# 1984 COLUMBIA BASIN AGRICULTURAL RESEARCH



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# COLUMBIA BASIN AGRICULTURAL RESEARCH

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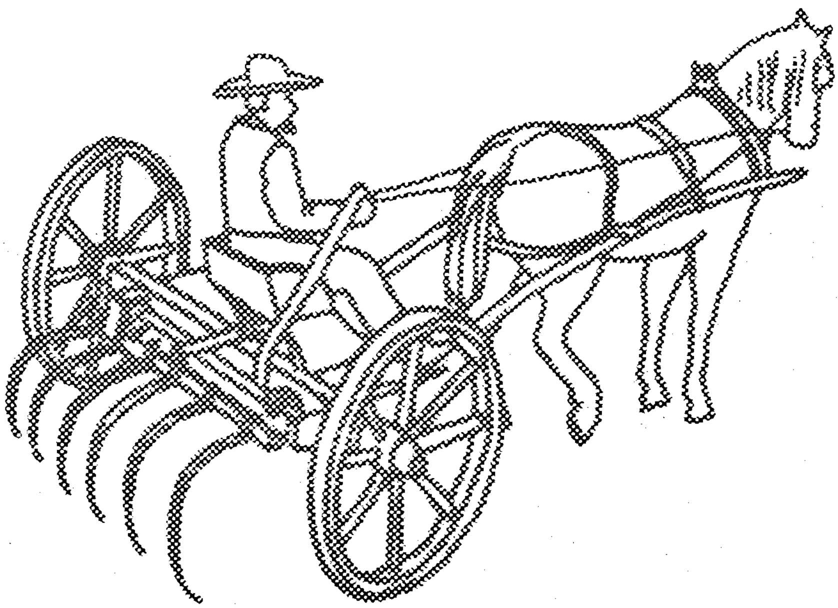

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# CEREAL BREEDING AND TESTING PROJECT

Charles R. Rohde, Charles R. Crampton, and Kathleen Van Wagoner[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 Cephlasporium stripe; 3) quick establishment in a high residue seedbed; 4) good emergence when seeded deep or when in low soil moisture in the seed zone; 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.

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Table 1. Yield data of winter wheat varieties tested in the lower yielding areas of eastern Oregon, 1978-1983

| Variety | Moro | Pilot Rock | Echo | Lexington | Heppner | Arlington | Condon | Average |
|---|---|---|---|---|---|---|---|---|
| | | | | (Bushels per acre) | | | | |
| Stephens | 55.5 | 43.0 | 32.4 | 43.5 | 43.1 | 40.9 | 32.9 | 41.6 |
| OR7996 1/ | 49.3 | 42.3 | 34.4 | 42.6 | 42.5 | 39.0 | 32.5 | 40.4 |
| Faro | 51.7 | 37.3 | 33.5 | 40.4 | 41.1 | 41.5 | 32.2 | 39.7 |
| Tyee | 51.5 | 41.6 | 29.1 | 38.6 | 43.2 | 39.0 | 34.3 | 39.6 |
| Jacmar | 53.9 | 37.6 | 31.2 | 38.2 | 36.4 | 43.6 | 35.6 | 39.5 |
| OR7794 1/ | 46.7 | 41.6 | 31.0 | 38.6 | 40.1 | 39.0 | 32.4 | 38.5 |
| Daws | 49.4 | 40.9 | 29.4 | 37.7 | 39.4 | 36.6 | 34.9 | 38.3 |
| Hill 81 | 49.0 | 40.6 | 31.1 | 38.1 | 39.3 | 37.1 | 31.8 | 38.1 |

1/ Varieties being considered for release to farmers.

Table 2. Yield data of winter wheat varieties tested in the higher yielding areas of eastern Oregon, 1978-1983

| Variety | Pendleton | Holdman | Weston | LaGrande | Flora | Baker 1/ | Average |
|---|---|---|---|---|---|---|---|
| | | | (Bushels per acre) | | | | |
| OR7996 2/ | 82.1 | 56.3 | 80.2 | 74.7 | 45.8 | 60.2 | 66.6 |
| Stephens | 77.0 | 53.2 | 76.3 | 74.8 | 51.8 | 40.1 | 62.2 |
| OR7794 2/ | 74.2 | 52.9 | 72.6 | 73.6 | 47.3 | 50.0 | 61.8 |
| Hill 81 | 71.6 | 48.8 | 67.8 | 78.5 | 53.0 | 44.6 | 60.7 |
| Tyee | 74.1 | 55.6 | 68.2 | 69.9 | 42.2 | 42.3 | 58.7 |
| Daws | 72.1 | 51.3 | 69.9 | 71.9 | 45.6 | 38.8 | 58.3 |
| Faro | 72.8 | 50.8 | 67.6 | 70.1 | 43.7 | 38.2 | 57.2 |
| Jacmar | 67.2 | 55.1 | 66.1 | 65.7 | 41.4 | 33.3 | 54.8 |

1/ Tested in 1979 and 1981 only.

2/ Varieties being considered for release to farmers.

Table 3. Yield data of winter wheat varieties tested under irrigation in eastern Oregon, 1978-1983

| Variety | Pendleton | Hermiston | Summerville | Average |
|---|---|---|---|---|
| | | (Bushels per acre) | | |
| OR7996 | 80.5 | 86.2 | 61.4 | 76.0 |
| OR7794 | 84.8 | 76.7 | 65.4 | 75.6 |
| Stephens | 80.0 | 79.5 | 63.9 | 74.5 |
| Hill 81 | 75.7 | 78.6 | 65.7 | 73.3 |
| Daws | 70.6 | 76.4 | 59.5 | 68.8 |
| Lewjain | 67.6 | 78.8 | 57.6 | 68.0 |

Table 4. Yield data of spring wheat varieties tested in lower yielding areas of eastern Oregon, 1978-1983

| Variety | Moro | Echo | Lexington | Heppner | Arlington | Condon | Average |
|---|---|---|---|---|---|---|---|
| | | | | (Bushels per acre) | | | |
| Dirkwin | 40.7 | 20.6 | 34.1 | 27.3 | 33.6 | 26.1 | 30.4 |
| Twin | 41.2 | 20.2 | 32.3 | 25.5 | 32.6 | 27.7 | 29.9 |
| Borah | 39.1 | 19.5 | 29.5 | 31.0 | 30.2 | 25.9 | 29.2 |
| Wared | 39.8 | 21.2 | 32.3 | 24.7 | 29.6 | 26.4 | 29.0 |
| Waverly | 39.0 | 21.8 | 27.5 | 25.2 | 26.9 | 26.4 | 27.8 |
| Owens | 39.2 | 19.4 | 28.8 | 24.6 | 28.7 | 25.7 | 27.7 |
| Wampum | 34.7 | 19.2 | 29.1 | 27.6 | 27.1 | 26.5 | 27.4 |
| McKay | 40.7 | 17.9 | 28.2 | 24.6 | 27.3 | 24.1 | 27.1 |
| Fieldwin | 34.9 | 18.5 | 27.7 | 26.0 | 27.7 | 26.0 | 26.8 |
| Yecora Rojo | 37.8 | 12.4 | 29.4 | 24.8 | 26.0 | 28.5 | 26.5 |

Table 5. Yield data of spring wheat varieties tested in higher yielding areas of eastern Oregon, 1978-1983

| Variety | Pendleton | Weston | Hermiston | LaGrande | Joseph | Baker | Average |
|---|---|---|---|---|---|---|---|
| | | | | (Bushels per acre) | | | |
| Dirkwin | 39.5 | 43.7 | 47.2 | 57.5 | 46.4 | 38.5 | 45.5 |
| Borah | 36.6 | 43.2 | 55.2 | 54.7 | 47.7 | 34.6 | 45.3 |
| Waverly | 36.0 | 40.9 | - | 60.0 | 48.5 | 40.3 | 45.1 |
| Crestone | 38.8 | 42.0 | 40.0 | 59.4 | 46.1 | 39.9 | 44.4 |
| Twin | 37.7 | 40.6 | 43.2 | 61.4 | 44.3 | 37.7 | 44.2 |
| Wampum | 34.1 | 39.0 | 47.8 | 58.6 | 46.2 | 36.2 | 43.6 |
| Owens | 34.3 | 41.7 | - | 64.1 | 42.8 | 33.6 | 43.3 |
| McKay | 33.9 | 40.7 | - | 55.6 | 39.7 | 32.1 | 40.4 |
| Wared | 35.2 | 39.4 | 46.3 | 46.5 | 38.8 | 34.9 | 40.2 |
| Yecora Rojo | 24.2 | 38.2 | - | 43.1 | 36.1 | - | 35.4 |

Table 6. Yield data of winter barley varieties tested in the lower yielding areas of eastern Oregon, 1978-1983

| Variety | Moro | Pilot Rock | Echo | Lexington | Heppner | Arlington | Condon | Average |
|---|---|---|---|---|---|---|---|---|
| | | | | (Pounds per acre) | | | | |
| Hesk | 3726 | 3107 | 2558 | 2944 | 2766 | 3029 | 2299 | 2918 |
| Scio | 3538 | 3139 | 2572 | 3043 | 3034 | 2714 | 2255 | 2899 |
| Steptoe (fall seeded) | 2907 | 3033 | 2623 | 3009 | 2509 | 2935 | 2908 | 2846 |
| Kamiak | 3153 | 2829 | 2750 | 2783 | 2344 | 2664 | 2170 | 2670 |
| Wintermalt | 3117 | 2700 | 2608 | 3088 | 2511 | 2525 | 1934 | 2640 |
| Hudson | 2823 | 2450 | 2671 | 2628 | 2063 | 2548 | 1927 | 2444 |



Table 7. Yield data of winter barley varieties tested in the higher yielding areas of eastern Oregon, 1978-1983

| Variety | Pendleton | Holdman | Weston | Hermiston | LaGrande | Summerville | Baker | Flora | Average |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | (Pounds per acre) | | | | |
| Scio | 6311 | 3592 | 4713 | 5708 | 4942 | 4783 | 1801 | 2934 | 4348 |
| Hesk | 5716 | 3447 | 4691 | 5685 | 5009 | 4730 | 1984 | 2414 | 4210 |
| Mal | 5806 | 3407 | 4770 | 5340 | 4898 | 4854 | 1485 | 2451 | 4126 |
| Boyer | 5737 | 3463 | 4679 | 5358 | 4978 | 4692 | 1715 | 2344 | 4121 |
| Schuyler | 5497 | 3748 | 4415 | 4598 | 4420 | 4513 | 1632 | 2459 | 3910 |
| Wintermalt | 5382 | 2808 | 3649 | 4689 | 4187 | 3876 | 1917 | 2072 | 3572 |
| Steptoe (fall seeded) | 4832 | 2714 | 3834 | 4227 | 4020 | 3996 | 1692 | 2288 | 3450 |

