(3)

Fallow-Cropping Systems in the Pacific Northwest

Technical Bulletin 146

**AGRICULTURAL
EXPERIMENT
STATION**

**Oregon State
University
Corvallis, Oregon**

January 1983

Fallow-Cropping Systems in the Pacific Northwest

CONTENTS

Procedures 4

Results and Discussion 5

Literature Cited 11

AUTHORS: F. E. Bolton is associate professor and D. M. Glenn is an assistant professor, Department of Crop Science, Oregon State University, Corvallis 97331.

Fallow-Cropping Systems in the Pacific Northwest

F. E. Bolton and D. M. Glenn

ABSTRACT

A study of precipitation and yield levels in fallow-wheat rotations at three Pacific Northwest locations demonstrated that in the Columbia Plateau region, the variability and skewness of precipitation increased with decreasing mean amounts of precipitation. The seasonal distribution of precipitation had a marked effect on wheat yield. Comparisons of precipitation patterns with approximately the same cumulative precipitation total, but differing in seasonal distribution, indicated that the amount of precipitation received in the fallow period had a greater effect on yield than did the amount of precipitation received in the crop season. In areas of very low precipitation, fallowing was necessary to provide enough soil water to establish and produce an adult plant that could respond to crop season precipitation. In areas with higher levels of precipitation, where annual cropping was not successful, water stored during the fallow season also contributed directly to the yield potential of the crop. As the level of precipitation increased, the role of improved varieties and improved agronomic management shifted in emphasis. In general, varietal improvement plus the interaction of improved varieties and agronomic management became more important under more favorable climatic conditions. Under climatic conditions that favored a fallow-wheat rotation, wheat *(Triticum aestivum)* was produced with the same average water-use efficiency despite large differences in yield and precipitation levels of different locations.

Additional index words: fallow-wheat rotation, water-use efficiency, precipitation variation, varietal improvement, agronomic management.

Winter cereals are produced in the semiarid regions of the Columbia Plateau of the Pacific Northwest with a fallow-crop rotation (14 months fallow, 10 months crop). Yields, limited primarily by the precipitation level, vary considerably from year to year and between locations. Research relating wheat yields to the amount of soil water and precipitation in this region (Leggett, 1959) indicated that approximately 10 centimeters of stored soil water was necessary to grow a winter wheat crop to the point of initial grain production; thereafter, each additional centimeter of stored soil water produced a yield increase of approximately 155 kilograms per hectare. Regression analysis of these relationships demonstrated that crop season precipitation was more effective than water stored in the fallow season in increasing grain yield; however, the yield level was more closely related to the amount of water stored during the fallow season.

Similar relationships have been developed for the Great Plains (Army et al., 1959; Eck and Stewart, 1959; Jackson and Sims, 1977; Johnson, 1964; Johnson and Davis, 1980; Po Chop et al., 1975). These relationships have been used to estimate yield levels, determine regional adaptability of various cropping systems, and determine fertilizer needs of winter wheat. In all cases, grain yield was strongly related to the amount of soil water stored in the fallow period. Smika (1970) concluded from a historical study of cropping system effects on winter wheat yields that fallowing was necessary for stable winter wheat production in areas of the Great Plains with less than 430 millimeters mean annual precipitation because of insufficient total amount and erratic occurrence of precipitation.

Weather is uncertain in the short term, but knowledge of long-term weather probabilities can help counter effects of climatic uncertainty. Three semiarid locations in the Columbia Plateau (Lind, Washington, and Moro and Pendleton, Oregon) provided long-term weather and yield records for developing probabilistic information on precipitation patterns and assessing their effect on wheat production. The objectives of this study were to:

1. Characterize the variation in precipitation in the Columbia Plateau of the Pacific Northwest;

2. Examine the historical effect of precipitation distribution on winter wheat yields; and

3. Determine the relative effect of agronomic management and varietal development on winter wheat yields.

Procedures

Precipitation data and general weather information have been collected since experiment stations were established in Lind, Washington (1918), in Moro, Oregon (1910), and in Pendleton, Oregon (1929). Mean monthly precipitation values are presented to characterize the winter precipitation pattern at each location (Table 1). Winter wheat *(Triticum aestivum)* records from standard variety trials provided yield and planting date information for Kharkov (a standard check variety) and for improved

Table 1. Mean monthly precipitation values at three semiarid locations in the Pacific Northwest

	Monthly precipitation (mm)												
Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lind, Wash.	27	22	19	16	19	23	6	8	13	23	31	33	240
Moro, Ore.	42	29	24	19	20	18	5	6	16	24	43	43	289
Pendleton, Ore.	49	38	41	38	34	33	8	8	17	35	49	55	405

varieties that are grown predominantly in each of the three areas each year. The same varieties were not necessarily predominant in all three areas in a given year.

