ROOT DEVELOPMENT OF WHEAT PLANTS

Betty Klepper, R. W. Rickman, R. K. Belford, and G. E. Fischbacher[1]

INTRODUCTION

Formation of grain yield in wheat can be understood only if the components that influence final yield are studied. Four major components of yield are heads per acre, spikelets per head, kernels per spikelet and weight per kernel. Each of these components of yield develops at different times during the growing season and each has a different variability from year to year depending on the climatic pattern of a wheat-growing region. Table 1 lists these yield components, the calendar interval over which they develop, processes that control each component, and their characteristic variability in the Pacific Northwest.

Table 1. The production and loss of yield components of winter wheat under Pacific Northwest conditions

Yield component	Process involved	Time	Relative variability*
Heads per acre	Stand establishment	Oct-Nov	4
	Tiller production	Dec-Mar	3
	Tiller abortion	Apr	4
Spikelets per head	Spikelet production	Mar-Apr	1
	Spikelet "abortion"	Apr-May	3
Kernels per spikelet	Floret production	May	2
	Pollination	Early June	1
	Kernel "abortion"	June	2
Weight per kernel	Kernel growth	June	2
	Kernel filling	June-July	3

*Ratings are 1 (least variable from year to year) to 4 (most variable from year to year)

[1]First, second, and last authors are plant physiologist, soil scientist, and physical science technician, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801; R. K. Belford is a visiting soil scientist, Letcombe Laboratory, England.

Tiller production and survival is the component that varies most from year to year and it is also closely related to final yield.

Flexibility in the number of head-bearing stems produced allows the plant to respond to good and bad years by making an adjustment in a yield component early in the year (Table 1). Other yield components exert influence after March, but the number of heads per acre is determined over a long period. The important factors controlling this number include stand (main stem) establishment in autumn, tillering and tiller establishment in late winter and early spring, and tiller abortion in spring. Because of the importance of tiller production and abortion to final yield, we have made detailed studies in time of appearance and rate of tiller growth.

MATERIALS AND METHODS

The naming system developed for describing all the leaves, tillers, and roots on the seedling is shown in Figure 1. This naming system permits exact descriptions of plants and their development over time, and allows detailed studies of the effects of management practices on tiller production, abortion, and root production to be done.

Leaves on the main stem are numbered in order of their appearance. The tillers, which develop from buds at the base of each leaf, are named for the leaf with which they are associated. For example, T2 is the tiller from L2. The "seed tiller" or coleoptilar tiller is given the name "TO" and is the tiller which causes "twinning" in some years. Twinning was discussed in the 1981 Field Day Report. Tiller leaves are given two-digit names. For example leaf 3 on tiller 1 is L13 and leaf 1 on tiller 3 is L31. Each of the leaves on a tiller is capable of producing a tiller of its own. The tillers produced by tillers, or subtillers, are named according to the leaf to which they are related. Tiller T12 would appear from the second leaf on T1. It is also possible to have a third rank of tillers produced from the leaves on subtillers, but these are not common in commercial plantings.

This system has been used to track the developmental history of 'Stephens' wheat (Triticum aestivum (L.) em Thell) in both field and laboratory work.

RESULTS AND DISCUSSION

Figure 2 shows when specific tillers become visible on 'Stephens' winter wheat. The number of leaves on the main stem of the wheat plant is used to measure the time of appearance of each tiller. For example, T1 would normally be visible at about the time the fourth leaf begins to appear. If a piece of paper is laid across Figure 2 with 4.4 main stem leaves showing, the plant should have a visible TO, T1, and T2. There would be about 2.5 leaves on TO, 1.9 leaves on T1, and 1.2 leaves on T2. Tillers that are missing or that have fewer leaves than this pattern when the mainstem has 4.4 leaves have been delayed by some kind of stressful growing condition.

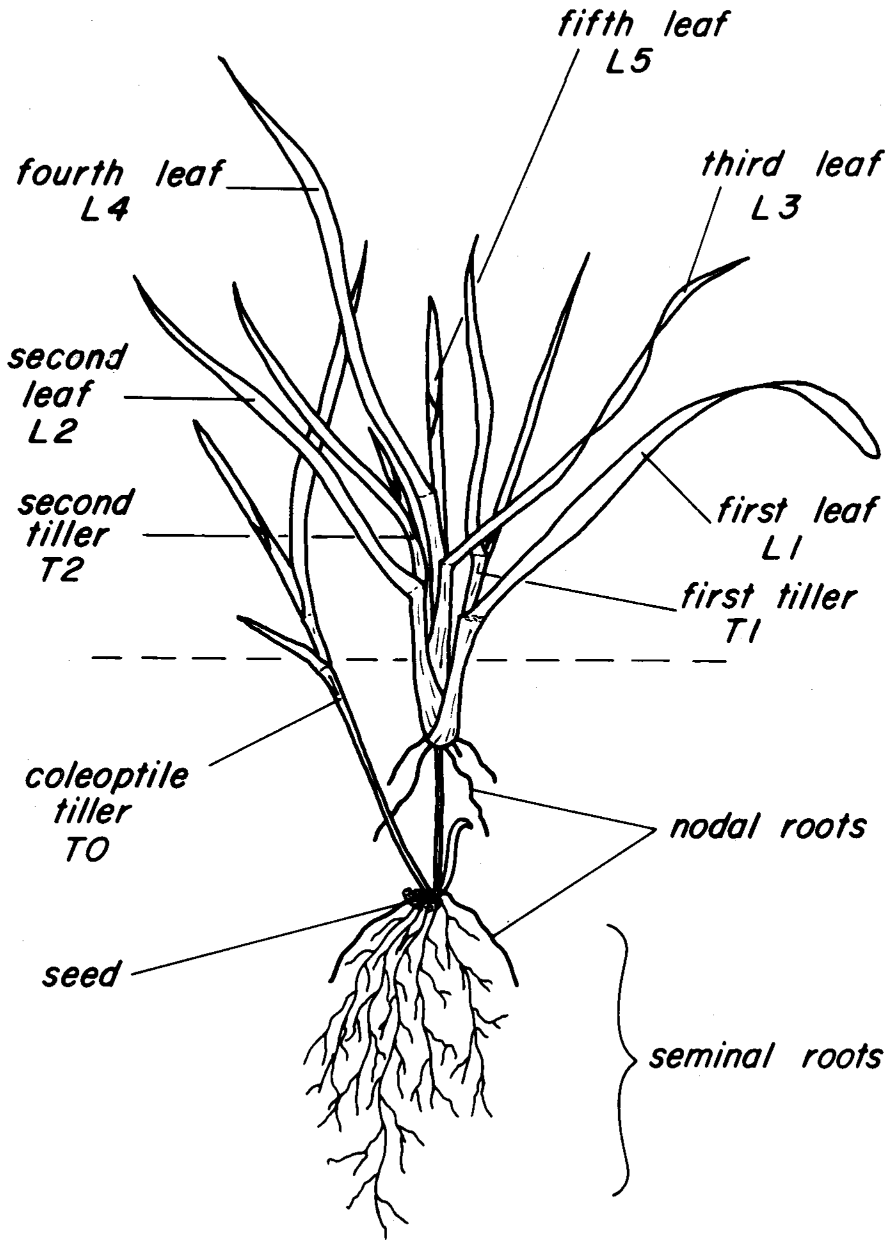


Figure 1. Diagram of a wheat plant showing main stem (leaves L1-L5), T0, T1, and T3 with 1.3 leaves.

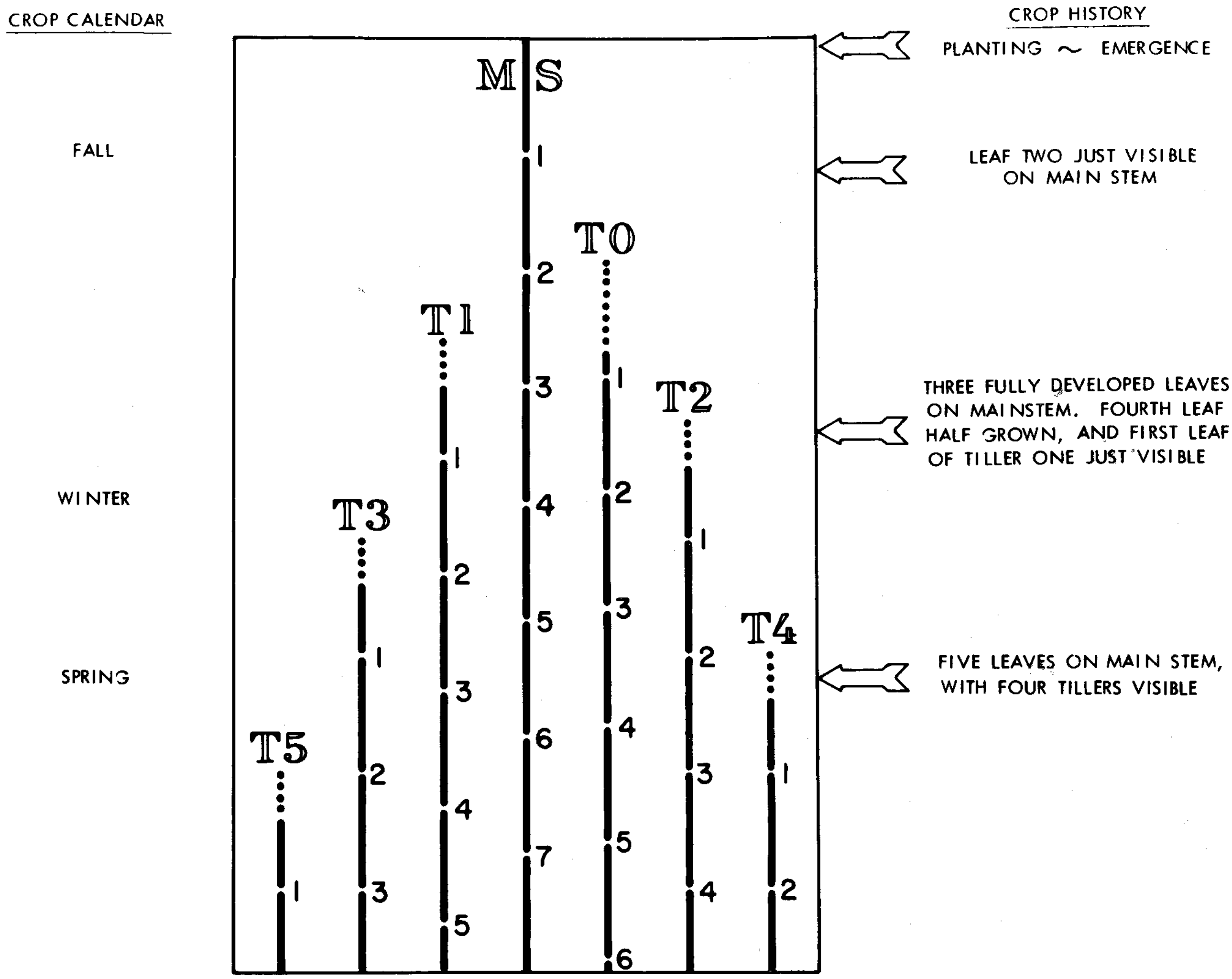


Figure 2. Developmental history of the leaves and tillers of a typical plant of winter wheat.

Development of each tiller of the plant in Figure 1 was accurately described by laying the ruler or paper across Figure 2 at the number of mainstem leaves visible on the plant. A scheme for describing the root system is also being developed at Pendleton. Crown root development follows a pattern similar to tillering. Each leaf is attached to the stem at a "node." Each node is capable of producing two pairs of roots; the first pair appears at about the same time that the tiller appears at that node, but the second pair develops only when tiller growth is strong.

Subsequently, each tiller produces its own nodal root system in the same way as the mainstem and can thus absorb its own supplies of water and minerals from the soil. In doing this, the tiller must compete with older, better-rooted stems. One may conclude that part of the mechanism for tiller abortion lies in the failure of late tillers to establish a root system sufficient to supply their own needs. Our research is designed to examine this possibility. A better understanding will explain how current management practices affect the number of headed tillers per acre. Then, the influence of specific practices on yield can be assessed.