Table 8. Yield data of spring barley varieties tested in the lower yielding areas of eastern Oregon, 1978-1983

| Variety | Moro | Echo | Lexington | Heppner | Arlington | Condon | Average |
|---|---|---|---|---|---|---|---|
| | | | | (Pounds per acre) | | | |
| Steptoe | 3080 | 1840 | 2500 | 2489 | 2800 | 2432 | 2524 |
| Hector | 2994 | 1793 | 2370 | 2074 | 2581 | 2302 | 2352 |
| Gem | 2675 | 1458 | 2411 | 2272 | 2617 | 2385 | 2303 |
| Advance | 2684 | 1477 | 2281 | 2383 | 2509 | 2326 | 2277 |
| Cayuse (oats) | 2474 | -- | -- | -- | -- | -- | -- |

Table 9. Yield data of spring barley varieties tested in the higher yielding areas of eastern Oregon, 1978-1983

| Variety | Pendleton Irrigated | Weston | Hermiston | LaGrande | Joseph | Baker | Average |
|---|---|---|---|---|---|---|---|
| | | | | (Pounds per acre) | | | |
| Steptoe | 3766 | 3326 | 3466 | 4441 | 4397 | 3550 | 3896 |
| Kombar | 4142 | 3588 | 3730 | 4465 | 3231 | 3223 | 3730 |
| Gus | 4146 | 3072 | -- | 3870 | 4011 | 3259 | 3672 |
| Kimberly | 3482 | 3247 | 2689 | 3735 | 3723 | 3103 | 3458 |
| Advance | 3411 | 2992 | 2784 | 4039 | 4006 | 2714 | 3432 |
| Clark | 3628 | 2926 | -- | 3656 | 3368 | 2974 | 3310 |
| Klages | 3294 | 2988 | 2519 | 3462 | 3462 | 2791 | 3199 |
| Morex | 2843 | 2409 | -- | 2840 | 3536 | 2813 | 2888 |
| Cayuse (oats) | 3278 | -- | -- | -- | -- | -- | -- |

# WINTER SURVIVAL OF FALL PLANTED SPRING BARLEY IN THE COLUMBIA BASIN

Mathias F. Kolding[1]

Researchers, extension personnel, and seedmen are frequently asked about the winter survival of fall planted spring barley in Oregon. Questions about a particular barley's ability to survive the mild marine winters are probably more noticeable when: 1) several wet years have encouraged an increase of annual cropping where wheat may follow barley, 2) spring barley is used in the wheat fallow areas and survives as volunteers in the ensuing wheat crop, 3) winter crop loss was minimal during the preceding winters, 4) popular spring barley cultivars such as 'Steptoe' are hardier than expected, or 5) growers are more aware of admixtures in their cereal crops. Answers to grower questions about field survivability of different spring barleys are not readily available so several fall planted trials were established to observe survival differences.

## METHODS

Twenty-four spring barley selections were planted in three randomized block experiements with four replications of single 15-foot row plots spaced at 12 inches. They were planted at the Columbia Basin Agricultural Research Center near Pendleton on October 14, 1982, and at the research center near Hermiston on November 1 and November 15, 1982. Stand establishment was satisfactory. Survival observations were made in April 1983.

On August 31, 1983, a trial of 36 selections was planted in single 12-foot rows at the research center near Hermiston. In addition, two four-replication, randomized block trials with four row plots 15 feet long, spaced at 12 inches, were planted at the research center near Pendleton. One trial, planted October 17, had 18 entries; the other, planted October 17, had 15 entries. In mid-November, the 18-entry trial was sprayed with metribuzin at one-third pound of active ingredients per acre. The 15-entry trial received no herbicide. Plant stands were uniform and satisfactory before winter freezes. Survival notes were taken March 7, 1983.

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## RESULTS

None of the 36 selections and varieties planted August 31, 1983, survived the freezing temperatures of the 1983-1984 winter. 'Steptoe', 'OR M-1', 'OR M-3', and 'Clark' are some examples in this planting which did not survive at the Columbia Basin Agricultural Research Center near Hermiston, Oregon (Table 1). No winter damage was observed in the plots planted in the fall of 1982. The trial planted August 31, 1983, was a spring breeding screening primarily intended to estimate fall aphid damage and barley yellow dwarf virus infections. It demonstrates the sensitivity of larger plants to injury when exposed to cold temperatures. Some faster growing lines had headed by the first killing frosts.

Table 1. Winter survival of fall planted spring barleys at the Columbia Basin Agricultural Research Centers near Pendleton and Hermiston, Oregon

| Location planting date | | Pendleton 14 Oct 1982 | Hermiston 1 Nov 1982 | Hermiston 15 Nov 1982 | Hermiston 31 Aug 1983 |
|---|---|---|---|---|---|
| Variety or selection | | Survival index[1] | | | |
| 1. | Harrington | 9 | 9 | 9 | - |
| 2. | UT 1427 | 9 | 9 | 9 | - |
| 3. | OR M-1 | 9 | 9 | 9 | 1 |
| 4. | OR M-3 | 9 | 9 | 9 | 1 |
| 5. | Clark | 9 | 9 | 9 | 1 |
| 6. | Norbert | 9 | 9 | 9 | - |
| 7. | Gem | 9 | 9 | 9 | - |
| 8. | Ershabet | 9 | 9 | 9 | - |
| 9. | Advance | 9 | 9 | 9 | - |
| 10. | Briggs | 9 | 9 | 9 | - |
| 11. | Hector | 9 | 9 | 9 | - |
| 12. | Kombar | 9 | 9 | 9 | - |
| 13. | Steptoe | 9 | 9 | 9 | 1 |
| 14. | Empress | 9 | 9 | 9 | - |
| 15. | Diamant | 9 | 9 | 9 | - |
| 16. | WA969175 | 9 | 9 | 9 | - |
| 17. | Morex | 9 | 9 | 9 | - |
| 18. | Trebi | 9 | 9 | 9 | - |
| 19. | Klages | 9 | 9 | 9 | - |
| 20. | Otal | 9 | 9 | 9 | - |
| 21. | Paavo | 9 | 9 | 9 | - |
| 22. | E-804 (winter) | 9 | 9 | 9 | - |
| 23. | Stephens (wheat) | 9 | 9 | 9 | - |
| 24. | Hesk (winter) | 9 | 9 | 9 | - |

[1]Survival index: single character descriptor where 1 = less than 1% survival to 9 = more than 90% survival.

Spring barleys sown October 7, 1983, had a low rate of survival (Table 2). Spraying these plots with metribuzin may have influenced winter kill. Steptoe, which survived at greater than 90%, was the only variety surviving at levels greater than 10%.

Excellent differential winter survival was observed in the trial (Table 3) planted October 17, 1983. Survival indexes ranged from 2 for 'Minuet' to 9 for the winter barley 'Hesk'. The plants in this trial were at the three to four-leaf stage just before the first severe frosts.

Table 2. Winter survival of 18 spring barley selections planted October 7, 1983 and sprayed with one-third pound per acre active ingredient of metribuzin in November, 1983 at the Columbia Basin Agricultural Research Center, near Pendleton, Oregon

| Selection | Index[1] | Selection | Index[1] |
|---|---|---|---|
| 1. Steptoe | 8 | 10. FB80514 | 1 |
| 2. OR M-1 | 1 | 11. FB80516 | 1 |
| 3. OR M-3 | 1 | 12. FB80519 | 1 |
| 4. FB741209 | 1 | 13. FB80520 | 1 |
| 5. Kombar | 1 | 14. FB80521 | 1 |
| 6. Diamant | 1 | 15. FB80522 | 1 |
| 7. FB741206 | 1 | 16. FB80506 | 1 |
| 8. Summit | 1 | 17. FB757318 | 1 |
| 9. FB80512 | 1 | 18. FB757175 | 1 |

1 Survival index: single character descriptor where 1 = less than 1% survival to 9 = more than 90% survival.

Table 3. Winter field survival indexes of spring barleys sown October 17, 1983 on the Columbia Basin Agricultural Research Center near Pendleton, Oregon

| Variety | Survival index[1] | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | Average |
| 1. Hesk (winter check) | 9 | 9 | 9 | 9 | 9.0 |
| 2. Steptoe | 9 | 9 | 8 | 9 | 8.7 |
| 3. OR M-3 | 9 | 8 | 9 | 8 | 8.5 |
| 4. Trebi | 9 | 9 | 8 | 8 | 8.5 |
| 5. Morex | 8 | 7 | 7 | 7 | 7.2 |
| 6. Sunbar 560 | 7 | 6 | 6 | 7 | 6.5 |
| 7. Lewis | 3 | 6 | 4 | 6 | 4.7 |
| 8. Sunbar 550 | 5 | 4 | 4 | 5 | 4.5 |
| 9. Piston | 3 | 4 | 3 | 2 | 3.0 |
| 10. Harrington | 2 | 2 | 2 | 4 | 2.5 |
| 11. Klages | 2 | 3 | 2 | 2 | 2.2 |
| 12. Minuet | 2 | 2 | 2 | 2 | 2.0 |

1 Winter field survival index used for spring barleys (1 to 9) where
1 = less than 1% survival -- Considered very tender
2 = up to 25% survival
3 = 25% to 35% survival
4 = 35% to 45% survival
5 = 45% to 55% survival
6 = 55% to 65% survival
7 = 65% to 75% survival
8 = 75% to 85% survival
9 = More than 85% survival -- Hardy

## SUMMARY

Where spring frosts occur after barley seedling emergence, frost tolerance may save having to reseed. As expected, fall planted spring barleys had differential winter survival rates. Part of the difference in survival is accidental, and part may result from a selection's ability to survive spring freezes, since survival may have been a factor when it was picked as a superior line in breeders yield trials.

Some winters are so mild that most volunteer spring barley germinating in early September survives, but in most years plants have grown to such size that they lose their ability to harden in winter. Late fall germination of volunteer barley, as a result of dry summers, or delayed tillage practices, encourages smaller plants that harden more readily and are less susceptible to winter kill. Varieties appear to differ in cold hardening ability.

Herbicides, such as metribuzin when sprayed before freezes, may physiologically activate varieties so they are killed when exposed to freezing temperatures.

Growers, plagued with volunteer spring barley in ensuing wheat crops, need information about the tenderness of the variety they are using. They can evaluate that tenderness as a deleterious factor when exposed to spring freezes against possible volunteer survival the following winter.

More information about varietal winter survival is needed and several trials will be established in the fall of 1984.

# FORECASTING FOOT ROT OF WINTER WHEAT

A. P. Grybauskas and R. L. Powelson[1]

## INTRODUCTION

Pseudocercosporella herpotrichoides, causal agent of foot rot of winter wheat, is endemic to the winter wheat-growing regions of the Pacific Northwest (PNW). Depending on various climatic and agronomic factors, the severity of foot rot outbreaks varies considerably from year to year. Management practices like delayed seeding have been shown to reduce disease severity. Unfortunately, early seeding is important in the stabilization of soils in the hilly wheat-producing regions against wind and water erosion. It also allows many cultivars to approach their yield potential more often. During years with mild winters and prolonged cool-wet springs, unacceptable levels of disease occur. Management of foot rot, therefore, may require the use of fungicidal sprays since none of the cultivars grown have a high level of disease resistance.