Winter wheat was grown in these trials in a fallow-crop rotation in a replicated design. Mean annual yields for Kharkov and the improved varieties were used in the analysis. Nitrogen fertilizer was first used in the trials in the mid-1950s, with amounts varying from year to year. Weeds were controlled adequately with tillage during the fallow period and, beginning in the mid 1940s, broadleaf weeds in the crop were controlled with 2,4-D-type herbicides.

Yield trials at Lind were conducted on a Ritzville silt loam soil (coarse-silty, mixed, mesic Calciorthidic Haploxeroll). The soil holds approximately 4.6 centimeters of water in each 30-centimeter increment. Yield trials at Moro and Pendleton were conducted on Walla Walla silt loam soil (coarse-silty, mixed, mesic Typic Haploxeroll). This type of soil holds approximately 5.6 centimeters of water in each 30-centimeter increment. Runoff was not controlled at any location.

Partial correlation coefficients and descriptive statistics were calculated according to Snedecor and Cochran (1967).

Fallow and crop precipitation at the three locations were characterized as dry, normal, or wet, using the procedure outlined by Aktan (1976). Briefly, the mean total fallow precipitation level was calculated from the historic record at each location. The record was then divided into two subgroups, one above and one below this grand mean. For each subgroup, again, the mean level of total fallow season precipitation was calculated. These two mean values determined the upper and lower limits of the normal fallow season. Individual fallow seasons with total precipitation exceeding the upper limit of a normal fallow were characterized as wet. Fallow seasons with total precipitation less than the lower limit of a normal fallow season were characterized as dry. Precipitation for the crop season was characterized in a similar manner.

Results and Discussion

The stations at Lind, Moro, and Pendleton represent a sampling of precipitation variation in the Columbia Plateau of the Pacific Northwest. Wallen and Perrin (1962) demonstrated that in the semiarid regions of the Near East, the variability and skewness of regional precipitation increase with decreasing precipitation. A similar relationship exists in the Columbia Plateau (Table 2). The distribution of total seasonal precipitation at Lind is significantly skewed to a dry condition; Moro and Pendleton have a relatively normal distribution of total seasonal precipitation over time. The variation in precipitation also increases with a decrease in precipitation in

Table 2. Fallow and crop season precipitation levels at three Columbia Plateau locations

Location	Mean	Coefficient of variation	Skewness
	mm		
Lind, Wash. (1920-1980)			
Fallow	260	0.31	1.67**
Crop	218	0.33	1.69**
Moro, Ore. (1910-1980)			
Fallow	311	0.22	0.34 (n.s.)
Crop	268	0.25	0.29 (n.s.)
Pendleton, Ore. (1929-1980)			
Fallow	432	0.19	0.57 (n.s.)
Crop	377	0.21	0.24 (n.s.)

** Significant at the 0.01 level of probability.

the Columbia Plateau, as described by the coefficient of variation. These combined conditions of weather uncertainty and low precipitation impose severe constraints on wheat production in the drier areas of the Columbia Plateau.

Fallowing is generally necessary to produce winter wheat in an area of weather uncertainty in the Columbia Plateau. At each sampling location in the Columbia Plateau, the range of precipitation and probability of a given level of precipitation or less occurring for the fallow and crop seasons have been determined (Figure 1). For example, at Lind, Moro, and Pendleton, there is an 80 percent probability of occurrence that at least 166, 209, and 308 millimeters, respectively, will be received in the crop season. At all three locations, the normal condition occurs more than 50 percent of the time (range of 16 to 75%) for both the fallow and crop seasons. Consecutive normal fallow precipitation and normal crop season precipitation then occur approximately one-third of the time (range of 16% x 16% = 3% to 75% x 75% = 56%). Normal precipitation in both the fallow and crop seasons can be expected to occur in only one of three fallow-crop rotations. Two of every three rotations, on the average, experience dry or wet conditions in either or both the fallow or crop seasons. The amount of precipitation normal for Lind, however, creates a dry condition at Moro and rarely occurs at Pendleton.