THE EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZATION ON CROP DEVELOPMENT OF EARLY AND LATE PLANTED WINTER WHEAT

Michael Glenn[1]

The late planting of winter wheat in the lower Columbia Basin is a chronic problem that not only reduces yield levels, but increases the erosion hazard. Long-term trials in Sherman and Wasco Counties have demonstrated that the optimum range of planting dates for this area is from mid-September to mid-October. However, adequate seedbed moisture is often lacking or too deep in many years for successful planting to occur at this time. When planting is delayed, a less vigorous crop with fewer tillers, less leaf area, and a lower yield potential develops. Perhaps the use of both nitrogen and phosphorous fertilizer materials could be utilized to help late planted wheat compensate for its less vigorous growth.

METHODS AND MATERIALS

A date of planting trial was established in fall 1981 to examine wheat growth response to nitrogen (0 and 70 pounds nitrogen/acre) and phosphorous (0 and 90 pounds phosphorous/acre). Stephens soft white winter wheat was planted into a moist seedbed on September 26 and November 5. Soil moisture uptake and dry matter were measured every two weeks during the boot stage. Grain yield was determined at maturity by harvesting with a plot combine.

---

[1]Assistant professor, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

RESULTS AND DISCUSSION

The overall effect of late planting was to reduce the size and growth rate of the plants (Figures 1 and 2). Winter wheat planted September 26 had a greater dry weight and crop growth rate through the heading period when it received 70 pounds nitrogen/acre and 90 pounds phosphorous/acre in combination than with 70 pounds nitrogen/acre alone. Both treatments had a greater dry weight and crop growth rate than did the control or treatments receiving only 90 pounds phosphorous/acre. The crop growth rate and dry matter accumulation of winter wheat planted November 5 responded primarily to nitrogen with no significant top growth response to phosphorous or the combination of nitrogen and phosphorous.

Crop establishment during the recommended fall period resulted in greater tiller production compared with late planted winter wheat (Table 1). In late March, the combination of nitrogen and phosphorous fertilizers in the September 26 planting resulted in a significantly greater number of tillers than at the other fertility levels. However, this tillering response to the combination of nitrogen and phosphorous did not persist through the boot stage and only a significant nitrogen response was measured at the boot stage. In late March, the November 5 planting had only begun to form tillers and no fertilizer response was evident. By the boot stage, tiller production in the late planted wheat demonstrated a significant response to both nitrogen and phosphorous fertilization.

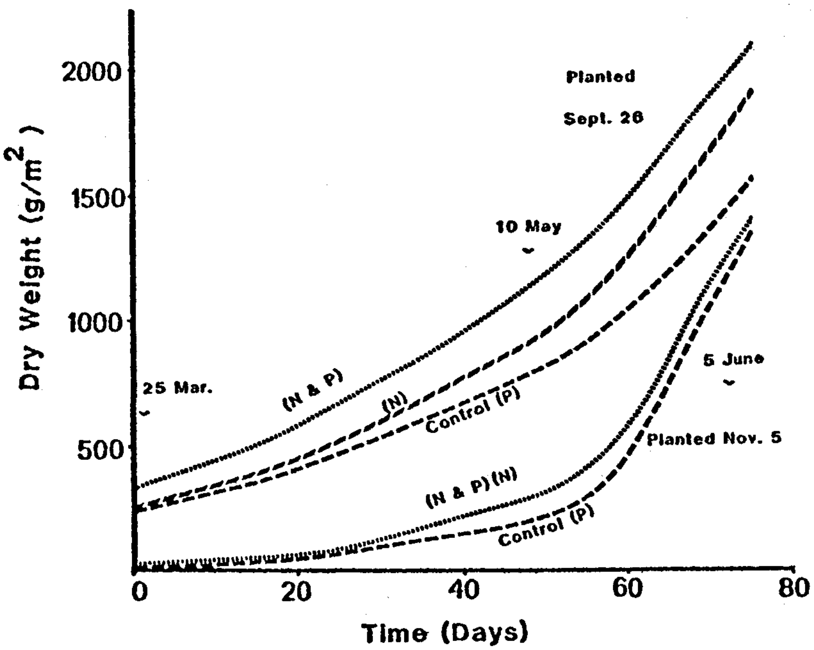


Figure 1. The effect of planting date and fertility level on dry weight accumulation of Stephens wheat.

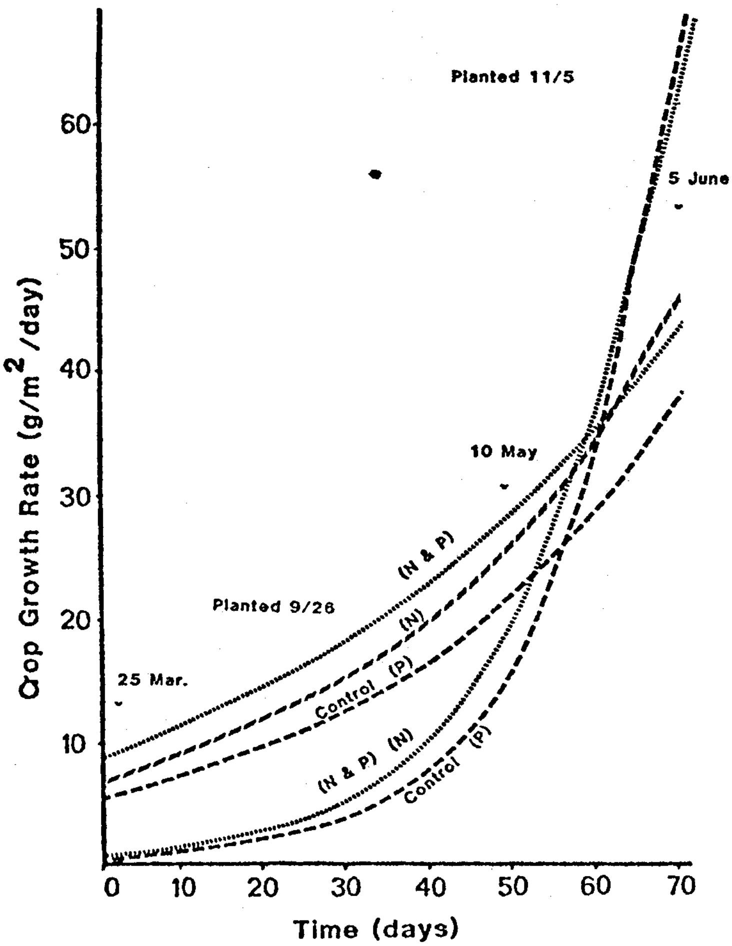


Figure 2. The effect of planting date and fertility level on the crop growth rate of Stephens wheat.

The 1981 growing season was remarkable for its combination of timely rains and cool temperatures. These conditions resulted in minimal plant water stress and very high yield potentials. For these reasons, the crop water usage of both early and late planted wheat reached comparable levels (Table 2). Under more characteristic water stress conditions for the area, early planted wheat would be expected to extract more water from the soil profile. The combination of 70 pounds nitrogen/acre and 90 pounds phosphorous/acre did result in significantly greater crop water usage for both the early and late planted winter wheat as compared to the other fertility levels. The enhanced crop water usage response to nitrogen and phosphorous did not result in a significant grain yield increase because of a sulfur deficiency in all treatments in 1981. The September 26 planting date responded only to nitrogen and the November 5 planting demonstrated no response to nitrogen or phosphorous.

Table 1. The effect of planting date and fertility level on tiller number during the tillering and boot stage

Fertility level (lbs/A)	Planted September 26 Growth stage		Planted November 5 Growth stage	
	tillering	boot	tillering	boot
	(tillers/m²)		(tillers/m²)	
ØN ØP	700[b][1]	603[b]	97	357[c]
ØN 90P	710[b]	583[b]	100	400[bc]
70N ØP	743[b]	673[a]	117	460[ab]
70N 90P	860[a]	707[a]	120	553[a]

Table 2. The effect of planting date and fertility level on crop water use and grain yield

Fertility level (lbs/A)	Planted September 26		Planted November 5	
	Crop water usage (in)	Grain yield (bu/A)	Crop water usage (in)	Grain yield (bu/A)
ØN ØP	8.12[b][1]	63.9[b]	8.36[b]	63.9
ØN 90P	7.92[b]	65.4[b]	8.36[b]	63.9
70N ØP	8.48[b]	78.8[a]	8.68[b]	65.4
70N 90P	9.24[a]	77.3[a]	10.16[a]	66.9

[1]Means followed by the same letter do not differ significantly

CONCLUSIONS

Late planted wheat responded to applications of nitrogen and phosphorous through increased tiller production, increased crop growth, and crop water usage. It could not be determined if these responses would result in a grain yield increase since a sulfur deficiency limiting grain yield occurred in 1981. Presumably, the yield level of late planted wheat will never reach that of wheat planted at a more optimal time in the fall. However, based on increased water extraction by the fertilized late seeding, these preliminary results do suggest that plant compensation through nitrogen and phosphorous fertilizer management may provide a means of increasing the grain yield of late planted wheat.

THE EFFECT OF WATER INJECTION ON STAND ESTABLISHMENT COMPONENTS

Fariborz Noori-Fard and F. E. Bolton[1]

Seedzone moisture is often deficient during the optimum period for winter wheat establishment in Sherman and Wasco County (mid-September through mid-October). Dry seedzone conditions are generally more prevalent with no-till cropping systems but they also occur in stubble mulch cropping systems. Planting into inadequate seedzone moisture will result in delayed crop emergence and reduced stand density. The overall response by the crop is a reduction in grain yield. Growth chamber and field studies in previous years have demonstrated that water injection with the seed at planting was an effective aid to emergence in dry seedbed conditions. Further field studies were conducted in fall 1981 to examine the effect of water injection with the seed on stand establishment and its related components.

METHODS AND MATERIALS

In early October 1981, Stephens winter wheat was seeded into a dry seedbed on both chemically fallowed land and on land recently harvested (non-fallowed). Water injection rates (Table 1) were applied with the seed as an aid to stand establishment. Water was directly added to the seed at planting using a rotary-strip tiller to prepare the seedbed, plant the seed, and inject water. Approximately 18 seeds/foot of row were planted with an 18-inch row spacing in four replicates per treatment.

---

[1]Graduate student and associate professor, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

Table 1. The effect of water injection with the seed on stand establishment parameters in the fall of 1981

	Water injection rates (gallons/acre)			
	0	50	100	150
Pre-plant soil moisture percentage in the seed zone				
fallowed	8.4	8.4	8.4	8.4
non-fallowed	7.9	7.9	7.9	7.9
Post-planting soil moisture percentage in the seed zone (6 hours after planting)				
fallowed	8.4	9.5	10.4	11.6
non-fallowed	7.9	9.2	9.8	11.1
Seed water uptake percentage				
fallowed	21.5	23.1	25.0	26.1
non-fallowed	19.7	21.5	23.1	25.2
Emergence percentage				
fallowed	55	79	83	88
non-fallowed	46	58	70	79
Plant height (cm)				
fallowed	5	7	8	9
non-fallowed	4	4	5	6
Leaf area (cm^2/m^2)				
fallowed	9	116	123	129
non-fallowed	42	53	60	68
Dry matter (mg/m^2)				
fallowed	558	853	946	984
non-fallowed	235	366	465	539

Soil moisture of the seedzone was measured pre- and post-planting. Seed water uptake, emergence percentage, plant height and weight, and leaf area were monitored for 30 days after planting.

RESULTS AND DISCUSSION

Water injection significantly increased the emergence and development of winter wheat planted into a dry seedzone (Table 1). Increasing the amount of water injected with the seed enhanced the plant's response in all measured parameters of stand establishment. Water injection did increase the water content of the seedzone which resulted in a larger amount of seed water uptake (imbibition). Accelerated imbibition resulted in a greater emergence percentage and more vigorous plants, i.e., taller plants with a greater leaf area and dry weight.