Fungicides that produce methyl benzimidazole carbamate (MBC) are known to be effective in reducing P. herpotrichoides infections and to increase yields.

Economical use of these fungicides requires an assessment of the risk of severe disease for each particular field or portion of a field. Fungicide applications for the control of foot rot are made in late winter through early spring. Disease assessments during that time are not only difficult but also are poor indicators of disease outcome and, therefore, of fungicide need. Forecasting systems are risk assessment schemes based on observations, experimentation, and information from the literature. The relative importance of individual factors contributing to increased risk are given an arbitrary score, e.g., 1-4, and then the sum of the scores for the factors constitute a forecast score. The success of these systems is difficult to assess because none of the authors have published verification data, and some of the factors are relative to local practices. This study was undertaken to develop a forecast of P. herpotrichoides applicable to the PNW, and to investigate improvements of the score-sheet system through the use of multiple regression analysis.

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## MATERIALS AND METHODS

A data base was collected over two seasons (1979-1980 and 1980-1981) from 39 commercial winter wheat fields, representing a wide range of production areas (25 to 105 centimeters (10 to 42 inches) annual precipitation in Oregon. Sites were selected in late winter through early spring with the aid of Extension agents and fieldmen for commercial agricultural chemical dealers. The selection was based on site disease history and visual inspection of plants for disease incidence. Sites determined by cooperators to require a MBC-generating fungicide (benomyl) for control of foot rot had three 3.6 x 6.1 meters (11.8 by 20.0 feet) plastic tarps placed in the fields at the time of application. These were removed shortly after spraying. The tarped areas thus provided three replicated areas of untreated wheat, interspersed between three replications of treated wheat.

Disease incidence and growth stage of the plants were recorded as close to the time of fungicide application as possible. Background data with respect to disease history, agronomic practices, and edaphic characteristics of the site were obtained directly from the growers or by inspection. Climatological data were obtained from the closest meteorological station. Plant samples for the assessment of disease incidence and severity (proportion of tillers with at least half of the culm diameter necrotic) were obtained in June. Yields were determined in July by hand harvesting 2 rows 1.2 or 2.4 meters (4.8 or 9.6 feet) long from the center of each experimental unit.

## RESULTS AND DISCUSSION

The 1979-1980 and 1980-1981 growing seasons were generally conducive to disease development. There were no sites in the study without *P. herpotrichoides*-infected plants, even though some sites were selected for low-disease history and no visual symptoms in spring. In general, 15 of the 21 sites examined in the 1979-1980 season had greater than 70% disease incidence, and nine had greater than 50% severely infected tillers by the end of the season. The 1980-1981 season produced eight of 17 sites with a disease incidence at the final assessment of 70% or greater, and nine sites with at least 50% of the tillers with severe lesions (Table 1).

### Predictive Models

Individually, none of the disease, agronomic or meteorologic factors collected could be utilized as predictors of disease outcome (Table 2). For example, the correlation coefficients for seeding date with yield loss and disease incidence were 0.446 and 0.376, respectively. Several previous studies have shown that delayed seeding reduces disease severity. The poor correlation for this well-documented effect illustrates the complexity of disease development over a wide range of cultural and environmental conditions and thus the need to examine multiple factors. Regression models that

Table 1. Mean incidence and severity of foot rot for benomyl-sprayed and unsprayed plots examined during the 1979-1980 and 1980-1981 growing seasons

**1979-1980**

| Site[1] | Incidence[2] spray | Incidence[2] check | Severity[3] spray | Severity[3] check |
|---|---|---|---|---|
| M2 | 15.4 | 34.9 | 4.3 | 23.1 |
| P1 s | 53.7 | 77.0 | 13.5 | 26.7 |
| U10 | 95.4 | 98.7 | 67.3 | 84.5 |
| U11 | 77.5 | 78.7 | 30.4 | 30.6 |
| U12 | 48.9 | 88.2 | 22.4 | 53.2 |
| U14 | 33.4 | 41.8 | 9.5 | 16.1 |
| U1 | 52.8 | 88.0 | 21.7 | 38.7 |
| U2 | 35.4 | 87.7 | 15.0 | 59.0 |
| U3 | 18.7 | 66.4 | 8.3 | 28.1 |
| U4 | 47.3 | 89.0 | 32.1 | 74.6 |
| U5 | 50.3 | 94.9 | 15.2 | 80.2 |
| U6 | 44.6 | 97.8 | 18.4 | 68.2 |
| U7 | 54.7 | 90.7 | 24.9 | 61.9 |
| U8 | 52.8 | 83.6 | 34.7 | 54.2 |
| U9 | 22.4 | 33.7 | 5.3 | 16.7 |
| W1 s | 37.1 | 44.8 | 10.7 | 1.37 |
| W2 s | 4.7 | 18.4 | 0.6 | 3.6 |
| W3 s | 38.1 | 71.1 | 13.1 | 27.9 |
| Y1 | 47.5 | 88.9 | 23.9 | 37.3 |
| Y2 | 49.6 | 89.3 | 18.9 | 63.7 |
| LSD. (.05)[4] | 19.8 | | 16.3 | |

**1980-1981**

| site | Incidence spray | Incidence check | Severity spray | Severity check |
|---|---|---|---|---|
| U9 | 17.5 | 58.0 | 10.4 | 41.6 |
| U7 | 25.7 | 97.5 | 17.7 | 95.1 |
| U4 | 12.0 | 17.1 | 5.1 | 7.9 |
| U11 | 17.5 | 53.9 | 7.2 | 24.2 |
| U1 | 8.4 | 30.1 | 3.8 | 21.4 |
| U6 | 2.3 | 87.7 | 13.0 | 75.5 |
| U5 | 49.7 | 91.4 | 27.1 | 82.2 |
| U8 | 22.4 | 74.1 | 8.5 | 58.0 |
| U3 | 1.3 | 11.3 | 0.6 | 6.6 |
| U2 | 17.5 | 50.5 | 11.1 | 15.0 |
| U13 | 19.8 | 17.4 | 8.2 | 7.0 |
| P1 | 15.5 | 98.6 | 10.0 | 75.9 |
| La1 | 21.0 | 57.3 | 11.0 | 52.3 |
| L1 | 42.2 | 79.7 | 24.3 | 73.7 |
| Y1 | 85.9 | 99.6 | 57.7 | 90.5 |
| M1 | 58.4 | 89.4 | 49.4 | 81.8 |
| LSD. (.05)[4] | 28.1 | | 22.6 | |

[1] Site codes followed by (s) indicate supplementary sites that were determined by cooperators not to require fungicide application.

[2] Mean percentage of disease incidence based on 100 tillers per replicate, up to three replications per site.

[3] Mean percentage of disease severity (tillers with at least half culm diameter necrotic) based on 100 tillers per replicate, up to three replications per site.

[4] Difference required between sprayed and unsprayed plots within a site for significance at P = 0.05.

Table 2. Correlation coefficients for foot rot incidence, severity and resultant yield loss correlated with various factors

| Factor | Factor description | Disease incidence[2] | Disease severity[1] | Yield loss[3] |
|---|---|---|---|---|
| SDEPTH | Seeding depth from original soil surface | -.400 | -.342 | -.385 |
| TILLAGE | Moldboard, disc or low till | -.546 | -.616 | -.432 |
| SDATE | Seeding date, continuous numbering from Sept. 1 | .376 | .228 | .446 |
| SRATE | Seeding rate (lbs/acre) | .355 | .396 | .434 |
| RSPACE | Row spacing in inches | -.597 | -.531 | -.431 |
| HSTROT | Foot rot history | .176 | .327 | .198 |
| DIMID | Disease incidence in March | .323 | .394 | -.007 |
| GSNOV | Zadoks _et al_. growth stage mid November | -.294 | -.189 | -.277 |
| HTSDTSP | Heat sum median temp seed date to spray date | -.421 | -.208 | -.472 |
| HTSDSPED | Heat sum effective day temp seed to spray date | -.362 | -.179 | -.428 |
| HTSDSPEN | Heat sum effective nite temp seed to spray date | -.451 | -.239 | -.491 |
| R01SDTSP | Sum rain days $\geq$ 0.1 in. seed to spray date | .673 | .556 | .586 |
| WRSDTSP | Wang rainy days sum seed date to spray date | .676 | .618 | .586 |
| WR2SDTSP | Wang rainy days/2 sum seed date to spray date | .505 | .418 | .557 |

[1]Mean percentage of disease incidence based on 100 tillers per replicate, up to three replications per site.

[2]Percentage of tillers with severe lesions (greater than half culm diameter necrotic).

[3]Yield loss relative to spray yield [1-(check yield/spray yield) x 100]. Positive coefficients increase yield loss; negative coefficients decrease yield loss.

utilized variables mimicking those found in the published score-sheet systems had $R^2$ values of 0.50 when only five variables were included, and increased up to 0.74 when 12 variables were included. In the model with five variables, only one, standard rain event summed from seed date to spray date, had a significant regression parameter. Addition of any new variables improved the proportion of total variance accounted for, but also made all the regression parameters not significant.

The best model was obtained by using the stepwise procedure and limiting the number of variables in the model based on the significance of the regression parameters. The model was

$$DIGT2 = 1.08 + 0.04\ RSF + 0.20\ SDEPTH - 0.05\ RSPACE$$

where: DIGT2 was proportion of severely infected tillers, FSF was daily rain score, summed from September through February; SDEPTH was seeding depth in inches from the original soil surface; and RSPACE was row spacing in inches. The $R^2$ value for this model was 0.74, and the significance of the regression parameters were: P = 0.0469 for the constant; P = 0.0012 for RSF; P = 0.0084 for SDEPTH; and P = 0.0231 for RSPACE.

The linear function that predicted disease severity at the end of the season, from data that could be collected by mid-season (March 1), was composed of agronomic variables and a transformed climatic variable. The rain score variable relates rain intensity to new infections. It was a good component of the predictor because both disease incidence and severity, at the end of the season, had a correlation coefficient of 0.91. It also indirectly characterized length of wet periods conducive to disease development. The other two variables, seeding depth and row spacing, were important in characterizing the microenvironment of the infection court.

The actual depth of seed placement was at most 1.5 inches, but many growers in the dryland growing regions use deep-furrow drills to place the seed into moisture at the time of seeding. The furrow openers can place the seed up to 4 inches below the original soil surface and then cover the seed with 0.5 to 1.5 inches of soil. The furrows eventually erode because of wind and rain. This erosion of the furrows would bring inoculum into contact with culm tissue, concentrate splashed inoculum, and protect the infection court from desiccation after infection has occurred.

Row spacing has been previously implicated as a factor in disease severity development, in particular in years when growing seasons are not very favorable to disease development. The wider spacings would produce subcanopy conditions which would be less favorable for disease development. The weather during the two seasons of this study was favorable, even in the late spring, for lesion development. The wider row spacings could reduce the probability of successful hits and thus affect disease incidence and severity directly. Wider row spacing and deep-furrow drilling are techniques used by growers in the lower-rainfall areas. The two variables may be in the model simply because they indirectly classify the climatic conditions of the site.