The seasonal distribution of precipitation has a marked effect on wheat yield. At the three locations, comparisons of precipitation patterns with approximately the same cumulative total but differing in seasonal distribution (Table 3) indicated the amount of precipitation received in the

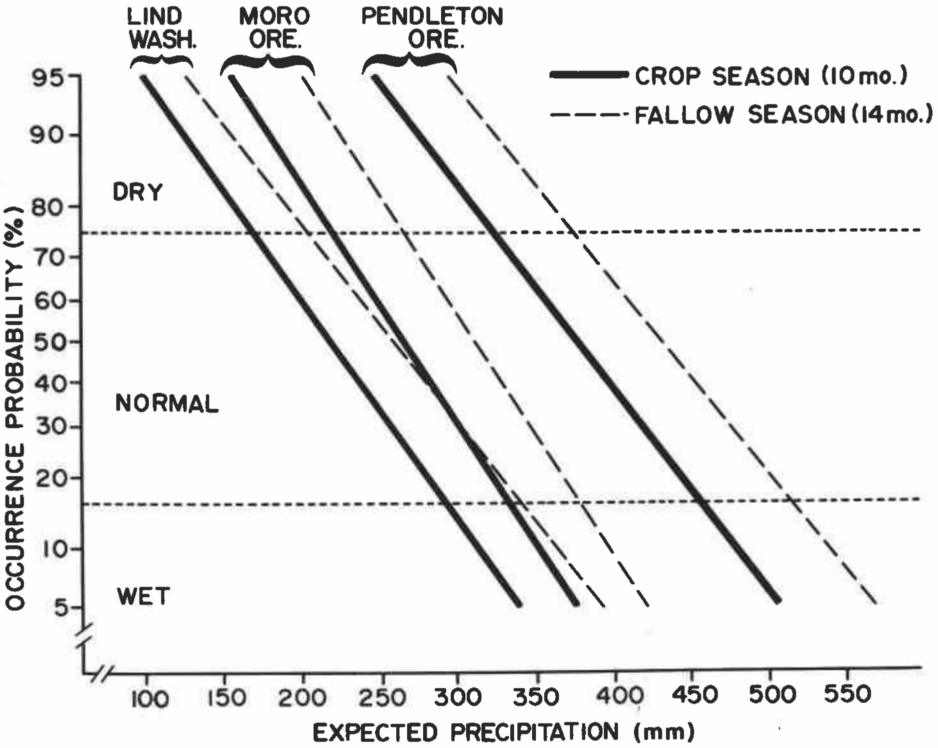

Figure 1. Expected precipitation levels for three semiarid locations in the Pacific Northwest.

fallow season had a greater effect on yield than did the amount of precipitation received in the crop season. This is partly because precipitation is stored more efficiently and at a greater depth in the fallow season than in the crop season (Glenn, 1981; Leggett et al., 1974).

Using a classification scheme of dry, normal, and wet for fallow and crop seasons, there are nine possible fallow-crop combinations that may occur. Four patterns (wet-wet, wet-dry, dry-wet, and dry-dry) occur with such a low frequency (3.5%) that the interpretation of precipitation distribution effects is meaningless in a general sense.

Partial correlation coefficients demonstrate the historical relationship between fallow season/crop season precipitation level and winter wheat production of the improved varieties in a cross section of years with the same planting date (Table 4). Before 1960 at Lind and Moro, the relative importance of precipitation was greater in the fallow season than during the crop season. From 1960 to 1980, the overall correlations diminished in magnitude, indicating agronomic and varietal advances lessened the effects of precipitation variation.

Table 3. Fallow-crop season precipitation distribution effects on wheat yield

Location	Fallow conditions	Crop conditions	Improved varieties	Standard (Kharkof)	Average total precipitation	Frequency of occurrence
			metric ton/ha	*metric ton/ha*	*mm*	*%*
Lind, Wash. (1920-1980)	Dry	Normal	1.71	1.50	423	18.2
	Normal	Dry	1.70	1.51	419	18.2
	Normal	Normal	1.96	1.72	478	38.2
	Normal	Wet	1.76	1.70	628	5.5
	Wet	Normal	2.76	2.54	667	5.5
Moro, Ore. (1910-1980)	Dry	Normal	1.59	1.39	514	13.9
	Normal	Dry	1.77	1.40	520	16.9
	Normal	Normal	2.03	1.88	579	33.9
	Normal	Wet	2.25	2.15	685	9.2
	Wet	Normal	2.54	1.96	676	13.9
Pendleton, Ore. (1929-1980)	Dry	Normal	3.25	2.58	704	21.7
	Normal	Dry	3.67	2.81	706	13.0
	Normal	Normal	3.86	2.89	809	32.6
	Normal	Wet	4.24	3.10	936	10.9
	Wet	Normal	4.67	3.41	944	6.5