During three field seasons, water injection with the seed has consistently demonstrated its effectiveness as an aid to plant emergence and stand establishment.

"INVERSION", A NEW TECHNIQUE FOR DOWNY BROME CONTROL

D. J. Rydrych[1]

Downy brome (cheatgrass) has been a continuous problem in stubble mulch and reduced tillage systems in eastern Oregon for the last 30 years. On occasion, heavy infestations can be found on annual cropping and in a moldboard plow culture. Only two herbicides have been registered for selective downy brome control in winter cereals (wheat and barley). Trifluralin (Treflan) is registered for use on winter wheat as a preplant seedbed herbicide that needs thorough soil incorporation. Metribuzin (Sencor or Lexone) is registered for use as a postemergence herbicide on winter wheat or barley that have crown root development. Early seeded cereals fit in these control systems. However, when lack of fall rainfall prevents downy brome germination, or when wheat is seeded in late fall, the two herbicides have some serious restrictions.

A new system of seedbed soil treatment was initiated in 1976 that would allow adequate crop safety, insure effective grass control in the wheat or barley crop, and allow the use of reduced tillage systems. The new concept is called "Inversion" and was developed for use in the dryland areas of eastern Oregon and the Pacific Northwest.

MATERIALS AND METHODS

Replicated plots were established during five years (1976-1981) at the Columbia Basin Agricultural Research Center, Pendleton, Oregon, and several off-station sites in eastern Oregon. The soil was classed as a Walla Walla silt loam (course-silty, mixed, mesic Typic Haploxeroll), pH 6.5, organic

[1]Associate professor of agronomy, Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, Oregon 97801.

matter 1.9 percent, and a depth of six feet. Nitrogen fertilizer was broadcast on the soil surface at 60 pounds per acre. Annual precipitation averaged 20 inches/year. A randomized block design with three replications was used in plots 10 feet wide and 20 feet long in areas that were dryland farmed in a wheat-fallow rotation. Herbicides were applied on the soil surface before planting, inverted once (PPI), twice (PPI), or none (PPS), and then seeded three inches deep in a 14-inch row spacing at 60 lb/A with a deep furrow grain drill. Dry weights of grain were obtained from 20 feet of two center rows from each plot at maturity (July). Treatments consisted of a nonweeded control, handweeded control, trifluralin (.75 lb/A), diclofop (1.00 lb/A), propham (.75 to 1.50 lb/A), and napropamide (1.00 to 1.50 lb/A). Herbicides were incorporated by "Inversion" using a tined harrow or rod weeder.

Table 1. Inversion of downy brome herbicides in winter wheat, Pendleton Station, Pendleton, Oregon, 1981

Treatment	Rate	Inversion	Avg. downy brome control	Avg. broadleaf* control	Crop Injury	Avg. wheat
	lb/A	times	%	%	%	lb/A
trifluralin	.75	0	68	100	0	4670
trifluralin	.75	1	90	100	0	6120
trifluralin	.75	2	96	100	0	5840
diclofop	1.00	0	90	100	0	5450
diclofop	1.00	1	96	100	0	5790
diclofop	1.00	2	99	100	0	5080
napropamide	1.00	1	98	100	1	6170
propham	.75	0	90	100	0	6560
propham	.75	1	93	100	0	6270
propham	.75	2	99	100	0	6300
propham + trifluralin	.50 + .50	0	85	100	0	6190
propham + trifluralin	.50 + .50	1	97	100	0	5770
propham + trifluralin	.50 + .50	2	99	100	0	5660
propham + diclofop	.50 + .50	0	93	100	0	5710
propham + diclofop	.50 + .50	1	98	100	0	6580
propham + diclofop	.50 + .50	2	97	100	0	6430
weeded control	----------	-	100	100	0	6020
control	----------	-	0	0	0	4600

Treated October 1, 1980, Inversion using flex harrow and rod weeder

*Note complete broadleaf control by use of bromoxynil @ .50 lb/A, postemergence

RESULTS AND CONCLUSIONS

The trials established on the Pendleton Station (Table 1) in 1981 were highly successful and have been tested successfully since 1976. Commercial adaptation of the "Inversion" technique is scheduled for the fall 1982 for diclofop and propham. Registration for these products is pending. The trials were established on a trashy fallow seedbed containing 1.5 tons of residual straw.

Trifluralin (Table 1) gave better downy brome control using two inversions rather than none (96 percent vs. 68 percent). This fact has limited the use of trifluralin to mild straw concentrations on the soil surface. Diclofop was highly effective on downy brome using only minimal soil disturbance. Diclofop gave 96 percent downy brome control with only mild soil inversion and excellent crop safety. Napropamide was highly active on downy brome using only mild soil inversion with good crop safety. Propham was highly active on downy brome regardless of inversion rate. This mode of action is very effective in a trashy seedbed because propham is not neutralized by the straw and needs very little soil incorporation. The propham trials showed that 90 to 99 percent downy brome control could be obtained with excellent crop tolerance as long as wheat seed was placed below the treatment zone at the 3-inch level.

Several combination treatments are possible when using the inversion system. None of the herbicides in this system are highly active on broadleaf weeds and other herbicides such as bromoxynil must be used for a weed-free seedbed.

Propham-trifluralin mixtures at very low rates were effective on downy brome (Table 1). The propham-diclofop mixture was more efficient at the low inversion rates and on a trashy seedbed.

These data show that soil inversion on trashy seedbeds is a system with high potential for the use of downy brome herbicides such as diclofop, propham, and perhaps napropamide. This technique could make foolproof downy brome control a reality in the 1980s by the use of "Inversion."

HESSIAN FLY FOUND IN EASTERN OREGON

Ron W. Rickman[1]

Hessian fly damage was observed on spring wheat on the Columbia Plateau Conservation Research Center near Pendleton, in 1979, 1980, and 1981. In 1981, the fly was found in off station plots both east and west of Pendleton. A survey was proposed to establish the extent and intensity of infestation of the insect.

The survey, funded by the Oregon Wheat Commission and conducted in July and August of 1981, covered Umatilla, Union, and Morrow Counties.

EXPERIMENTAL PROCEDURE

The spring wheat fields in the three county area were located by the respective county agents. From those fields several were selected to provide samples throughout the wheat-growing areas of each county. After the crops were ripe, but before harvest, several whole plants were pulled from each selected field. A subsample of 100 stems was selected from each field. Each subsample stem was examined at every node for the flax seed form of the Hessian fly. The number of stems in the subsample which had the insect present are shown in Figure 1.

RESULTS AND DISCUSSION

Hessian fly "flax seeds" (the pupae or resting stage of the insect) were found on spring wheat or spring-planted winter wheat in Umatilla County and the lower elevations of northern Morrow County. The insect was not found in Union or the higher elevations of Morrow County. It was not found in fall-planted winter wheat. Figure 1 shows the locations of the survey sampling sites and the percent of stems infected by the fly at each site. Oregon State University Extension Circular No. 1093, printed in September 1981, describes this insect and recommended control practices. Washington State University Extension Bulletin XB0909 provides greater detail on the insect, its natural habitat, and some wheat variety susceptibility information. Both circulars warn that farmers who are considering no-till cropping of spring wheat may see this insect become a damaging pest, particularly if the spring wheat is irrigated.

[1]Soil scientist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801.

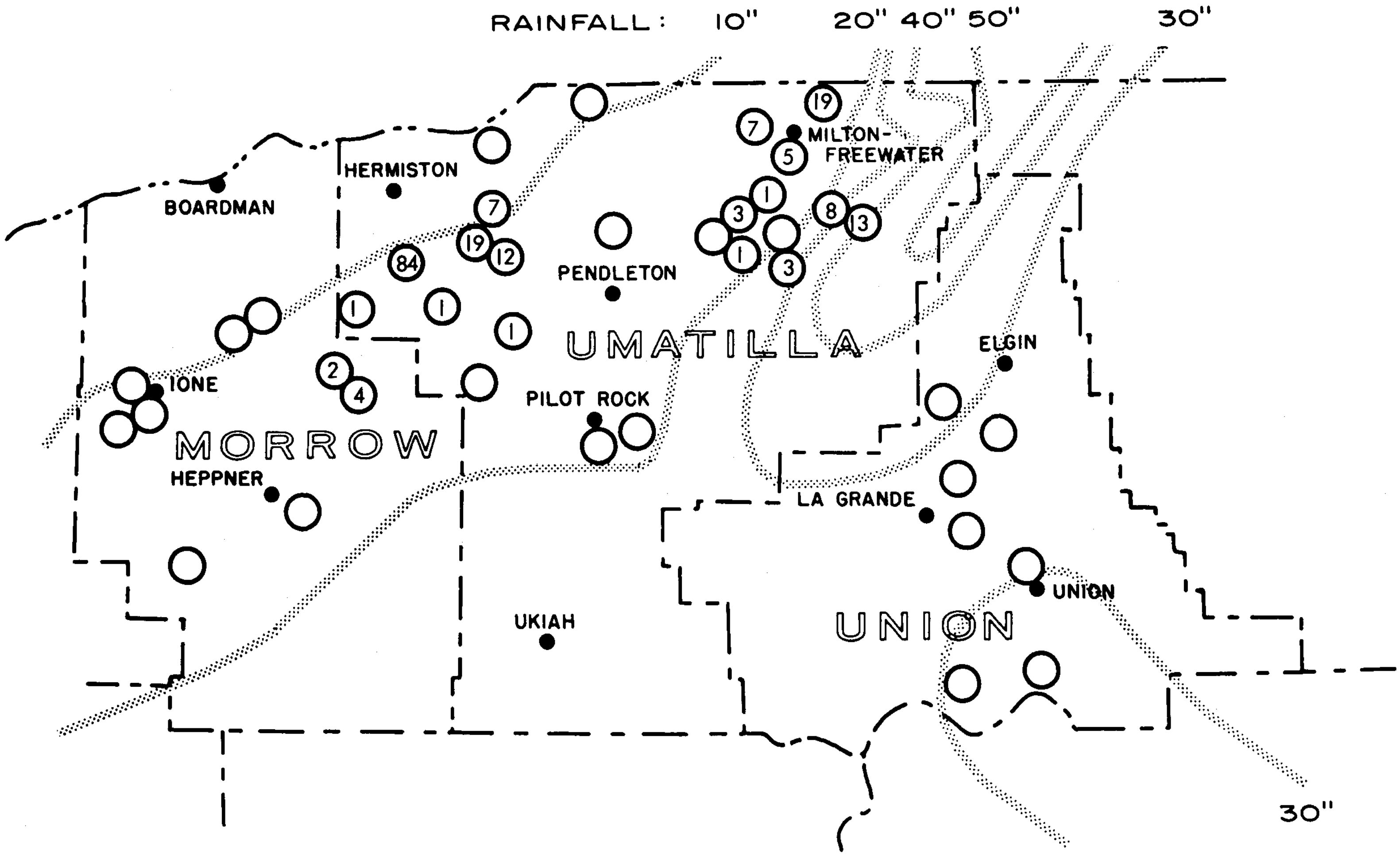


Figure 1. Percent infection of Hessian fly - 1981.

OIL SEED CROPS

F. V. Pumphrey[1]

Variety trials of oil seed crops were conducted in 1980 and 1981 to obtain yield and agronomic information. This information establishes a basis for making assumptions on the competitive potential of oilseed crops against currently grown crops.

Oil seed crops grown were safflower (*Carthamus tinctorius* L.), sunflowers (*Helianthus annuus* L.), winter rape (*Brassica napus* L.), spring rape (*Brassica napus* L. and *B. campestris* L.), and spring mustard (*Brassica nigra* L., *B juncea* L., and *B. alba* L.). The trials were planted on summer fallow land on the Pendleton location of the Columbia Basin Agricultural Research Center. Cultural practices considered to produce optimum yields were used. Yields and cultural practices are reported here. Climatic conditions of rainfall and temperatures were considered more favorable than average during 1980 and 1981; yields are assumed to be equal to or above what could be expected over a longer period of years.