## Foot Rot Yield Loss Threshold, Model

Yield per unit area is a function of the number of fertile tillers per unit area, the number of seed set per head, and the quality of the grain (weight per kernel). Any factors that affect any of these three main components directly or indirectly will affect yield. P. herpotrichoides has been implicated as a factor in all three components under certain conditions. Greatest yield losses occur when the pathogen infects host tissue early, and when conditions are optimal for maximum lesion development, thereby killing some tillers early in the season. Foot rot also reduces the number of seeds set and causes lodging which affects grainfill, greatly reducing seed quality. It is important to know the minimum yield losses that can be expected for particular levels of infection, and the lowest proportion of infected tillers that cause significant yield losses (Table 3).

Table 3. Predicted yield-loss intervals and actual yield losses caused by Pseudocercosporella herpotrichoides foot rot

| Percent severe foot rot | Predicted yield loss interval (%)[1] | Actual yield loss (%)[2] |
|---|---|---|
| 19 | $-2.4 \leq$ mean loss $\leq 15.3$ | 0 |
| 30 | $2.5 \leq$ mean loss $\leq 20.1$ | 18.7 |
| 54 | $13.1 \leq$ mean loss $\leq 30.7$ | 26.1 |
| 71 | $20.6 \leq$ mean loss $\leq 38.3$ | 27.4 |

[1]Probability of 0.95 that prediction interval contains the mean.

[2]Yield loss relative to 19 percent severe foot rot level.

A yield-loss equation was developed from these generated data by first converting the yield component to a percentage, based on the mean value for no effect on the number of kernels per head in the original data. Combinations of infected and uninfected tillers were then used as the data in the regression. The resulting relationship had an $R^2$ value of 0.93 and was of the form:

$$YL = -1.96 + 0.44\ SF$$

where YL was the percentage yield loss, and SF was the percentage of infected tillers with severe foot rot.

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# TILLER, LEAF AND ROOT APPEARANCE IN WINTER WHEAT: UNSTRESSED AND STRESSED DEVELOPMENT PATTERNS

R. W. Rickman and Betty Klepper[1]

## INTRODUCTION

Conservation tillage techniques provide improved erosion control over conventional seedbeds. Unfortunately, a seedbed that is ideal for controlling erosion can be unfavorable for establishment and growth of a wheat seedling. Such factors as high surface residues, cloddiness, and erratic moisture lines combine to cause potential problems with stand establishment. As new drill machinery is designed to minimize effects of these problems, techniques are needed to assess impacts of seedbed stresses on seedling vigor. This paper describes the developmental pattern of unstressed wheat plants and shows how this normal pattern is changed when seedlings are stressed.

## LEAF, TILLER, AND ROOT NAMING SYSTEM - NODES OF THE PLANT

To describe a wheat plant, we number each leaf, tiller and root with the number of the node from which it forms (Figure 1). The first node in the crown (Node 1) bears the first leaf (L1) and the first tiller (T1) as well as the roots associated with this node (1A, 1B, 1X, 1Y). The successive leaves of wheat are produced on alternate sides of the stem so the base of the second leaf (L2) is immediately above Node 1 on the opposite side of the stem from L. The main stem nodes are numbered successively up the stem beginning at the bottom of the crown where Node 1 is normally found. Below the crown are three more nodes. The coleoptilar node, located just below Node 1, is given the number "0" and the two nodes below it are given negative numbers (-1, -2). These negative numbered nodes are present in the seed and produce the seminal roots.

The nodes which form the crown of a wheat plant (usually Nodes 1 through 6) all are produced after the plant has germinated.

Tiller leaves, roots, and subtillers also develop from nodes which make up the tiller itself. Two digit numbers identify tiller nodes (10, 11, 20, ...) and three digit numbers are used for subtillers (100, 101, ...).

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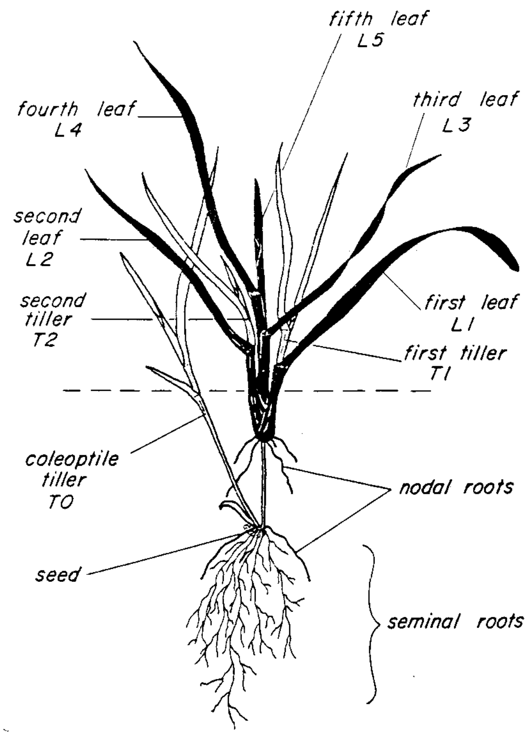



Figure 1. Winter wheat plant with labeled leaves, tillers, and roots.

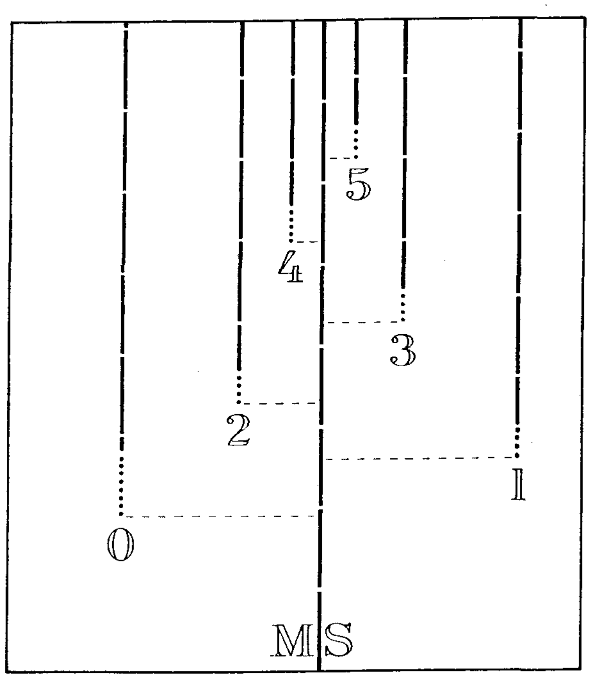



Figure 2. Diagram of leaf and tiller development pattern for wheat.

## SHOOT DEVELOPMENT PATTERN

The leaves on the main shoot (MS) of wheat elongate successively with the same amount of "biological time" being required for elongation of each leaf. The main shoot is the stack of nodes -2, -1, 0, 1, 2... through the node which produces the flag leaf. As the fourth leaf (L4) elongates, T1 appears in unstressed plants (Figure 2). This tiller continues to develop in lock-step with the MS once it begins so the number of leaves on T1 and on the MS always will remain offset by about three. For example, an unstressed wheat plant with 5.2 leaves on the MS will have a little more than two leaves on its T1. The general scheme presented in Figure 2 applies to all varieties of wheat, both winter and spring, both red and white. The steps of biological time represented by the small breaks in the vertical lines in the figure are called "phyllochrons". A phyllochron is the length of "biological time" it takes for a leaf to elongate. For example, it is the length of time it takes to go from a mainstem leaf number of 4.2 to one of 5.2.

This same pattern of leaf and tiller development is presented in the lower right one-half of Figure 3. To find the number of leaves and tillers on a plant with Figure 3, a vertical line that we call an "age line" is drawn upward from the bottom of the figure. For example, an age line from five phyllochrons after emergence in Figure 3 intersects the sloping lines representing T3, T2, T1, T0, and main stem. An unstressed plant five phyllochrons old will have each of these tillers formed. A horizontal line or a straight edge placed across the figure from left to right where the age line hits a tiller line will permit reading the number of leaves on that tiller from the right side of the figure. With the age line at five phyllochrons, the main stem will have five leaves, T0 will have 3.2 leaves, T1 will have 2.5 leaves, and so on.

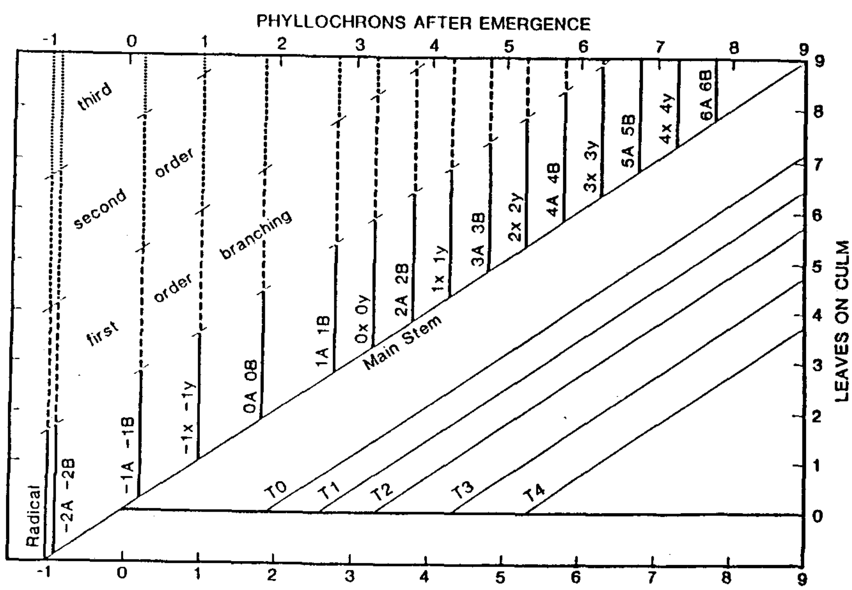



Figure 3. Diagram of leaf, tiller, and root development pattern for wheat.

## BIOLOGICAL TIME OR GROWING DEGREE DAYS

The measurement of "biological time" under field conditions is by the use of cumulative growing degree days (GDD) with a zero centigrade base temperature. The use of GDD for predicting and comparing wheat development under field conditions was discussed in the 1983 Columbia Basin Agricultural Research, Special Report 680. To calculate base zero GDD's, follow these steps:

1. Obtain daily maximum and minimum Fahrenheit temperatures from planting to the present for a location close to the field you are interested in.

2. Calculate the average Fahrenheit temperature each day from

$$\frac{\text{Max} + \text{Min}}{2}$$

3. Convert this average temperature from Fahrenheit (F) to centigrade (C) degrees with this formula

$$C = \frac{5}{9}(F-32)$$

4. Add together all of the positive values from planting to the present to obtain the cumulative GDD's for the crop. Table 1 shows an example of this calculation.

The computations of GDD in the 1983 report mentioned above used a base temperature of 3 centigrade. Be sure not to mix computations and growth estimates from GDD's calculated using different base temperatures.