Table 4. Partial correlation coefficients of improved wheat variety yield with the fallow/crop season precipitation level (cross section of years with the same planting date)

Location	Improved varieties	
	pre-1960	1960-1980
Lind, Wash.		
Fallow	.592***	.094 (n.s.)
Crop	.352**	.372**
Moro, Ore.		
Fallow	.523***	.442**
Crop	.360**	.351*
Pendleton, Ore.		
Fallow	.....	.319*
Crop	.....	.518***

*, **, *** = significant at the 0.10, 0.05, and 0.01 levels of probability, respectively.

At Lind (1960-1980), the relative importance of fallow season precipitation was reduced, partly because of the successful use of a deep furrow drill to plant in residual moisture at more optimal times and more independent of timely fallow season rainfall irrespective of total precipitation. Yield was no longer strongly related to the fallow season precipitation level, presumably because the low level of precipitation in the area produced a small amount to store. The variation in yield was related to the level of precipitation in the crop season. Fallowing is necessary, however, to store sufficient water to bring the wheat crop to the point where grain production can begin and respond to the level of crop season precipitation.

At Moro (1960-1980), the variations in grain yield continued to be more strongly related to the level of precipitation during the fallow season. The precipitation level during the fallow season appeared to be more important in determining the yield potential and realized yield.

At Pendleton, information on planting dates prior to 1960 was insufficient to calculate partial correlation coefficients. From 1960 to 1980, wheat yields were more strongly related to the precipitation level in the crop season than to the level in the fallow season. In this highest precipitation zone, the level of fallow season precipitation appears to determine the relative yield potential; however, the variation in crop season precipitation can significantly alter the realized yield.

The study demonstrated that the need for fallowing varies with the level of precipitation. In areas of very low precipitation, fallowing is necessary to provide water to bring the crop to the point of producing grain. In areas where the precipitation level is insufficient to grow crops annually, fallowing raises the yield potential to the point where the crop can respond to the amount of crop season precipitation.

The improvement of agronomic management practices and varietal plant types has helped make wheat production less susceptible to the vagaries of the environment. This has resulted in more efficient use of water (Figure 2). At Lind, there has been a 101 percent increase in water-use efficiency (WUE) from improved management (60%), improved varieties (26 − 1 = 25%), and the interaction of varieties and management (101 − 60 − 25 = 16%). At Moro, there has been a 52 percent WUE increase from improved management (7%), improved varieties (37 − 5 = 32%), and the interaction of varieties and management (52 − 7 − 32 = 13%). At Pendleton, there has been a 75 percent increase in WUE from improved management (18%), varietal improvement (48 − 14 = 34%), and the interaction of management and improved varieties (75 − 18 − 34 = 23%).