Similar trials were conducted under irrigated conditions at the Hermiston Research and Extension Center; results of those trials are found in the 1982 Research Report of that Center. This work with oil seed crops was in cooperation with Experiment Stations in Idaho, Oregon, and Washington. The three-state approach on developing oilseeds as alternate crops was funded by the Pacific Northwest Regional Commission.

Safflower

Safflower seedlings have a frost tolerance similar to spring barley; thus, the crop is planted about the same time spring barley is planted. This allows the plants to become established before the onset of warmer, drier weather. Flowering and seed filling occur during July and early August.

Most of the wheat farms in the region have the machinery--drill, sprayer for herbicide application, and combine--necessary for safflower production. The seedlings are poor competitors with weeds but herbicides are available which will do a reasonable job of controlling weeds. The matured seeds are easily harvested from the standing plants with a combine. The spines which develop after blooming discourage any contact with the plant during combining.

Cultural practices, seed yields, and oil content of safflower grown in variety trials conducted in 1980 and 1981 are presented in Tables 1 and 2.

---

[1]Agronomist, Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, Oregon 97801.

Table 1. Agronomic information on Safflower Yield Trials at the Columbia Basin Agricultural Research Center, Pendleton, Oregon

Seedbed preparation	- Summerfallow, preplant sweeping, pack
Planting	- Date--April 3, 1980 Rate--20 lbs/acre April 9, 1981 Row spacing--one foot Depth--one inch
Weed control	- Treflan, 1 pint/acre preplant; hand weeded
Fertilization	- 130 lbs/acre of 16-20-0 worked into seedbed
Insects	- None
Diseases	- Tracers of sclerotina wilt and rust
First bloom	- Early July
Harvest	- Mid September

Table 2. Seed yield and oil content of safflower varieties grown dryland at the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980 and 1981

Variety	Seed yield		Oil content	
	(pounds/acre)		(percent)	
	1980	1981	1980	1981
Sun Hi 317	1070	700	39.9	36.2
Sun Hi 208	920	610	37.4	34.3
sun Hi 112	1025	760	40.9	37.2
Sun Hi 742	920	-	40.0	-
Sun Hi 541	960	700	42.3	39.6
Carmex 353	950	710	40.0	37.3
Cal West 74	960	680	41.9	36.6
UC-1	940	640	35.3	32.5
Sidwell	940	-	30.8	-
Gila	1020	-	38.0	-
Hartman	-	570	-	33.2
5% LSD	ns	107	-	-

Climatic conditions of rainfall and summer temperature were more favorable than average for full season crops; however, yields were a half ton or less per acre. These yields are similar to yields produced on summerfallow at the Pendleton location during the last several decades. Full season annual crops, as safflower, are not compatible with the wet winter-dry summer precipitation cycle of this region.

Sunflowers

Sunflowers are grown primarily for oil which is extracted from the kernel of the seed. Minor uses are for confection and for silage. The silage varieties are taller and later maturing than varieties used for oil.

Sunflower seedlings can withstand very light frosts; thus, planting is done about the time the last spring frosts are expected. The sunflower plant has considerable ability to adjust the head size to moisture available to the plant; thus, an exact plant population per acre is not needed. Uniformity of stand is desirable.

Herbicides now available should minimize weed competition. Wilt may be a problem on dryland and possibly may be the only disease problem. Head moth and possibly other insects attacking the heads were a serious problem in these trials. Of the three pests--weeds, insects, and diseases--insects appear to present the biggest problem to production. Birds eating seeds from the heads are also a pest problem.

Cultural practices, seed yield, oil content of the seed, and silage yield are presented in Tables 3, 4, and 5. Sunflowers are a full season crop as they are planted in late April or early May and harvested in September or October. This full season growth characteristic is not compatible with Oregon's dry summers. Severe moisture stress develops in July and August and is the primary factor limiting yields.

Table 3. Agronomic information on Sunflower Variety Trials at the Columbia Basin Agricultural Research Center, Pendleton, Oregon

Seedbed preparation	- Summerfallow, preplant sweeping, pack
Planting	- Date--May 20, 1980 10,000 plants/acre --April 21, 1981 Row spacing--one foot - Depth--1-1/2 inches
Weed control	- Treflan, 1 pint/acre preplant; hand weeded
Fertilization	- 130 lbs/acre of 16-20-0 worked into seedbed
Insects	- Head moth, serious damage; would require control in commercial production
Diseases	- None
Bird damage	- Seed loss from heads to small birds, ie. pine siskins
Harvest	- Seed in early September Silage in early August

Table 4. Seed yield and oil content of sunflower varieties grown dryland at the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980 and 1981

Variety	Seed yield	Oil content
	(pounds/acre)	(percent)
1980		
Sun Hi 372A	825	45.3
Sigco 894	1150	46.4
DO 704XL	965	44.7
5% LSD	214	-
1981		
DO 844	620	45.6
DO 164	570	45.4
DO 704XL	570	43.2
Sigco 894	550	44.1
Sigco 432	670	42.0
Sigco 448	430	44.1
Cal West 904	520	46.3
St 315	410	42.4
IS 7116	475	45.8
IS 907E	490	45.1

Table 5. Yield of green weight and 70 percent moisture sunflowers grown dryland at the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980 and 1981

Variety	Green weight[1]	70% moisture
	(tons/acre)	
1980		
Sigco 894	9.5	7.0
Sungro 372A	10.4	7.6
DO 716	9.2	6.7
1981		
Sungrow 372A	17.2	16.0
Sungrow 380	13.8	15.6
St 304A	15.9	17.5
St 301A	17.1	17.1
St 108	9.2	12.0
Sigco 894	12.8	15.8
Sigco 449	13.4	16.0
NK 254	16.9	18.6

[1] Average dry matter when harvested in 1980 was 22 percent and in 1981 varied from 28 to 39 percent.

Winter Rape

Winter rape should be planted sufficiently early in the fall to provide growing conditions which will allow the seedlings to emerge and grow several leaves before winter. Planting in early September is suggested. The small seeds dictate that maximum planting depth should be less than one inch; thus, the seed has to depend on fall rains for moisture for germination because moisture is not maintained this close to the surface by summer fallowing. The variability with which late August and September rains occur indicates that germination and plant establishment would occur many years much later than desired.

Cultural practices, seed yield, and oil content are presented in Tables 6 and 7. The combination of these seed yields and the current price of approximately 10 cents per pound provides sufficient gross return per acre to make winter rape production competitive with barley, peas, and wheat.

Table 6. Agronomic information on Winter Rape Variety Trials at the Columbia Basin Agricultural Research Center, Pendleton, Oregon

Seedbed preparation	- Summerfallow	
Planting	- Date--September 11, 1979	Rate--8 lbs/acre
	September 9, 1980	Row spacing--one foot
	Depth--one half inch	
Weed control	- Hand weeded	
Fertilization	- 200 lbs/acre of 16-20-0 worked into seedbed	
Insects	- Flea beetle, seed pod maggot, aphids	
Diseases	- None	
First bloom	- Mid-April	
Harvest	- Mid-July	

Concluding that winter rape could be a potential alternate crop should be tempered with the relation of precipitation during these two years of testing to the normal precipitation. Precipitation was favorably distributed and above average starting in the fall of 1979 through the spring of 1981.

Winter rape varieties are classified for human food (edible oil) or for industrial oils according to their erucic acid content. In these trials, erucic acid content was not measured.

Table 7. Seed yield and oil content of winter rape varieties grown dryland at the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980 and 1981

Variety	Seed yield		Oil content	
	(pounds/acre)		(percent)	
	1980	1981	1980	1981
Dwarf Essex	1900	2660	47.6	46.9
Gorczanski	1825	2890	47.1	48.8
Norde	2040	2680	47.1	47.1
Brink	1560	2040	46.2	46.6
Rapora	1520	2790	43.9	46.8
Quinta	1710	2840	43.7	45.8
Primor	1270	2700	41.5	46.3
Sipal	1110	2050	43.4	46.7
ORB 78-253	1760	-	45.8	-
Oleagineau	1350	-	44.8	-
ORB 78-259	-	1180	-	45.2
Bishop	-	2180	-	44.6
Herkules	-	2980	-	47.3
Jet Neuf	-	2930	-	45.6
5% LSD	697	302	-	-

Spring Rape

Spring rape is a rapidly growing, cool season crop. Seedlings have moderate frost tolerance. Planting should be done about the same time spring barley is planted. Cultural practices, seed yield, and oil content are reported in Tables 8 and 9. Observations and results indicate more yield from winter rape than from spring rape.

Spring Mustard

Mustard is a rapid growing, cool season crop. Planting in the spring should be as early as possible which promotes blooming and seed filling before warmer temperatures in the summer.

Table 8. Agronomic information on Spring Rape Variety Trials at the Columbia Basin Agricultural Research Center, Pendleton, Oregon

Seedbed preparation	- Summerfallow, spring sweeping, pack
Planting	- Date--April 9, 1980 Rate--8 lbs/acre April 9, 1981 Row spacing--one foot
Weed control	- Treflan, 1 pint/acre preplant; hand weeded
Fertilization	- 130 lbs/acre of 16-20-0 worked into seedbed
Insects	- Flea beetle, aphids
Diseases	- None
Harvest	- Late July

Table 9. Seed yield, oil content, and plant height of spring rape varieties grown dryland at the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980 and 1981

Variety	Seed yield		Oil content		Plant height
	(pounds/acre)		(percent)		(inches)
	1980	1981	1980	1981	
Brassica napus L.					
Regent	1410	2180	40.5	41.4	45
Altex	1260	2190	38.6	40.4	43
Midas	1540	-	40.3	-	45
Tower	1280	-	37.8	-	38
Andor	-	2155	-	39.9	-
DI-820	-	2290	-	40.0	-
DJ-63	-	2070	-	41.0	-
ZN6-2836	-	2100	-	41.5	-
Brassica campestris L.					
Candle	1350	1950	37.0	40.4	30
Torch	1480	-	37.0	-	28
Hear	580	-	34.3	-	30
DH-716	-	2110	-	42.4	-
CZY5-1366	-	1870	-	42.0	-
CZY6-1366R	-	1950	-	41.1	-
5% LSD	208	ns	-	-	-

Mustard species and varieties vary as to their uses in food and flavoring. Potential acreage for mustard is very limited because of the demand for the product. Most mustard is grown under contract to a processor of mustard. Cultural practices, seed yield, and oil content are reported in Tables 10 and 11.

Table 10. Agronomic information on Spring Mustard Variety Trial at the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980

Seedbed preparation	- Summerfallow, spring sweeping, pack
Planting	- Date--April 26, 1980 Rate--5 lbs/acre Depth--one half inch Row spacing--one foot
Weed control	- Hand weeded
Fertilization	- 130 lbs/acre of 16-20-0 worked into seedbed
Insects	- Flea beetle, aphids
Diseases	- None
First bloom	- May 26
Full bloom	- June 10
Harvest	- Early August

Table 11. Seed yield and oil content of spring mustard varieties grown on the Columbia Basin Agricultural Research Center, Pendleton, Oregon in 1980

Variety	Seed yield	Oil content
	(pounds/acre)	(percent)
Lethbridge 22A	870	34.8
Stoke	1080	33.3
Domo	1030	35.8
Blaze	790	31.7
Eklo	810	30.5
Commerical Brown	740	29.0
Gisilba	790	23.5
Sabre	840	24.5
Commerical Yellow	750	23.8
Kirby	560	22.8
5% LSD	150	-

SUMMARY

Minimal production problems were experienced with safflower, winter rape, spring rape, and spring mustard. Stand establishment with winter rape would be a problem those years when little rainfall occurs between mid-August and early November. Sunflower production problems consisted primarily of insects eating the head and birds eating seeds from the head.