Under most Pacific Northwest planting conditions, it takes from 130 to 150 base zero GDD's for emergence and 90 to 100 base zero GDD's for each leaf to elongate. For example, if 500 GDD's had passed since planting, one would expect to find a little more than 3.5 leaves on a winter wheat crop. These plants probably would have tillers at the "0" and at the "1" node (Figure 2 or 3).

Table 1. Cumulative growing degree days example. The max, min temperatures represent 8 a.m. readings as done on most experiment stations. The temperatures reported for Monday are for the 24 hours from 8 a.m. Sunday to 8 a.m. Monday.

| Day | Max | Min | Ave (°F) | Ave (°C) | Cumulative degree days |
|---|---|---|---|---|---|
| Mon | 52 | 40 | 46.0 | 7.8 | 7.8 |
| Tues | 55 | 38 | 46.5 | 8.1 | 15.9 |
| Wed | 49 | 37 | 43.0 | 6.1 | 22.0 |
| Thurs | 56 | 34 | 45.0 | 7.2 | 29.2 |

## ROOT APPEARANCE WITH RESPECT TO SHOOT DEVELOPMENT

Two pairs of four roots may form from each node. If each node is divided into four equal sized pie-shaped sections or quadrants, one root will usually form from each section. Crowding from older roots, tillers, or twisted mainstem development can make the exact points of origin of roots within a node unsymmetrical.

The four quadrants of the node are named by their location with respect to the midrib or center of the leaf attached to the node. The quadrant to the left of the leaf midrib is labeled A. The one to the right is labeled B. The one closest to the midrib is called X and the one opposite is Y. The root names tell their node of origin and their orientation (quadrant location) at the node. For example, the 2B root comes from Nodes number 2 and began in the quadrant to the right of the midrib of L2.

The seminal roots come from the two nodes (-2 and -1) that are present in the seed. The -2A and -2B roots elongate almost immediately after the radicle and only after these three roots have elongated does the coleoptile show significant growth. The coleoptile depends on water taken up by these three roots for emergence. After emergence, the A and B roots at the -1 node elongate. In addition, another seminal root often appears at the -1 node in especially vigorous seedlings. Thus, there can be up to six seminal roots on a normal wheat plant.

The sequence of root appearance at main stem nodes relative to plant phyllochrons is diagramed in the upper left half of Figure 3. The verticle lines are labeled with names of pairs of roots. The expected time of appearance of each pair can be read (in terms of phyllochrons after emergence) across the top of the figure. Notice that the Radicle and Node -2 roots begin elongating about one phyllochron before emergence.

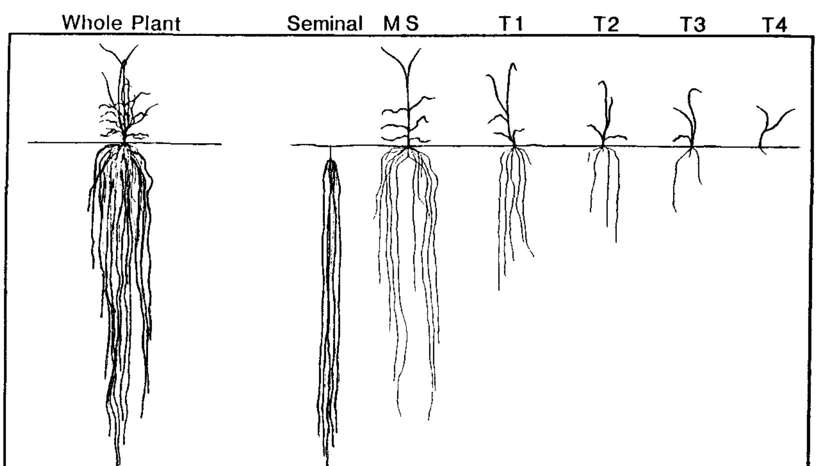
The crown root system (which forms from Nodes 1 to 5 or 6) begins to develop when tillering begins. A pair of roots (one in each of the A and B quadrants) appears at about the same time that the tiller is produced at that node. About two phyllochrons later, a second pair (one in each of the X and Y quadrants) may elongate, especially if there is a tiller at the node.

Figure 3 summarizes the relationship between shoot and root development and root branching as well. A horizontal line across Figure 3 at the number of leaves on the main stem of the plant will cross each root pair line in the region of branching expected on those roots. For example, a plant with 5.5 leaves on the MS has secondary branching on seminal roots (Radicle, -2 and -1 nodes), but the crown roots (Nodes 1 and above) just have beginning first order branches or are unbranched. The individual tillers begin to form at their own nodes when the tiller has three leaves. Figure 4 illustrates the relative number of leaves, number of roots, and relative length of roots that are on an unstressed plant just before boot stage.

## EFFECT OF STRESS ON PLANT DEVELOPMENT PATTERNS

Stresses are detected in a wheat crop by observing a population of plants rather than only one plant. Table 2 provides a comparison of observations on plants from severely compacted and uncompacted sites in a field. Many more of the plants in the compacted soil skipped some or all their tillers. If 100 plants had been observed from each soil condition, none of the plants from compacted soil developed T0 while 79 from uncompacted soil developed T0. Similar comparisons apply to all the other tillers.

Since each tiller on a plant will only appear during a brief "window" of time (within ½ a phyllochron or less of the time scheduled on either Figure 2 or 3) missing tillers show not only stress but when the stress occurred. From Table 2, for example, plants from compacted soil experienced a major stress during the second phyllochron (the time when T0 was expected -- see Figure 2 or 3). During phyllochrons 3 through 5, compacted plants produced only 75 to 80% of the number of T1's, T2's, or T3's as plants in uncompacted soil. This indicates a prolonged consistent difference in the growing environment between the two treatments. Roots at the X and Y nodes may also be skipped and although A or B roots are rarely skipped they will be weak if the tiller at their node does not form or aborts after beginning. Comparisons of this type which utilize observations of the plants themselves in the field were used to evaluate opener designs and to evaluate fertilizer placement trials as reported by Wilkins et al. (1982).




| | Whole Plant | Seminal | M S | T1 | T2 | T3 | T4 |
|---|---|---|---|---|---|---|---|
| LEAVES | 22 | – | 8 | 5 | 4 | 3 | 2 |
| ROOT AXES | 29 | 5 | 12 | 6 | 4 | 2 | – |

Figure 4. Relative sizes of the tillers, leaves, and roots of a wheat plant just before boot stage.

Table 2. Percent of winter wheat plants with identified tillers present in compacted and uncompacted soil

| Treatment | Tillers present (%) | | | | |
|---|---|---|---|---|---|
| | T0 | T1 | T2 | T3 | T4 |
| Compacted soil | 0 | 74 | 82 | 69 | 28 |
| Uncompacted soil | 79 | 97 | 100 | 93 | 90 |

## SUMMARY

The orderly developmental pattern of wheat shoots and roots can be predicted using growing degree days to time development. With stress, tillers and roots fail to elongate and the leaves on those culms already present elongate but are smaller than normal. The stress history of a crop can be "read" from the sizes and relative development of the leaves, tillers, and roots. The timing of stress in actual days is done by the relationships between GDD and days as indicated in the 1983 Columbia Basin Agricultural Research, Special Report 680.

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# WINTER WHEAT RESPONSE TO NITROGEN, SULFUR, AND PHOSPHORUS IN THREE TILLAGE-ROTATION CROPPING SYSTEMS

P. E. Rasmussen, D. E. Wilkins, E. L. Klepper, and R. W. Rickman[1]

## INTRODUCTION

Annual cropping in the Pacific Northwest is often possible where yearly precipitation exceeds 14 inches, especially on soils less than five feet deep. Winter wheat rotated with a spring cereal is often more manageable than continuous winter wheat because of more efficient weed control and easier stubble management. Seeding of winter wheat into spring grain stubble with minimum- or no-tillage provides surface residue for overwinter erosion control. Fertilizer needs of winter wheat increase when annually cropped because nutrient buildup by fallowing is eliminated and competition from residue-decomposing organisms is more intense. In this study, nitrogen (N), sulfur (S), and phosphorus (P) response by winter wheat in a winter wheat-spring barley rotation was compared to response in a winter wheat-fallow rotation. Annually cropped winter wheat was seeded with conventional (moldboard plow) and minimum (sweep-skew treader) tillage.

## MATERIALS AND METHODS

Stephens winter wheat was seeded in replicated plots at the Columbia Plateau Conservation Research Center in mid-October at 78 pounds seed/acre in seven-inch rows. Fertility treatments included no-fertilizer, N alone, N plus S, and N plus P plus S. All P and S and 30 pounds N/acre, when applied, were banded with the seed; the remaining N was broadcast. Weeds and volunteer growth were controlled with herbicides.

## RESULTS AND DISCUSSION

Unfertilized winter wheat in 1983 yielded 65, 34, and 19 bushels/acre for winter wheat/fallow-conventional tillage, winter wheat/spring barley-conventional tillage, and winter wheat/spring barley-minimum tillage, respectively (Table 1). Yield without fertilization in the wheat/fallow rotation was twice that for annual cropping, reflecting the gain in nutrients released by fallowing. Yield without fertilizer, under annual cropping, was

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40% less for minimum tillage than yield for conventional tillage. Residue appeared to cause a significant decrease in wheat growth and nutrient availability.

Maximum yields in 1983 were not attained by N alone. All tillage-rotation combinations responded to P application, and the annual-crop rotations to S. Yield increases from P were similar, 10-13 bushels/acre, in wheat/fallow and wheat/barley rotations. Sulfur increased yield nearly 20 bushels/acre under annual cropping, but did not significantly increase yield in the wheat/fallow rotation. When both P and S were applied, yield increases from 90 pounds N/acre were 31 and 49 bushels/acre under wheat/fallow and annual cropping, respectively.

Under annual cropping, winter wheat yield response to N, P, and S was nearly the same for conventional and minimum tillage, 20 vs 20 for N alone, 38 vs 42 for NS, and 50 vs 48 for NPS. Nutritional needs and fertilizer efficiencies thus do not appear to differ significantly between conventional and conservation tillage systems.

In 1983, a favorable moisture year, conventionally tilled winter wheat yielded 84 bushels/acre after barley compared to 96 bushels/acre after fallow. Minimum-tilled wheat yielded 67 bushels/acre after barley, or 80% of conventional tillage yield. The lower yield under minimum tillage may have been caused by either substantial immobilization of that portion of the N that was broadcast or a change in the tillering pattern. Excessive skipping of the first, second, and third tillers sometimes occurs in conservation tillage. Replacement of these tillers by later-developing ones delays plant maturity and often results in lower grain yield per plant even though tiller number may be the same as in conventional tillage. Causes of missing tillers and management methods to promote early tiller retention in conservation tillage are being investigated.