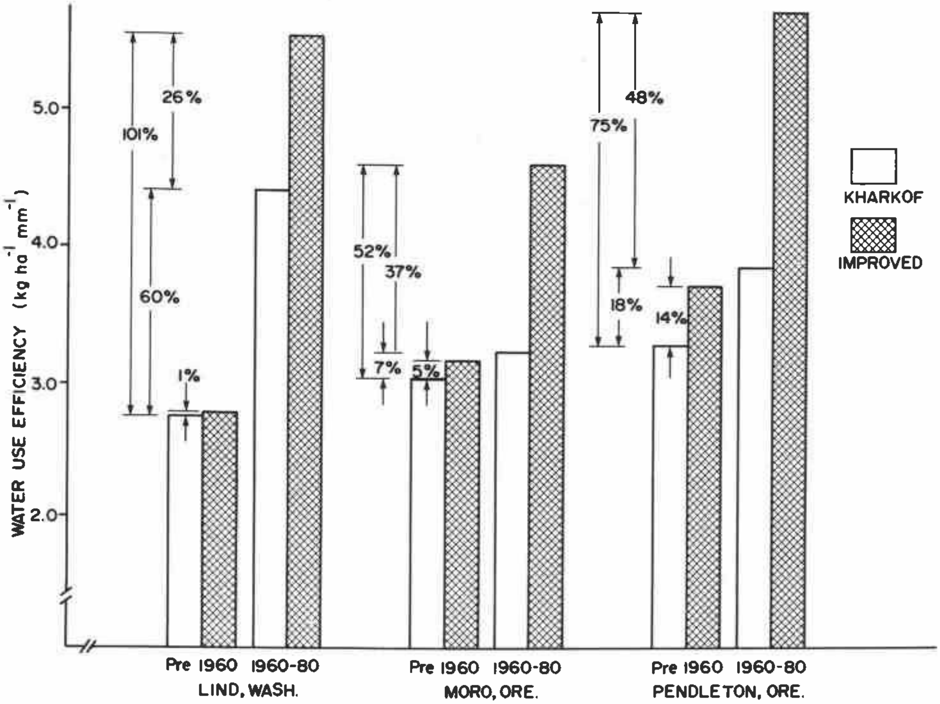

Figure 2. Historical improvement in water-use efficiency from management and varieties for three semiarid locations in the Pacific Northwest.

As the level of precipitation increased, the role of improved varieties and improved agronomic management shifted in emphasis. In general, varietal improvement and the interaction of improved varieties and agronomic management became more important under more favorable climatic conditions.

The Moro location was not as productive as those in Lind and Pendleton because of natural disasters and accidents in management practices. This is reflected in the lower increase in WUE from management (7%) and the interaction of management and improved varieties (13%), despite increases in WUE because of improved varieties (37%). Locations in Lind and Pendleton were equally productive (WUE equal to 5.56 and 5.74 kilograms per hectare per millimeters, respectively), despite large differences in yield and precipitation level. This demonstrates the necessity to include varietal improvement with the best agronomic management practices even in areas with limited yield potential.

Literature Cited

Aktan, Selman. 1976. Nitrate-nitrogen accumulation and distribution in the soil profile during a fallow grain rotation as influenced by different levels of soil profile moisture. M.S. thesis, Oregon State University.

Army, T. J., J. J. Bond, and C. E. Van Doren. 1959. Precipitation-yield relationships in dryland wheat production on medium to fine textured soils of the Southern High Plains. *Agronomy Journal,* 51: 721-724.

Eck, H. V., and B. A. Stewart. 1959. Response of winter wheat to phosphate as affected by soil and climatic factors. *Agronomy Journal,* 51: 193-195.

Glenn, D. M. 1981. The effect of precipitation variation on soil moisture, nitrogen response and winter wheat yields in eastern Oregon. Ph.D. dissertation, Oregon State University.

Jackson, G. D., and J. R. Sims. 1977. Comprehensive nitrogen fertilizer management model for winter wheat. *Agronomy Journal,* 60: 373-377.

Johnson, W. C. 1964. Some observations on the contribution of an inch of seed-time soil moisture to wheat yield in the Great Plains. *Agronomy Journal,* 56: 29-35.

Johnson, W. C., and R. G. Davis. 1980. Yield-water relationships of summer-fallowed winter wheat: a precision study in the Texas Panhandle. SEA-ARR, Southern Series, No. 5.

Leggett, G. E. 1959. Relationships between wheat yield, available moisture and available nitrogen in eastern Washington dryland areas. Wash. Agric. Expt. Sta. Bull. 609.

Leggett, G. E., R. E. Ramig, L. C. Johnson, and T. W. Massee. 1974. Summer fallow in the Northwest. In *Summer Fallow in the Western United States,* Conservation Research Report No. 17, ARS-USDA, pp. 110-135.

Po Chop, L. O., R. L. Cornia, and C. F. Becker. 1975. Prediction of winter wheat yield from short term weather factors. *Agronomy Journal,* 67: 4-7.

Smika, D. E. 1970. Summer fallow for dryland winter wheat in the semiarid Great Plains. *Agronomy Journal,* 62: 15-17.

Snedecor, G. W., and W. G. Cochran. 1967. *Statistical Methods.* Ames: Iowa State University Press.

Wallen, C. C., and G. Perrin. 1962. A study of agroclimatology in semi-arid and arid zones of the Near East. FAO/UNESCO/WMO Technical Report.