The economics of production of these crops except winter rape were not favorable for a grower in 1980 and 1981. Price per pound of oil seed crops was in the range of 10 to 12 cents per pound. The location in the Pacific Northwest where this price was being paid varied; thus, a grower could have had considerable transportation costs in marketing. An increase in price per pound, an increase in production per acre, or a reduction in cost of production is needed to make most oil seed crops financially feasible for the grower.

FORMATION OF SOIL FROST AS INFLUENCED BY CROP RESIDUE MANAGEMENT

J. L. Pikul Jr.[1]

Frozen soil has been implicated as a major factor contributing to high soil erosion losses in the Pacific Northwest. Soil losses can be especially high during heavy rainfall or rapid snow melt when subsurface frozen soil layers are present. Serious erosion has occurred even on soils that were not frozen more than 12 centimeters deep. Consequently, differences in tillage and residue management could have significant effects on frost formation and hence erosion control. A frozen soil layer greatly reduces internal water movement much like a severely compacted soil does. This poor internal-drainage condition impairs water movement into the soil profile thereby increasing runoff and soil erosion.

Repeated soil freezing at night and thawing during the day, as occurs in late winter, is also suspected as a wasteful natural mechanism because it encourages evaporation rather than storing water in the soil. As the soil surface freezes, water migrates from deeper soil layers towards the freezing front, and then freezes. Because the frozen layers hold a large amount of

[1]Soil scientist, Columbia Plateau Conservation Research Center, USDA-ARS, Pendleton, Oregon 97801.

water, a thaw during the day often produces saturated conditions in soil layers near the surface. Evaporative water loss under these conditions is especially high because evaporation then proceeds at a rate similar to that for a free water surface.

Preliminary indications are that crop residue cover and tillage both have a significant impact on soil freezing. However, because of the difficulty of research involved, very little information is available on the mechanisms for frost formation and how management affects the processes involved. The objectives are to: 1) test and improve the prediction of soil frost based on commonly available meteorological information, and 2) determine which tillage, compaction and residue management techniques reduce the severity of soil frost in the winter and enhance water conservation during the summer.

METHODS

Field plots were established on a Walla Walla silt loam at the Columbia Plateau Conservation Research Center near Pendleton during 1979 and 1981. One 40-meter by 40-meter site was selected on a uniform 30-meter high wheat stubble field. In September one-half the area was burned, leaving a bare surface. On the remaining half, interrow chaff was redistributed uniformly over the soil surface. Surface residues were 9,000 and 13,500 kg/ha (4 and 6 tons/acre) for 1979 and 1981, respectively. To restrict our comparison to the presence and absence of surface residue we did no tillage.

Each plot was instrumented to measure soil temperatures at numerous depths down to 60 centimeters, air temperatures and windspeeds at various heights up to 120 centimeters above the surface. Both incoming and outgoing components of shortwave and longwave radiation were measured. Soil surface heat flux was measured with heat flux plates. Frost depth was measured daily during freezing weather by hand sampling.

RESULTS

Frost penetration and duration were different under burned stubble and standing wheat stubble during 1980 (Figure 1). Soil freezing began on January 17. Our first frost depth observations were made during a partial thaw on January 24. During the ensuing period from January 25 to February 1, the average air temperature dropped to -10.5°C and five centimeters of snow covered the plots. On February 2, the snow melted and partial soil thawing during the day followed by nighttime refreezing occurred through February 6. Maximum frost penetration during this freezing period was 28 and 20 centimeters in the burned and stubble plots, respectively. Average air temperature for the February 2 to 13 thaw period was 1.2°C. On the stubble plot, the ice lens had decomposed into a soft, poorly defined layer on February 10, but a hard, well defined ice lens remained in the burned plot until February 14.

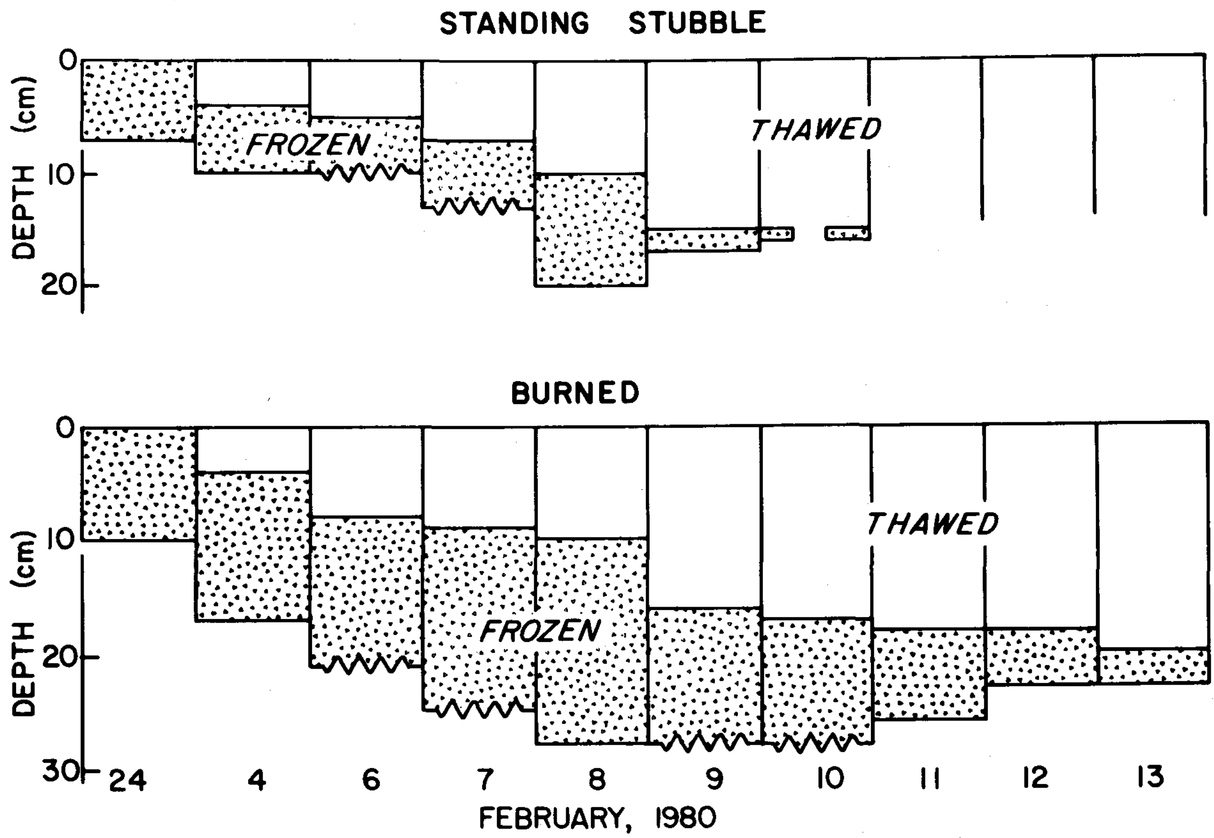


Figure 1. Depth of soil frost under standing stubble and burned stubble in late January and early February 1980

In 1982, frost penetration was again sensitive to the surface treatment, but the duration was nearly the same in both surface treatments (Figure 2). Soil freezing began February 3, but in contrast to 1980, there was no snow cover during the freezing period from February 3 to 9. Average air temperature for the freezing period was -6.3°C. Maximum frost penetration was 21 and 15 centimeters for the burned and stubble plots, respectively. Both plots were completely thawed on February 15, however the stubble plot thawed slightly earlier as evidenced by a decomposed, poorly defined ice lens on February 14.

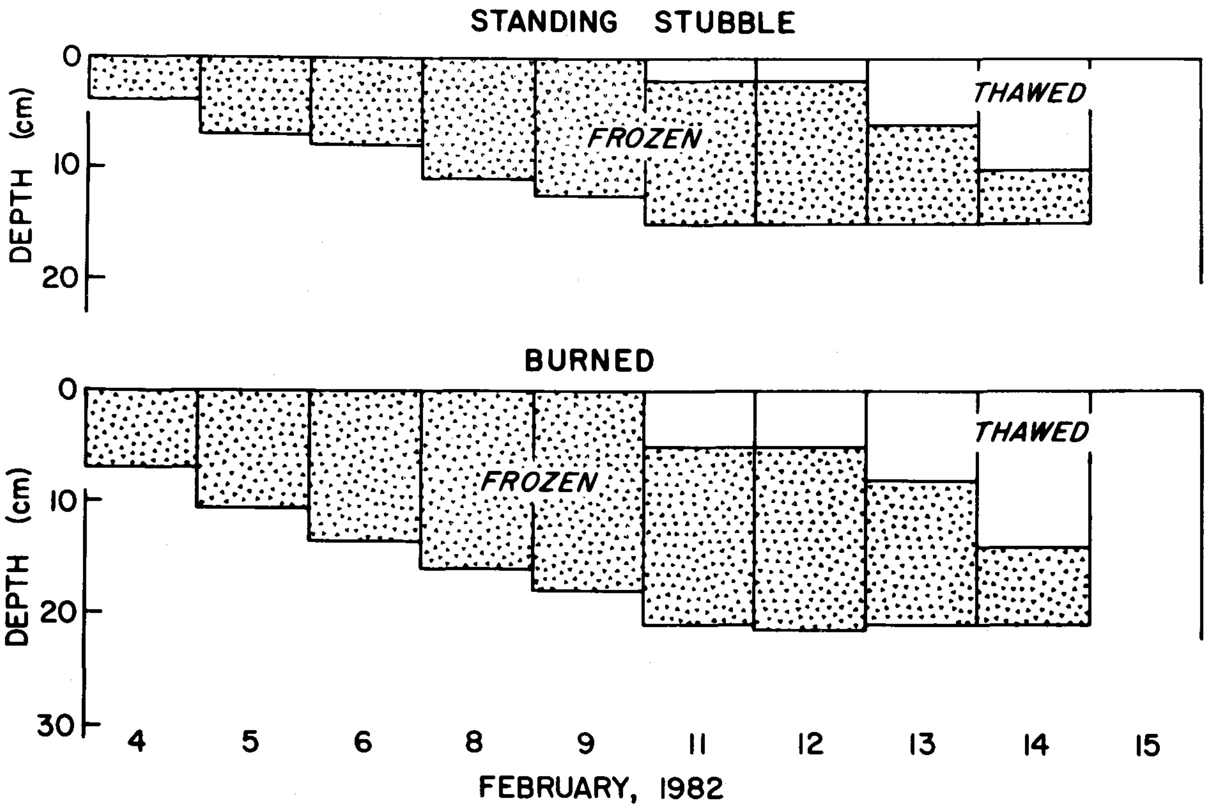


Figure 2. Depth of soil frost under standing stubble and burned stubble in early February 1982.

Soil heat flux was measured to understand causes for the different freezing depths in the stubble-covered compared to burned plots in 1980 (Figure 3). With the exception of the partial soil thaw on January 24, large heat losses (negative values) are associated with soil freezing. From January 25 to February 1, air temperatures remained below freezing and significant differences of soil heat loss occurred between the two plots. Standing stubble acted as a thermal insulating layer over the soil surface, and, therefore, reduced soil heat loss by 40 percent and reduced the depth of frost penetration by 30 percent as compared to the bare plot. The thawing period of February 2 to 13 was characterized by low air temperatures and cloudy conditions. Positive heat flux into the bare surfaced plot was 20 percent greater than into the standing stubble. Although heat input was greater on the bare surfaced plot, it was not enough to offset frost depth differences between the burned and stubble plots. Consequently soil thawing occurred five days later on the bare surfaced plot.