Table 1. Effect of N, P, and S fertilizer on grain yield of winter wheat in three tillage-rotation systems

| Rotation[1] | Tillage[2] | N-P-S applied, lbs/acre 0-0-0 | 90-0-0 | 90-0-36 | 90-17-27 |
|---|---|---|---|---|---|
| | | Grain yield, bu/acre | | | |
| W/F | Conventional | 65 | 79 | 83 | 96 |
| W/B | Conventional | 34 | 54 | 72 | 84 |
| W/B | Minimum | 19 | 39 | 61 | 67 |

[1]W/F = winter wheat/fallow; W/B = winter wheat/spring barley.

[2]Conventional = moldboard plow, cultivate, rodweed; minimum = sweep, skew tread.

# SULFUR RESPONSE TRIAL - 1983

Floyd E. Bolton[1]

Response to sulfur (S) fertilizer in the lower Columbia Plateau during the past 10 to 15 years has been somewhat erratic. Usually at only specific sites have consistent yield increases been found. However, during the past four seasons, high yield levels of soft white winter wheat from good climatic conditions have been achieved. There were indications of sulfur deficiencies in areas where previous trials had shown little or no response. It was suspected that lack of sulfur may have reduced yields in areas that were currently producing at higher levels than ever before. Several seasons of higher than normal yield levels may have depleted the available sulfur to a critical level.

## METHODS AND MATERIALS

A trial was established on the Moro Station in the fall of 1982 with four levels of sulfur (0, 9, 18, and 36 pounds/acre) and two levels of nitrogen (N) (0 and 71 pounds/acre). The trial was seeded with Hill 81 soft white winter wheat on September 17, 1982. The N source was ammonium nitrate (34-0-0) and the S source was potassium sulfate. Both materials were applied broadcast just before seeding. Triple super phosphate (0-45-0) was applied at the rate of 45 pounds of $P_2O_5$ per acre uniformly over all plots and worked into the soil surface just before seeding to insure that phosphorus would not be a yield limiting factor.

## RESULTS AND DISCUSSION

Sulfur increased grain yield when no N was applied (Table 1). There was no additional yield increase above 9 pounds S/acre.

Application of 71 pounds N/acre doubled yield. Applied S did not significantly increase grain yield when N was applied. Apparently, nitrogen enabled the plant roots to explore the soil profile and pick up enough sulfur to meet crop need. Positive response to sulfur at low nitrogen levels was an indication that sulfur is near the critical level. The addition of small amounts of sulfur (10-15 pounds/acre) may be good insurance for sustaining high yield levels.

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Table 1. Winter wheat grain yield response to nitrogen and sulfur at Moro, Oregon in 1983

| Fertilizer and rates pounds/acre | | |
|---|---|---|
| Nitrogen | Sulfur | Grain yield bushels/acre |
| 0 | 0 | 39 |
| 0 | 9 | 49 |
| 0 | 18 | 45 |
| 0 | 36 | 49 |
| 71 | 0 | 88 |
| 71 | 9 | 83 |
| 71 | 18 | 92 |
| 71 | 36 | 87 |

# EFFECTS OF TIMING AND DEPTH OF NITROGEN APPLICATION ON PROTEIN CONTENT OF HARD RED WINTER WHEAT

Mylen G. Bohle and Floyd E. Bolton[1]

## INTRODUCTION

Hard red winter wheat (HRW) represents a potential alternate crop for eastern Oregon. Thus far, however, yields have been lower than that of soft white winter wheat and, more importantly, protein content has been well below levels needed for high bread-baking quality.

The rainfall pattern in eastern Oregon may be a primary reason for low protein in HRW. Because of low growing-season precipitation, wheat exhausts topsoil moisture before heading and must rely on subsoil moisture to complete growth. Nitrogen (N) and phosphorus (P) in the upper soil profile may not be available in sufficient amount during grain filling to produce high protein levels. Nitrogen was applied at jointing and heading at different depths in the soil to determine if protein content could be raised to acceptable levels.

## MATERIALS AND METHODS

Wanser winter wheat was seeded in September, 1982, into four N-P fertilizer combinations. Nitrogen was applied at 0 and 71 pounds/acre with and without 18 pounds P/acre. Fertilizers were broadcast as ammonium nitrate and triple super phosphate and tilled into the soil before seeding.

In March 1983, four holes were drilled on each side of 3.28 feet of row to depths of 24 or 48 inches, then capped. At either jointing or heading, 18 pounds N/acre was applied in a water solution. Zero-N treatments received water only.

At harvest, grain from all treatment combinations was analyzed for protein. All protein values were adjusted to 11.5% moisture level.

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## RESULTS AND DISCUSSION

Fall-applied N increased percent protein in grain significantly (Table 1). Phosphorus appeared to increase protein content about one percentage point when N was applied but had little effect in the absence of N fertilization. When 71 pounds N/acre was applied in the fall, spring application of N at either jointing or heading did not increase protein. With no fall-applied N, 18 pounds N/acre increased protein level when applied at heading, but not when applied at jointing. Deep application (24 or 48 inches) of N at either jointing or heading did not increase protein above levels for surface-applied N.

Because irregular stand establishment of the 1983 crop may have affected results, this experiment is being repeated in 1984 to achieve more definitive conclusions. None of the fertilization practices in 1983 increased protein levels above 11.2%.

Table 1. Nitrogen and phosphorus application effects on protein level in hard red winter wheat

| Spring-N applied (lbs/acre) | Time of N application (growth stage) | Depth of N application (inches) | Fall fertilization N-P (lbs/acre) | | | |
|---|---|---|---|---|---|---|
| | | | 0-0 | 0-18 | 71-0 | 71-18 |
| | | | - - - - - (% protein)- - - - | | | |
| 0 | - | - | 6.5 | 6.6 | 9.3 | 10.0 |
| 18 | Jointing | 0 | 6.6 | 7.1 | 10.8 | 10.7 |
| 18 | Jointing | 24 | 6.7 | 6.9 | 9.6 | 10.8 |
| 18 | Jointing | 48 | 7.5 | 7.1 | 9.1 | 10.8 |
| 18 | Heading | 0 | 8.0 | 7.6 | 9.7 | 11.2 |
| 18 | Heading | 24 | 8.8 | 8.1 | 9.2 | 9.8 |
| 18 | Heading | 48 | 8.5 | 7.9 | 9.3 | 10.6 |
| | Average | | 7.5 | 7.3 | 9.6 | 10.6 |

# EFFECT OF STUBBLE MANAGEMENT IN A WHEAT-FALLOW ROTATION ON WATER CONSERVATION AND STORAGE IN EASTERN OREGON

Robert E. Ramig and L. G. Ekin[1]

Water limits crop production in most dry-farmed areas, especially in the wheat production areas of eastern Oregon and Washington. Yields depend on water stored during fallow because only 20 to 25% of the annual precipitation occurs during the April 1 - July 31 growing season. Conservation and storage of precipitation require infiltration into the soil and adequate soil depth for storage, then reduced evaporation to retain the stored water. Crop residue management, tillage, reduction of runoff and evaporation, seedbed preparation, and weed control -- all contribute to efficient water conservation. The objective of this study was to determine the effect of wheat stubble management on water conservation and storage in a fallow-wheat sequence in the cool, wet winter - hot, dry summer climate of eastern Oregon and Washington.

## MATERIALS AND METHODS

Water conservation and storage data were collected at three locations (Table 1) during the 1978-1980, 1979-1981, 1980-1982, and 1981-1983 fallow-wheat crop cycles. Average crop year precipitation during these four cycles (Table 2) was 1.5, 16.9, and 11.0% above the 28-year average for Pendleton, Moro, and Ione, respectively.

Wheat stubble treatments after late July or early August harvest were: (1) burned in September except at Ione where the soil is susceptible to wind erosion, (2) flailed in September leaving the stubble flat on the ground, and (3) left standing over winter. The burned treatment is representative of conditions after a harvest or post-harvest fire. All plots were sprayed in March with 16 ounces of glyphosate in 20 gallons of water per acre to kill germinated weeds and volunteer wheat. Plots were chisel cultivated in late March at Ione and Moro, and sweep cultivated in early May at Pendleton. Nitrogen fertilizer as anhydrous or aqua ammonia was injected into the soil at recommended rates a few weeks after the above tillage and the areas rodweeded as required (usually two or three times), to control weeds during the summer. All sites were seeded to soft white winter wheat in October.

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Table 1. Location, cooperator, and characteristics of experimental sites

| Oregon Location | Cooperator | Soil series | Elevation, feet above sea level | Average crop year[1] precipitation, inches |
|---|---|---|---|---|
| Pendleton | C. Spratling | Walla Walla silt loam | 1592 | 16.63 |
| Moro | S. Burnet | Walla Walla silt loam | 2002 | 11.51 |
| Ione | T. Martin | Ritzville silt loam | 1401 | 9.75 |

[1]For 28-year (1956-1983) period at Pendleton and Moro Experiment Stations and Charles Doherty Farm near Ione. Crop year is September 1 - August 31.

Precipitation was measured with standard U.S. Weather Bureau rain gauges at the sites during the study. Soil water was measured by foot increments to a depth of 8 feet at approximately monthly intervals with a neutron moisture meter. There were three neutron access tubes in each treatment.

## RESULTS AND DISCUSSION

The 19-month water conservation and storage period of the 24-month fallow-wheat cycle was divided into three unequal parts for analysis of water storage or loss. The first part, called Winter 1, was the 7-month storage period from wheat harvest in July or August through February 28 of the fallow year. The second part, Summer 1, was the 8-month loss period from March 1 of the fallow year through October 31. The third part, Winter 2, was the 4-month storage period from November 1 through February 28 of the crop year. Table 2 shows the effect of stubble management on water conservation and storage for the three parts of the 19-month water conservation period at three locations in north central Oregon.

More water was stored at Pendleton and Moro during both Winter 1 and Winter 2 where the stubble was left standing or flailed than where the stubble had been burned. The stubble on the soil surface during Winter 1 trapped snow and rain, insulated the soil surface, protected the soil from drying winds, and slowed the loss of water by evaporation. There was little difference in water storage between flailed and standing stubble at any site. More water was stored at all three locations during Winter 1 when the soil profile was dry and residue remained on the undisturbed surface than during Winter 2 after the profile was wet and the soil surface structure was abraded by cultivation and seeding.

Table 2. Effect of wheat stubble management in a fallow-wheat rotation on the conservation and storage of water at three locations in Oregon. Data are the average of four fallow-wheat cycles, 1978-1980 through 1981-1983

| Oregon Location and average crop year precip.[1] | Wheat stubble management | Water Storage: Winter 1, 7-months, Aug 1-Feb 28 | | Summer 1, 8-months, Mar 1-Oct 31 | | Winter 2, 4-months, Nov 1-Feb 28 | | Total 19-months | |
|---|---|---|---|---|---|---|---|---|---|
| | | inches | %[2] | inches | %[2] | inches | %[2] | inches | %[2] |
| Pendleton 16.88 inches | Burn | 6.92 | 57 | -1.20 | -118 | 3.50 | 46 | 9.22 | 34 |
| | Flail | 7.88 | 67 | -2.25 | -133 | 3.82 | 50 | 9.45 | 36 |
| | Stand | 8.58 | 70 | -1.82 | -127 | 3.67 | 48 | 10.43 | 39 |
| Moro 13.46 inches | Burn | 5.85 | 66 | -0.45 | -106 | 4.19 | 60 | 9.56 | 42 |
| | Flail | 6.95 | 78 | -1.22 | -117 | 4.26 | 61 | 9.99 | 44 |
| | Stand | 6.90 | 78 | -1.41 | -120 | 4.52 | 64 | 10.01 | 44 |
| Ione 10.82 inches | Burn | -- | -- | -- | -- | -- | -- | -- | -- |
| | Flail | 4.62 | 63 | - .72 | -113 | 2.76 | 53 | 6.66 | 38 |
| | Stand | 4.10 | 56 | - .29 | -105 | 2.57 | 50 | 6.38 | 36 |

[1] Average crop-year precipitation for the 5 crop years 1978-1979 through 1982-1983. Crop year is September 1 through August 31.