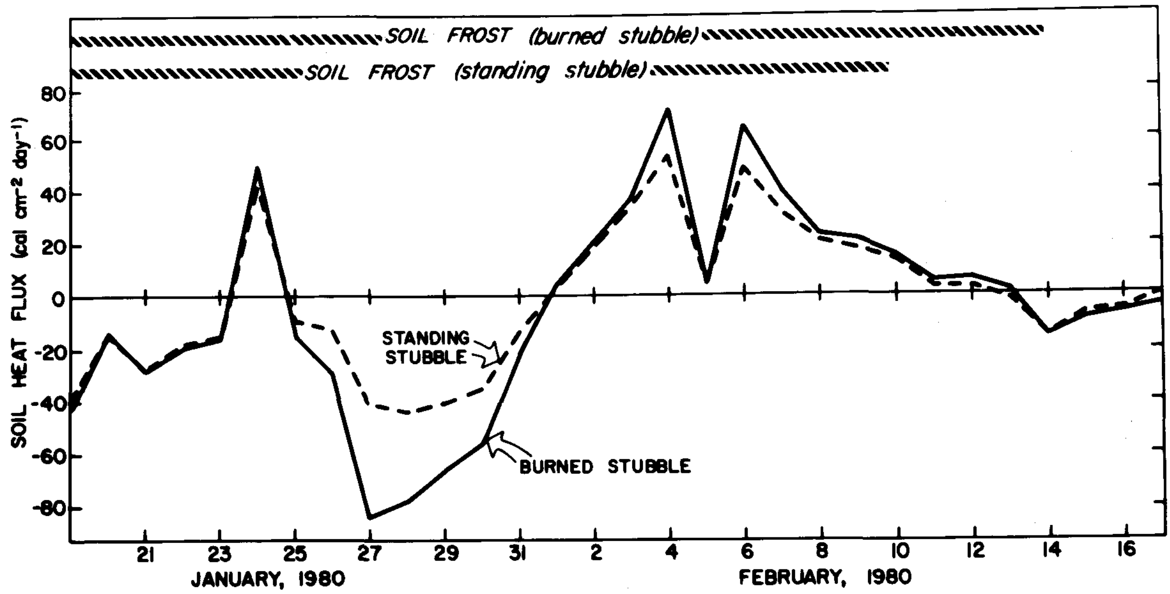


Figure 3. Soil surface heat flux for standing stubble and burned stubble in late January and early February 1980. Presence of soil frost is indicated by a solid bar.

In 1982, soil heat flux measurements during freezing and thawing were again sensitive to surface crop residue (Figure 4). At the onset of soil freezing, on February 3, both plots typically exhibited high heat loss. Significant heat loss differences between the two plots developed during February 4 to 9 when air temperatures remained below freezing. Standing stubble reduced soil heat loss by 20 percent and reduced the depth of frost penetration by 30 percent as compared to the bare surfaced plot. The rapid thawing period of 1982 was characterized by clear days and warm air temperatures (7.5°C). Heat flux into the bare surfaced plot was 40 percent greater than into the standing stubble. Both plots thawed the same day, because high heat input into the bare surface had offset the differences in frost depth.

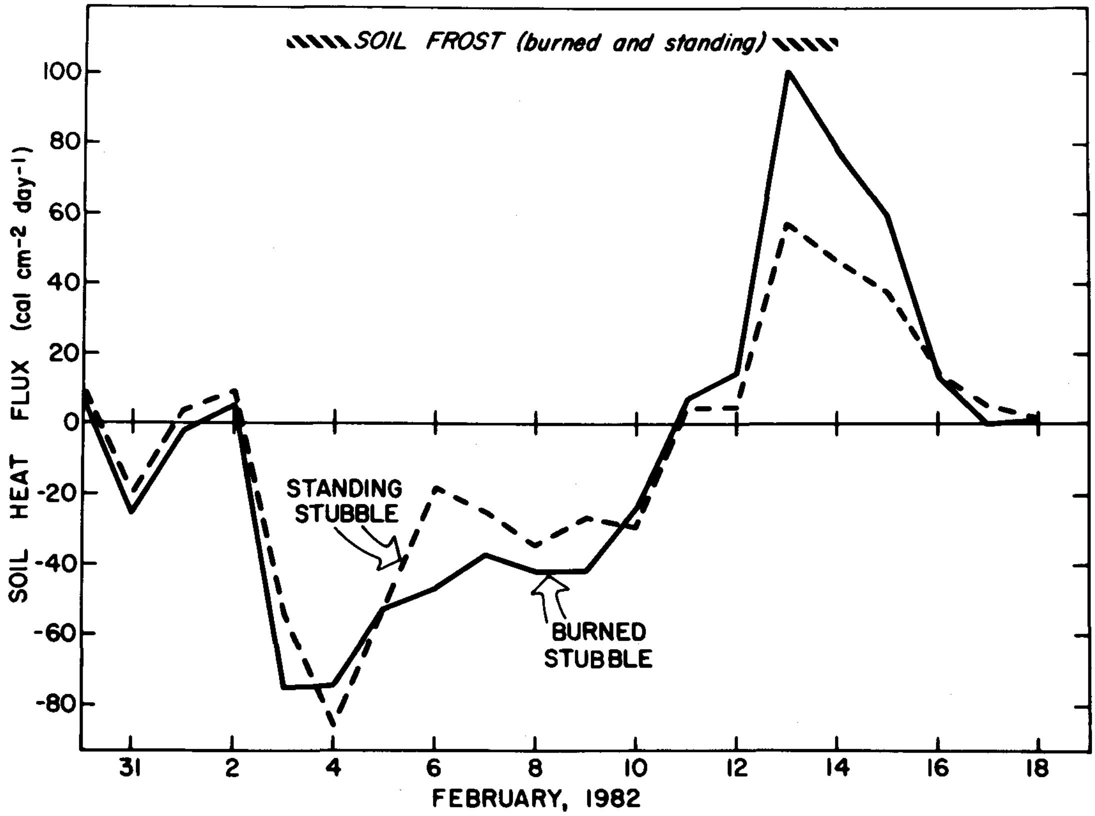


Figure 4. Soil surface heat flux for standing stubble and burned stubble in early February 1982. Presence of soil frost is indicated by a solid bar.

CONCLUSIONS

For the two winters of 1980 and 1982, standing stubble consistently reduced the depth of frost penetration by 30 percent as compared to a bare surfaced plot. However, the persistence of soil frost is linked to both the soil surface and the prevailing weather conditions during the thaw. Surface residue did not influence the duration of soil frost during the clear sky, rapid thawing conditions of 1982. But during the thaw of 1980, when cloudy and low daytime temperatures were accompanied by freezing to near-freezing nights, straw on the surface favored soil thawing. Weather conditions during the 1980 thaw would be typical for the moisture laden, frontal type storm systems of this area. Appreciable rainfall during the advance of the storm system would pose a serious erosion threat because a frozen layer impedes water infiltration from surface to subsurface layers. Soil frost is a liability for soil erosion. If frost is in the ground and rainfall exceeds the infiltration capacity, then conditions are prime for accelerated soil erosion.

SOIL EROSION IN A WHEAT-PEA ROTATION

J. F. Zuzel, R. N. Greenwalt, and R. R. Allmaras[1]

INTRODUCTION

For the last five years, we have operated an erosion research site on the Harold Kirk ranch, about 15 kilometers (9 miles) east of the Research Center. In the 1978 Research Progress Report we discussed the site and data obtained during the winter of operation. The research site consists of six plots; two have been maintained in continuous fallow. Two plots are seeded to winter wheat each fall, and two plots are seeded to peas each spring. Table 1 shows the site characteristics.

Table 1. Erosion research site characteristics

Characteristic	Description
Elevation	732 m (2400 ft)
Annual precipitation	533 mm (21 in)
Slope	NNW facing, 16%
Soil type	Thatuna silt loam
Internal soil drainage	Moderate to poor
Soil tolerance for erosion	6.7 tonnes/ha·yr (3 tons/A·vr)
Plot size	4.05 m X 33.5 m (13.3 ft X 110 ft)
Cropping sequence	Winter wheat-peas

[1]Hydrologist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon; research assistant, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon; and soil scientist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801.

OBJECTIVES

Two objectives of this study are as follows:

1. To measure and evaluate the effects of climate on the runoff and soil erosion process in relation to soil management, crop cover, and soil erodibility in the wheat-pea rotation.

2. To measure and evaluate factors of the Universal Soil Loss Equation (USLE) under the prevailing climatic and management conditions at the research site.

MEASUREMENTS

Air temperature, dewpoint temperature, windspeed, precipitation, solar radiation, and soil temperatures in the plow layer are measured during the erosion season. At least once a week we monitor ground water levels and measure the water equivalent of the snow. Collection tanks are equipped with continuously recording water level sensors from which runoff rates and volumes can be calculated during an event. These collection tanks are sampled to determine sediment concentrations after each major event.

PLOT MANAGEMENT

Conventional tillage practices similar to those found in a wheat-pea rotation are followed. All plots, including those in permanent summerfallow, are moldboard plowed cross-slope in late summer. Seedbed preparation for the wheat plots then consists of disking, spring toothing, and/or harrowing operations in an up-and-down-slope direction. Fifty-six kilograms/hectare (50 pounds/acre) of N is incorporated before planting with another 56 kilograms/hectare (50 pounds/acre) of N applied as top dressing in the spring. Plots to seed to peas in the spring are fall disked only, and then disked, spring toothed, and/or harrowed in the spring after 112 kilograms/hectare (100 pounds/acre) of 16-20-0 is applied broadcast. Seeding operations are performed in an up-and-down-slope direction using a double disk drill (7-inch spacing). All operations after moldboard plowing are done with a crawler tractor. Herbicides are applied when necessary for weed control. This final up-and-down hill direction is not a good practice but is done experimentally to give the practice (P) factor a value of 1 instead of some other unknown value less than 1, which is used for cross-slope planting.

The permanent summer fallow plots are prepared in the fall in the same manner as the wheat plots with a "simulated" seeding operation performed. In the spring, the plots are re-tilled identical to the pea plots and again receive a "simulated" seeding operation. Non-selective herbicides are used to maintain a black fallow condition on the perennial summer fallow plots. The fallow plots are not fertilized.

RESULTS

Wheat yields have averaged 4,368 kilograms/hectare (65 bushels/acre) and pea yields have averaged 3,635 kilograms/hectare (3,246 pounds/acre).

The USLE estimate for the wheat-pea rotation at this site is 15 tonnes/hectare (6.7 tons/acre) per year versus an observed 9 tonnes/hectare (4 tons/acre) per year. On continuous fallow, we observed a soil loss of 18 tonnes/hectare (8 tons/acre) per year; the USLE estimates 38 tonnes/hectare (17 tons/acre) per year. The soil loss tolerance value of 6.7 tonnes/hectare (3 tons/acre) per year average has been exceeded with poor management (up- and down-slope seeding, low residues) on the wheat-pea rotation. November to May precipitation has been 132, 99, 106, and 101 percent of normal for the four complete years of record (1978-1981). Table 2 summarizes the observed soil losses and runoff by plot for the period of record. Subsurface characteristics are a major factor in the generation of runoff.

Table 2. Observed runoff and soil loss and USLE predicted soil loss at the Kirk erosion site

Plot number	Treatment[1]	Runoff[2] mm/yr	Soil loss[3] Observed	Soil loss[3] Predicted by USLE
			- - - tonnes/hectare per year - - -	
1	W-P-W-P	28.5 (1.12)	11 (4.9)	15 (6.7)
2	P-W-P-W	18.4 (0.72)	3 (1.3)	15 (6.7)
4	W-P-W-P	61.2 (2.41)	20 (8.9)	15 (6.7)
6	P-W-P-W	13.4 (0.53)	3 (1.3)	15 (6.7)
Average		30.4 (1.20)	9 (4.0)	15 (6.7)
3	F	33.5 (1.32)	20 (8.9)	38 (17.0)
5	F	34.1 (1.34)	17 (7.6)	38 (17.0)
Average		33.8 (1.33)	18 (8.0)	38 (17.0)

[1]W is wheat; P is peas; F is permanent summerfallow

[2]Numbers in parenthesis are inches/year

[3]Numbers in parenthesis are tons/acre per year

A statistical analysis of yearly runoff and soil loss data shows a significant correlation between runoff volume and soil loss. Subsurface characteristics are a major factor in the generation of runoff. Shallow seismic and soil sampling data indicate a dense and slowly permeable layer underlying the site at depths of 120 centimeters (48 inches). Spatially discontinuous areas of high density-low permeability soils occur at 30 to 40 centimeters (12 to 16 inches).

The largest single year soil losses were observed during 1980 on Plots 1 and 4, when excessive soil compaction was produced by reseeding these plots to wheat under high soil moisture conditions. This compaction drastically reduced the infiltration rate and produced large runoff volumes and consequent soil loss.

A probabilistic analysis of 60 soil loss events from Plots 3 and 5 indicates that the probability of a soil loss event in excess of the soil loss tolerance value of 6.7 tonnes/hectare (3 tons/acre) is only about 20 percent. Also, 50 percent of the soil loss events from these plots can be expected to yield less than 3 tonnes/hectare (1.34 tons/acre). These low occurrence probabilities may help explain the USLE overestimates of erosion at this site. Frequency analysis of November-to-April rainfall records at the Columbia Basin Agricultural Experiment Station suggests we have not yet sampled during years of very high precipitation and probable high runoff. For this reason, the experimental site will be maintained in anticipation of observing some extreme events.

SUMMARY

1. The USLE apparently overestimates soil loss at the experimental site both for the wheat-pea rotation and the permanent summer fallow plots. However, the record is short and we have not yet observed the results of an extremely wet winter.

2. Poor subsurface soil drainage characteristics play a major role in runoff generation and soil loss on this Thatuna silt loam.

3. Fifty percent of the observed soil-loss events yields less than 3 tonnes/hectare (1.34 tons/acre).

4. Seeding or reseeding with high soil moisture conditions produces excessive soil compaction, reduced infiltration rates, increased susceptibility to soil freezing, and increased runoff and erosion.

SOIL COMPACTION AND ROOT DISEASES OF PEAS

R. R. Allmaras, J. M. Kraft, and J. L. Pikul Jr.[1]

INTRODUCTION

The National Agricultural Lands Study (January 1981) estimated that crop production losses from soil compaction in the United States in 1980 might have been as great as $3 billion, or 4 percent of the $70 billion total cash receipts for crops. Some experts think the loss estimate is too high; others think it is too low. But neither group has developed a set of factors to guide estimates of the overall damage. Does soil compaction produce adverse mechanical resistance to root growth, increase root disease hazard, accelerate runoff and erosion, impede soil drainage and delay field workability, or increase the draft associated with tillage? These are some of the many factors to be evaluated if soil compaction losses are to be more accurately estimated.

Some soil compaction is inevitably produced by tractive effort and passage of tillage machinery through the soil. Pea rooting is notoriously inhibited by soil compaction. We began to evaluate how much soil compaction is occurring, what effects it has on production and soil conservation, and what can be done to reduce any adverse effects. Our work thus far indicates that compaction drastically reduces internal drainage of a Walla Walla silt loam. This internal drainage reduction has many consequences to production and soil conservation, but we will limit our discussion to these internal drainage reductions and how they dominate the suite of root diseases in peas.

MATERIALS AND METHODS

Measurements of compaction and its effects were made on a Walla Walla silt loam in three fields as follows: land not tilled since 1913, land cropped for 30 years alternately to peas and wheat, and land cropped for 50 years to wheat-fallow. Field measurements included dry bulk density, organic carbon, pH, weight of coarse fragments, saturated hydraulic conductivity, and hydraulic head (with tensiometers). These measurements were made carefully enough to distinguish compaction and describe flow of water in the soil. Saturated hydraulic conductivity measures the rate of water flow through a saturated soil; hydraulic head describes wetness of the soil and the driving force for water flow. Counts of _Pythium ultimum_ and _Fusarium solani f. sp. pisi_ propagules in the soil characterize the potential for root rot damage in peas.

---

[1]First and last authors are soil scientists, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801; J. M. Kraft is a plant pathologist, USDA-ARS, Prosser Research and Extension Center, Prosser, Washington 99350.

RESULTS AND DISCUSSION

Locating a Zone of Compaction

Compacted zones can be located by several types of measurements but a spike in soil bulk density is the most common locator. In a wheat-pea rotation on a Walla Walla silt loam (Figure 1), the bulk density increased from 1.1 to 1.2 and back again to grams centimeters^{-3} within a depth increment of 10 centimeters (3.9 inches). A very careful measurement was needed to locate the compacted zone. This compacted zone may be called a pressure pan,

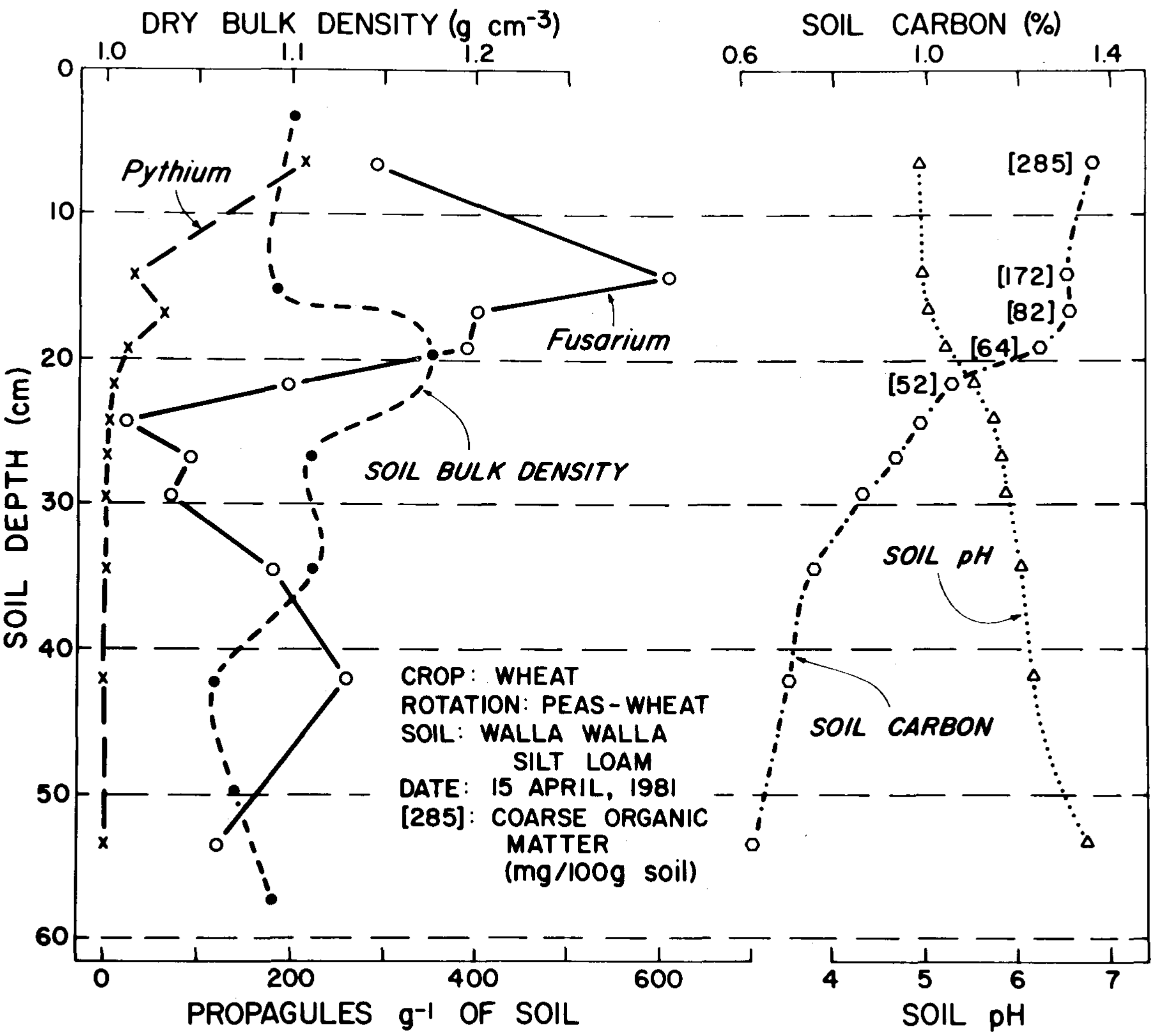


Figure 1. Typical pressure pan, associated soil chemical properties, and distribution of propagules of Pythium ultimum and Fusarium solani f. sp. pisi in a Walla Walla silt loam cropped to alternate peas and wheat.

tillage pan, traffic pan, plow pan, plow sole, or traffic sole because it was produced by both the tractor (traffic) and the plow. Scientists prefer to call this layer a pressure pan because it is "an induced subsurface soil horizon or layer having a higher bulk density (and lower total porosity) than the soil material directly above and below, but similar in particle size analysis and chemical properties."

The large decrease in soil carbon at the same depth as the spike in the soil bulk density (Figure 1) indicates that the pressure pan coincides with the depth of tillage. Further evidence of tillage depth was obtained by the large reduction in straw fragments (coarse organic matter) at about the 18-centimeter (7.1-inch) depth. The increase in pH from 5.0 to 5.5 at the 20-centimeter (7.9-inch) depth was produced by long-term use of NH_4^+-type fertilizers. These changes of soil carbon and soil pH in or near the pressure pan could be symptoms of a pressure pan changing to a hard pan. This trend could reinforce the adverse effects of soil compaction because hard pans usually denote "cementation caused by some chemical constituent."

Compaction Effects on Drainage

Internal drainage was measured in a wheat-fallow field that had soil compaction nearly identical to that in the wheat-peas field shown in Figure 1. A maximum bulk density spike of 1.3 grams centimeters^{-3} was found at 20 centimeters (7.9 inches).

Measurements of saturated hydraulic conductivity (Table 1) foretell that compaction could seriously reduce internal drainage of this Walla Walla silt

Table 1. Long term management and associated compaction effects on saturated hydraulic conductivity

Long term management	Depth of measurement (cm)	Saturated[1] hydraulic conductivity (cm/day)
Wheat-fallow	17 -- in pressure pan	1.6
	34 -- beneath pressure pan	34.4
Idle land[2]	18	7.2
	36	31.7

[1]Water movement rate when soil is saturated

[2]Personal communication indicates land was farmed for several years and then converted to a churchyard in 1913

loam. Under saturated conditions, water movement in the pressure pan of the wheat-fallow field would be at least 20 times slower than in soil layers below the pressure pan. In the idle soil, the beginning of a pressure pan may have occurred at the 18-centimeter (7.1-inch) depth during the few years of tillage before 1913. The saturated hydraulic conductivity of 1.6 centimeters/day (0.6 inches/day) within 20 centimeters (7.9 inches) of the surface indicates that the plow layer of this soil could easily be saturated during heavy late winter and early spring precipitation.

The pressure pan seriously slows internal drainage during winter as illustrated by the hydraulic heads versus time in Figure 2. Tensiometers were carefully placed above (17 centimeters; 6.7 inches) and below 25 centimeters; 9.8 inches) the pressure pan. The tensiometer at 60 centimeters (23.6 inches) indicated how fast the water penetrated after it had passed through the pressure pan. Beginning on October 11, hydraulic heads below the pressure pan were decreasing and the soil was wetting slowly as water from rains before October 1 penetrated through the pressure pan. A 2.5-centimeter (1-inch) rain on November 17 had excessively wetted the plow layer down to the 17-centimeter (6.7-inch) depth, but it then took almost 20 days and an additional 3.0 centimeters (1.2 inches) of rain to wet the soil just beneath the pressure pan. But still the soil remained dry (about 250 mbar) below the pressure pan. Whenever freezing air temperatures occurred, upward water movement occurred. Yet the soil below the pressure pan remained relatively dry. The relatively dry soil beneath the pressure pan and the slow water movement through the pressure pan both tell us that soil water drainage is super sensitive to compaction. In fact, we are planning to use drainage measurements to locate the pressure pans.