[2] Percent storage is water storage for the period divided by the precipitation for that period times 100.

There was a net loss of stored water (represented in Table 2 as negative storage and negative percent storage) during the 8-month Summer 1 fallow period at all locations. This loss occurred even though the average summer precipitation ranged from 5.54 to 7.05 inches. The hot, dry summers evaporated all the summer rainfall plus about 1.20 inches of water already in the soil profile. It should be noted that greatest summer water losses occurred where the profiles were wettest after Winter 1. Also, there was less loss of water during Summer 1 where the stubble had been burned in the fall and the cultivated soil provided a uniform fine, loose soil mulch rather than a rough porous soil and stubble mulch.

As expected, water conservation and storage during Winter 1 were positively correlated to precipitation; the greater the precipitation, the greater the water storage. This was not true during Winter 2. There was less water storage during Winter 2 at Pendleton where there was more precipitation than at Moro because the 8-foot soil profile at Pendleton was full of water and the excess water drained into the fractured rock below this depth. We had no way of measuring this deep percolation loss which we estimated to be 0.6 to 1.0 inch of water.

Under the conditions of this study, a greater percentage of the 19-month precipitation was stored at Moro than at Pendleton. The soil profiles at both Pendleton and Moro were usually dried to permanent wilting percentage only to a depth of 5 or 6 feet after wheat harvest. Water storage at the end of the 19-month water conservation period was approximately 10 inches at both locations regardless of stubble management. Dividing 10 inches of water by the depth of dry soil after harvest (5.5 feet) gives a water storage value of 1.80 inches of water that is available to the plant for each foot of soil depth -- a value we consistently have found for our Walla Walla silt loam soils at both locations. Because Pendleton receives more precipitation than Moro, yet stores no more water, the fallow-wheat cropping sequence in the Pendleton area does not make maximum use of the renewable water resource.

## CONCLUSIONS

1. Stubble left on the surface, either flailed or standing, increased water storage during Winter 1 at all locations.

2. Only at Pendleton did the standing stubble give better storage than flailed stubble during Winter 1.

3. No water is stored (usually there is a net loss) during the hot, dry 8-month (March 1 - October 31) summer fallow period.

4. After fallow tillage and seeding, there is little benefit from stubble management on water storage during Winter 2.

5. Soil water extraction by the wheat crop to a depth of only 6 feet makes a fallow-wheat cropping sequence less efficient for conservation and full use of the water resource at Pendleton than at Moro.

# INFLUENCE OF SPEED ON PLACEMENT OF SEED AND FERTILIZER WITH A USDA MODIFIED OPENER

D. E. Wilkins, P. E. Rasmussen, and D. A. Haasch[1]

## INTRODUCTION

Placement of fertilizer below crop residue and accessible to cereal seedling roots is critical in conservation tillage systems (Klepper et al., 1983 and Wilkins et al., 1982). Placement of both seed and fertilizer can be achieved with a split-boot opener that places liquid fertilizer below the seed (Wilkins et al., 1982). To get adequate separation between seed and fertilizer, it is necessary for soil to flow in over the fertilizer before the seed is deposited. Soil type, soil wetness, and speed of seeding influence the separation between seed and fertilizer.

This research evaluated the effect of speed on placement of seed and fertilizer with a USDA modified opener.

## MATERIALS AND METHODS

Stephens winter wheat was seeded with USDA modified openers at 77 pounds per acre on October 21, 1983, in a Walla Walla silt loam at the Columbia Plateau Conservation Research Center. Seeding speeds were 2, 3, and 4 mph. Fertilizer (urea ammonium nitrate, 32-0-0) was banded at 0 and 200 pounds/acre in 16-inch row spacings. A high rate of nitrogen (200 pounds/acre) was used to determine the distribution of fertilizer more precisely. Poor separation between seed and fertilizer delays germination and reduces emergence of wheat seedlings.

Soil samples were taken from the row in 3/8-inch vertical increments to determine soil water, seed, and fertilizer distributions. Stand counts were made 11, 13, 14, 17, and 21 days after seeding. The time to 50% emergence was determined by regression analysis of the stand count data.

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## RESULTS AND DISCUSSION

Seed zone soil moisture was ideal for germination and emergence after seeding. The lowest water content in these tests was 12.3%, in the top 3/4 inch of soil. All the seed was placed in soil with moisture in excess of 15.7%. Wilkins et al. (1983) showed that seed zone soil water potential greater than 4 bars (< 11.1% moisture) in Walla Walla silt loam soil induced stress during germination and emergence.

The placement of fertilizer was not significantly altered as seeding speed increased from 2 to 4 mph (Table 1). More than 98% of the $NH_4$ fertilizer was placed below the seed. Seed placement was approximately ¼ inch deeper at a seeding speed of 4 mph than at 2 or 3 mph. The increased depth of seed placement at the highest seeding speed of 4 mph was caused by less soil flowing in over the fertilizer before the seed was dropped into the furrow.

Table 1. Effect of speed of seeding with modified USDA opener on vertical distribution of ammonium nitrogen and wheat seed

| Depth from surface of seedbed | Soil water | Depth distribution in seeded row Seeding speed - mph | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | | 3 | | 4 | |
| | | $NH_4$-N | Seed | $NH_4$-N | Seed | $NH_4$-N | Seed |
| (in) | (%) | - - - - - - - - - - - - (%)1/ - - - - - - - - - - - - | | | | | |
| 0.0-0.8 | 12.3 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 |
| 0.8-1.2 | 15.7 | 0.0 | 6.3 | 0.0 | 12.5 | 0.0 | 0.0 |
| 1.2-1.6 | 16.6 | 0.1 | 12.5 | 0.0 | 18.8 | 0.1 | 13.3 |
| 1.6-2.0 | 17.0 | 0.1 | 56.3 | 0.0 | 50.0 | 0.1 | 20.0 |
| 2.0-2.4 | 17.2 | 0.0 | 18.8 | 0.0 | 18.8 | 0.1 | 53.3 |
| 2.4-2.8 | 17.2 | 0.4 | 6.3 | 2.4 | 0.0 | 1.0 | 13.3 |
| 2.8-3.2 | 17.3 | 5.8 | 0.0 | 7.7 | 0.0 | 6.5 | 0.0 |
| 3.2-3.6 | 17.5 | 20.2 | 0.0 | 19.5 | 0.0 | 21.8 | 0.0 |
| 3.6-4.0 | 17.6 | 28.6 | 0.0 | 27.6 | 0.0 | 29.6 | 0.0 |
| 4.0-4.4 | 17.6 | 26.6 | 0.0 | 23.6 | 0.0 | 24.6 | 0.0 |
| 4.4-4.8 | 16.9 | 14.8 | 0.0 | 16.1 | 0.0 | 14.1 | 0.0 |
| 4.8-6.0 | 16.9 | 3.4 | 0.0 | 3.1 | 0.0 | 2.0 | 0.0 |
| Mean depth - in | | 3.9 | 1.8 | 3.9 | 1.7 | 3.8 | 2.0 |

1/ Percent of the total found in the upper 6 inches of seeded row.

The separation between seed and fertilizer for speeds from 2 to 4 mph was adequate to protect against toxic effects of fertilizer (200 pounds/acre in bands 16 inches apart) during germination and emergence. Differences in time to 50% emergence (Table 2) were not significantly different for the three planting speeds and the two fertilizer treatments (5% F test). Rickman and Klepper (1983) indicated that 100 growing degree days (3$^{o}$C) base) were required for 50% emergence for Stephens wheat grown on a Walla Walla silt loam in the Columbia Plateau. Using the mean time to 50% emergence as 12.5 days, there were 91 accumulated growing degree days to 50% emergence for these tests, indicating little or no stress during emergence.

Table 2. Effect of speed and amount of fertilizer placed with USDA modified opener on emergence of Stephens wheat

| Speed mph | Fertilizer lb/A | Time to 50% emergence days |
|---|---|---|
| 2 | 0 | 12.5 |
| 2 | 200 | 12.7 |
| Mean | | 12.6 |
| 3 | 0 | 12.6 |
| 3 | 200 | 12.4 |
| Mean | | 12.5 |
| 4 | 0 | 12.5 |
| 4 | 200 | 12.5 |
| Mean | | 12.5 |

## CONCLUSIONS

Seeding speeds up to 4 mph did not affect fertilizer placement with the USDA modified opener. The separation between seed and fertilizer decreased as seeding speed increased from 2 to 4 mph. For cool temperatures and adequate soil water, the separation between seed and fertilizer for seeding speeds from 2 to 4 mph was sufficient to avoid toxic effects of fertilizer during emergence.

# CROP RESIDUE DISTRIBUTION BY COMBINES

C. L. Douglas Jr., P. E. Rasmussen, L. L. Baarstad, and R. R. Allmaras[1]

## INTRODUCTION

Uniform distribution of wheat straw and chaff is necessary for success of conservation tillage programs. Fenster et al. (1977) found that straw windrows affected drill performance in conservation tillage and recommended straw spreaders for uniform distribution of residues. Heavy concentrations of chaff or straw can severely retard growth of seedlings (Cochran et al., 1982).

Many growers have noticed yellow strips during spring growth of cereals. These appear to be related to previous combine harvest patterns and may be caused by uneven residue distribution. Increasing grain yields since the 1960s associated with adoption of semi-dwarf varieties have been accompanied by higher straw yields. Chaff yields increased even more than straw yields. Combine header widths increased from 12 feet in the 1950s to more than 20 feet in the 1980s. All these factors significantly increased the amount of straw and chaff expelled from self-propelled combines.

Although non-uniform distribution of straw and chaff and the associated adverse effects have been frequently discussed, the distribution has not been measured. We developed a system to measure the distribution of straw and chaff and determined distribution patterns of cylinder and rotary-type combines. Included were combines with chaff and straw spreading devices.

## MATERIALS AND METHODS

The distribution of chaff plus straw was measured immediately after the material was expelled from seven cylinder and five rotary-type combines. Before the combine pass, a three-foot wide strip was mowed perpendicular to the direction of combine travel and a three-foot wide tarp was laid on the ground. The tarp was marked into three-foot sections. After the combine passed, the material on each section was removed and weighed. These measurements, along with weights of grain plus straw before combining and weights of uncut straw after combining, were used to estimate the distribution of straw and chaff within each header width.

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## RESULTS AND DISCUSSION

The average amount of residue (straw plus chaff) for all wheat fields sampled was 4.8 tons per acre and varied from 3.9 to 5.1 per acre depending on the field. The average amount combined was 2.7 tons per acre, and varied from 2.3 to 3.2 tons per acre. The percent of the straw plus chaff threshed ranged from 52 to 65%, and the cutting height varied from 11 to 18 inches.

Cylinder combines with no alteration (factory run) had very non-uniform distribution patterns (Figure 1). The 4.8 tons per acre residue, after combining, ranged from 2.1 to 9.0 tons per acre across the header width. Chaff made up 65% of the residue in the 9.0 tons per acre zone. In the one instance sampled, a straw-chopper did not improve the distribution. The straw-chopper reduced straw length but did little to improve straw or chaff distribution. A cylinder combine with a chaff spreading attachment distributed straw and chaff much more uniformly. However, chaff thrown beyond the header width caused some overlap and produced a peak in the distribution (Figure 1).

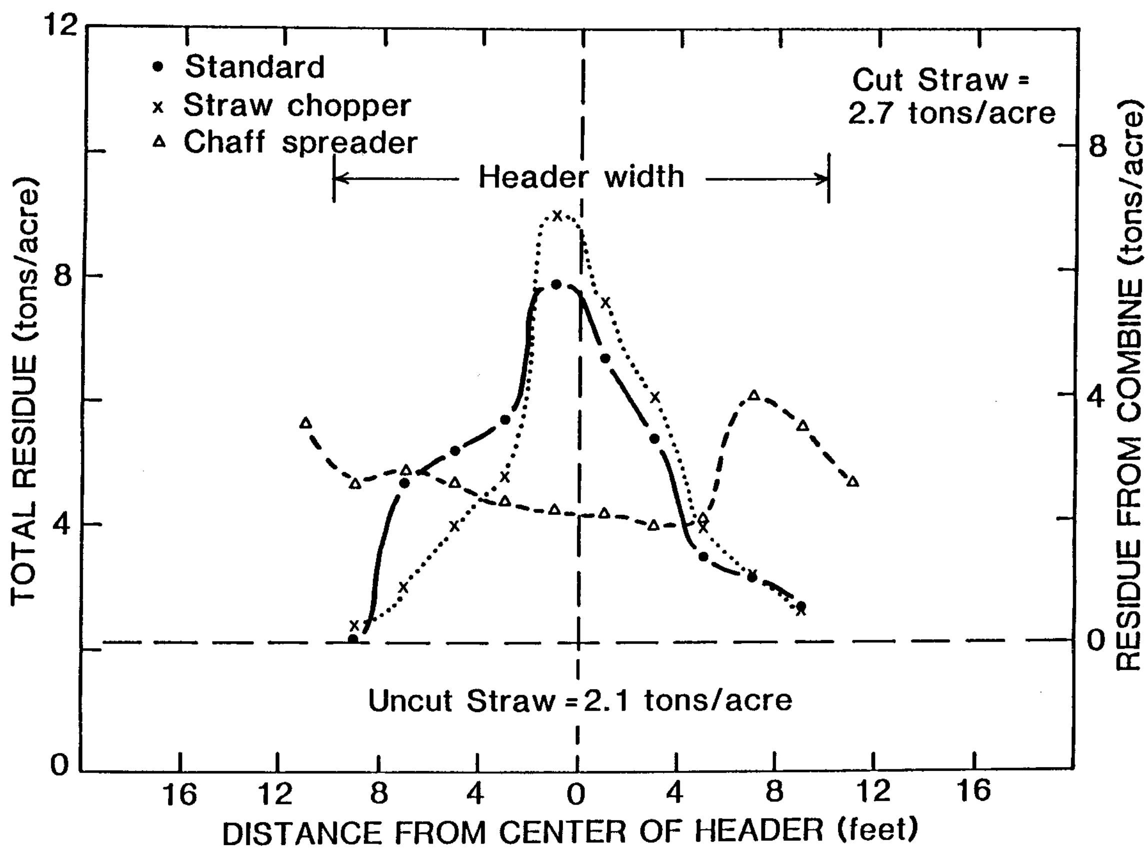


Figure 1. Straw distribution by cylinder combines.

A rotary combine with center exit and no attachments had a distribution pattern (Figure 2) similar to that produced by the cylinder-type combine without attachments (Figure 1). The residue concentration was as great as 9 tons per acre near the center and decreased to 2.1 tons per acre on the edge of the header width (Figure 2). A prototype retrofit spreader distributed the residue more uniformly but overthrow created a peak in distribution. Residue concentrations from the prototype spreader ranged from 3.5 to 7 tons per acre. Shop modification of a rotary combine (flails lowered and spreader speed increased) provided an amazingly uniform distribution of residue, with residue levels ranging from 3.9 to 5.7 tons per acre.

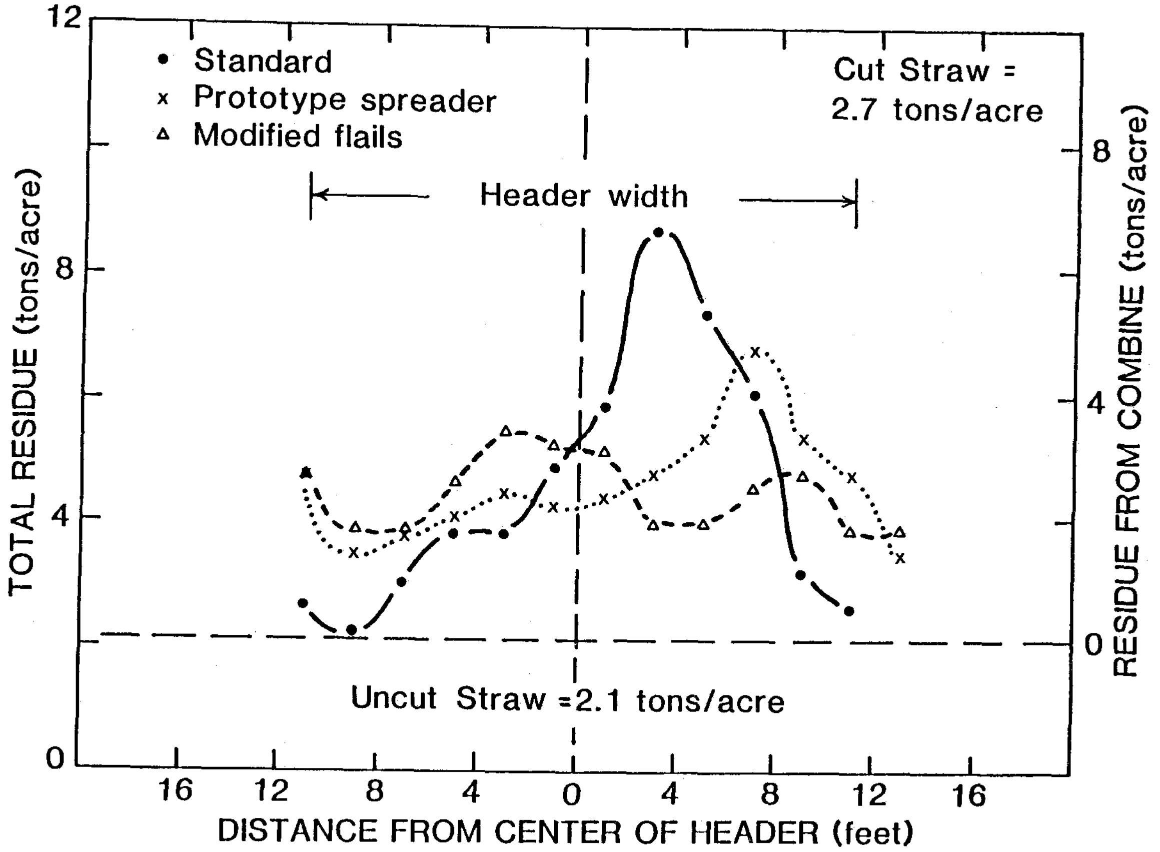


Figure 2. Straw distribution by rotary combines.

## CONCLUSIONS

The measurement procedure for straw plus chaff distribution behind combines was relatively fast, did not seriously interfere with harvest operations, and gave good estimates of straw and chaff distribution. In fields where the average straw plus chaff was 4.8 tons per acre and the harvested straw plus chaff averaged 2.7 tons per acre, crop residue concentrations after harvest ranged from 2.1 to 9.0 tons per acre. Results indicate that: a) standard factory-produced combines distributed straw and chaff unevenly in the field; b) straw-choppers did not automatically improve uniformity of distribution; c) a chaff spreading attachment on a cylinder-type combine improved distribution significantly; and d) shop modification of flails on a rotary-type combine gave a nearly uniform distribution. Improvements on combines are seriously needed to assure the uniform straw and chaff distribution so necessary for successful adoption of conservation tillage systems.

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Cochran, V. L., L. F. Elliott, and R. I. Papendick. 1982. Effect of crop residue management and tillage on water use efficiency and yield of winter wheat. Agronomy Journal 74:929-932.

# PRECIPITATION SUMMARY

CBARC - 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 Year Average | .75 | 1.39 | 1.88 | 2.20 | 1.94 | 1.49 | 1.65 | 1.48 | 1.35 | 1.29 | .35 | .45 | 16.22 |
| 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 | 2.28 | .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 | 2.61 | 1.86 | 1.99 | 1.54 | .48 | 1.12 | 1.02 | .50 | 19.93 |
| 1982-83 | 1.68 | 2.68 | 1.46 | 2.69 | 1.63 | 2.97 | 3.90 | 1.23 | 2.08 | 1.92 | 1.00 | .68 | 23.92 |
| *1983-84 | .82 | .91 | 2.79 | 3.44 | .99 | 2.56 | 3.23 | 2.37 | | | | | |
| 19 Year Average | .85 | 1.33 | 2.16 | 2.40 | 2.16 | 1.41 | 1.62 | 1.50 | 1.18 | 1.04 | .46 | .74 | 16.70 |

*Not included in 19 year average figures.

# PRECIPITATION SUMMARY

CBARC - 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 Year Average | .50 | 1.00 | 1.80 | 1.73 | 1.78 | 1.17 | .95 | .72 | .86 | .79 | .20 | .27 | 11.77 |
| 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 | 1.45 | .37 | 1.15 | .21 | .40 | 14.41 |
| 1982-83 | 1.42 | 1.96 | 1.08 | 1.89 | 1.40 | 2.43 | 2.74 | .61 | 1.96 | .39 | .80 | .60 | 17.28 |
| *1983-84 | .52 | .62 | 2.45 | 2.31 | .17 | 1.07 | 2.34 | 1.32 | | | | | |
| 19 Year Average | .49 | .77 | 1.68 | 2.00 | 1.76 | .91 | .91 | .72 | .71 | .63 | .31 | .53 | 11.41 |

*Not included in 19 year average figures.