In an earlier field day report (June 1977) we showed that fall chiseling after wheat or pea harvest significantly improves drainage during the ensuing winter, but the drainage improvement disappears after normal field traffic associated with pea planting.

Compaction Effects on Root Diseases of Peas

Because compaction dominates internal drainage in a Walla Walla silt loam (Table 1 and Figure 2), an ideal environment has been provided for root diseases of peas. The depth-distribution of *Pythium* and *Fusarium* in Figure 1 is typical of that found in nearly all of about 20 fields surveyed in June 1981. *Pythium* propagules are found almost exclusively in the plow layer; occasionally a small cluster of propagules occurred in the pressure pan. This soil layer is usually quite wet during most of the winter and early growing season (Figure 2). *Pythium ultimum* is widely known for abundance in wet soil conditions; and the propagule count in Figure 1 is high enough to expect damaged juvenile pea roots.

Except in the middle of the pressure pan, *Fusarium* propagules are found throughout the upper 60 centimeters (23.6 inches) of soil. Apparently these propagules can be found wherever there are pea roots. The absence of propagules in the pressure pan and their high counts just below the pressure pan are related to both the impaired drainage from compaction and the well-known

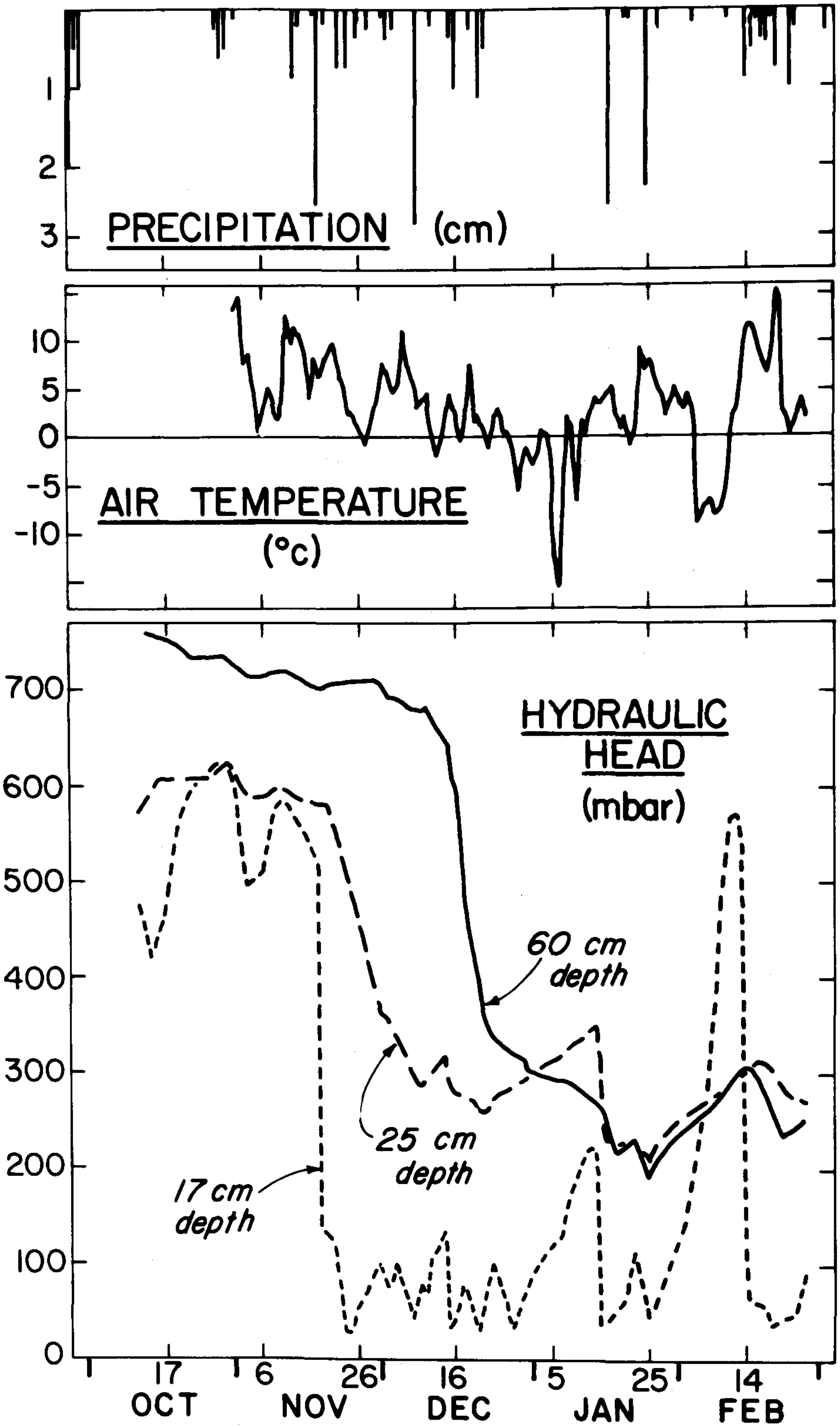


Figure 2. Precipitation, average daily air temperature, and hydraulic heads at selected depths in a compaction-affected Walla Walla silt loam during overwinter recharge (field was burned after harvest -- no tillage was performed).

tendency for Fusarium to thrive in moderately dry soil conditions. Fusarium propagules are absent in the pressure pan because they could not get established or were killed during anerobic conditions that undoubtedly existed during winter. Their presence in large numbers below the pressure pan is assured by the relatively dry conditions there even during the wettest periods of winter (Figure 2, 25-centimeter or 10-inch depth). The number of propagules in Figure 1 is enough to assure damage if there is any stress on the pea plant. In fields not planted to peas for a 10 to 20-year period, Fusarium propagules were found only below the pressure pan. This is additional evidence that the disease organism can live a saprophytic (no host plant) existence or remain dormant longer under the pressure pan, and that, when the host plant is available, these organisms can spread from this protected location throughout the profile including the plow layer.

CONCLUSIONS

Compaction produces and assures an ideal soil environment for the Pythium-Fusarium root-disease complex to survive and thrive. Following are several related research needs for pea production:

1. Fusarium propagules are available to infect the pea root throughout its whole life and depth -- thus an integration of tillage, variety, liming, and fertilization management is needed to reduce plant stress and damage to the roots.

2. Since some compaction is inevitable, research is needed to develop planters which break up the pressure pan just underneath the seeded row. Band fertilization should also be tested. Possibly these two practices together may accelerate early pea root development and reduce later stresses for water.

3. The long-term approach is to search for an introduced soil organism that antagonizes the Fusarium pathogen, because it is doubtful any other cultural practice can be developed to destroy the Fusarium propagule.

PRECIPITATION SUMMARY

Pendleton Station - Pendleton, Oregon

(Crop year basis, ie; September 1 through August 31 of following year.)

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
53 Year Average	.72	1.40	1.86	2.14	1.93	1.46	1.60	1.48	1.35	1.29	.32	.44	16.00
1964-65	.61	1.24	1.81	4.43	3.84	.47	.21	1.16	1.03	1.37	.75	1.33	18.25
1965-66	.20	.51	1.18	.45	2.35	.71	1.72	.51	.43	.99	1.14	.17	11.46
1966-67	.46	1.10	2.30	2.86	2.80	.32	1.51	1.60	.95	.55	.04	0	14.49
1967-68	.56	1.17	1.30	.76	.74	2.39	1.04	.21	.65	1.11	.34	.77	11.04
1968-69	.83	1.36	2.71	2.65	2.62	.78	.43	2.31	1.26	.75	.06	0	15.76
1969-70	.65	1.41	.44	2.39	5.23	1.50	1.87	1.05	.62	.85	.11	.05	16.17
1970-71	1.02	1.40	2.22	1.02	1.44	.77	1.28	1.65	1.66	3.14	.63	.33	16.56
1971-72	1.42	1.72	3.14	3.93	1.15	1.70	2.11	1.35	1.50	.91	.76	.35	20.04
1972-73	.49	.66	1.14	2.47	.89	.89	1.27	.58	1.03	.12	0	.09	9.63
1973-74	1.77	1.24	5.86	4.40	1.29	2.00	1.50	3.64	.38	.33	1.30	0	23.71
1974-75	.02	.35	1.56	1.76	3.73	1.68	.97	1.72	.68	.69	.05	1.38	14.59
1975-76	0	2.16	1.47	3.40	2.13	1.09	1.69	1.65	1.21	.58	.04	2.58	18.00
1976-77	.44	.53	.47	.59	.90	.57	1.72	.46	1.70	.31	.12	2.21	10.02
1977-78	1.54	.69	1.79	3.19	2.27	1.71	1.40	3.50	.81	1.27	.59	1.37	20.13
1978-79	1.61	0	1.68	2.28	1.31	1.54	1.74	1.82	1.15	.18	.12	2.08	15.51
1979-80	.17	2.56	2.31	1.05	2.85	1.55	2.12	1.20	2.45	1.42	.23	.18	18.09
1980-81	1.24	2.96	1.81	1.99	1.26	2.31	2.30	1.29	2.30	2.12	.40	.02	20.00
*1981-82	1.51	1.62	2.41	3.27	2.56	1.86	1.99						
17 Year Average	.77	1.24	2.02	2.33	2.16	1.29	1.46	1.52	1.16	.98	.39	.76	16.08

*Not included in 17 year average figures.

PRECIPITATION SUMMARY

Sherman Station - Moro, Oregon

(Crop year basis, ie; September 1 through August 31 of following year.)

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
71 Year Average	.59	.92	1.68	1.69	1.69	1.16	.94	.75	.79	.70	.20	.29	11.38
1963-64	1.63	.50	1.56	1.36	.60	.25	.60	.15	.08	1.30	.04	.18	8.25
1964-65	.16	.60	1.69	6.11	1.65	.16	.63	.72	.32	.59	.17	1.04	13.84
1965-66	.08	.36	2.07	.51	2.45	.54	.78	.06	.02	.13	1.31	0	8.31
1966-67	.47	.74	3.14	1.84	.91	.03	.55	1.47	.39	.32	0	0	9.86
1967-68	.26	.74	.84	.54	.97	1.04	.16	.10	.74	.10	.15	1.52	7.16
1968-69	.33	1.04	2.67	2.09	1.93	.44	.63	.84	.84	1.99	0	0	12.80
1969-70	.52	.76	.53	2.00	3.96	1.27	.88	.38	.33	.22	0	0	10.85
1970-71	.13	.68	2.36	1.21	1.63	.12	1.28	.84	.93	.81	.20	.09	10.28
1971-72	1.36	.45	1.50	1.03	2.25	.26	1.44	.40	.45	1.70	.07	.55	11.46
1972-73	.57	.43	.83	1.62	1.09	.34	.40	.21	.34	.25	0	.07	6.15
1973-74	.90	.85	3.70	3.99	1.29	.97	1.30	1.18	.38	.02	.41	0	14.99
1974-75	0	.37	1.02	1.39	2.01	1.47	1.25	.46	.53	.84	.40	1.26	11.00
1975-76	0	1.17	1.34	1.26	1.25	.93	.95	1.06	.14	.06	.79	1.17	10.12
1976-77	.04	.10	.43	.20	.18	.63	.50	.08	2.70	.28	.37	.90	6.41
1977-78	.88	.22	2.00	3.22	2.80	1.31	.74	1.42	.43	.44	.59	1.32	15.37
1978-79	.33	.01	.79	.69	1.59	1.54	.99	1.06	.28	.10	.07	1.05	8.50
1979-80	.53	2.59	2.23	.65	3.41	1.83	.94	.89	1.27	1.37	.16	.11	15.98
1980-81	.42	.79	1.73	2.95	1.52	1.22	.65	.41	1.06	1.15	.20	0	12.10
*1981-82	.92	.82	1.99	4.73	1.10	.72	.55						
18 Year Average	.48	.68	1.69	1.81	1.75	.80	.81	.66	.63	.65	.28	.51	10.73

*Not included in 18 year average figures.