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Integrated Cro[p…]
for Dryland Small Grai[n…]

In Montana, low yields of small grains are generally attributed to limited plant-available water and are accepted as a consequence of farming in a semiarid environment. Typically, integrated pest management (IPM) programs have not been developed for low-profit-margin crops such as dryland small grains, since programs dealing strictly with pest problems would not be practical under these conditions. Therefore, an integrated crop management (ICM) program was developed to help Montana producers more efficiently utilize their most yield-limiting resource (water) and maximize yields by increasing production efficiency. A field-monitoring program documented inefficient water use and low production efficiency as a result of inadequate crop management and pest damage. Plant diseases were one of the more important pest problems reducing efficient water use.

Data from 31 monitoring sites in 1981 indicated that one-third had crop management and pest problems that reduced yield by 30% or more (11). Factors that reduced efficient water use were identified and practical methods suggested to solve the problems. It was apparent that most producers were unaware of plant diseases and the associated yield losses. Documentation of yield loss illustrated the importance of disease management as one part of a total crop management program.

Small Grain Farming in Montana

Without stored soil water from winter snow and timely growing-season precipitation, Montana can be a difficult place to farm profitably. Net income for an average winter wheat crop of 30.4 hl/ha (35 bu/acre) is approximately $68.37/ha ($27.68/acre), and a spring wheat crop of 27.8 hl/ha (32 bu/acre) can be expected to return only $50.51/ha ($20.45/acre). A short growing season, low annual precipitation (25–45 cm, 10–18 in.), and seasonal rainfall variations that adversely affect most other crops have encouraged the development of a crop/fallow farming system based almost entirely on small grains (Fig. 1).

The bulk of Montana's small grain production is centralized in the north-central and northeastern counties. Approximately 1.2 million ha (3 million acres) of hard red winter wheat, feed and malt barley, and spring wheat are grown in north-central Montana. In north-eastern Montana, 890,000 ha (2.2 million acres) of high-quality durum and hard red spring wheat are produced.

Dryland Farming, Excess Water?

Crop/fallow farming in Montana was initiated as a means of ensuring harvestable crops in an area of highly variable seasonal rainfall distribution. This practice has resulted in the development of saline seeps (Fig. 2). Excess soil water penetrating below the root zone during fallow periods is the primary water source that causes most saline seeps. This water moves through salt-laden subsoil and collects above impermeable or slowly permeable layers of shale or clay. This saline water then moves downslope and resurfaces wherever soil substrata conditions force the water table near the surface (2).

In Montana, North Dakota, South Dakota, and the prairie provinces of Canada, geology, climate, and cropping practices are conducive to this problem. The 89,000 ha (220,000 acres) affected in Montana illustrate that current cropping practices are not efficiently utilizing available water. The key to controlling saline seeps is to reduce the amount of water moving below the root zone. This can be done with cropping systems more efficient in water use than crop/fallow rotations (2,5).

Estimating Potential Yield

Research data, originally collected to help producers utilize soil water on saline seep recharge areas, were used to estimate potential yields (4). Potential grain yield was based on total plant-available water,

Table 1. Estimates of potential yields for winter wheat, spring wheat, and barley in Montana based on total plant-available water

		Plant-available water							
	cm	5	10	15	20	25	30	35	40
Crop	in.	2	4	6	8	10	12	14	16
Winter wheat[a]									
hl/ha		0	0	12	24	37	49	61	73
bu/acre		0	0	14	28	42	56	70	84
Spring wheat[b]									
hl/ha		0	0	11	19	26	34	42	45
bu/acre		0	0	13	22	30	39	48	52
Barley[b]									
hl/ha		0	0	10	23	35	47	59	71
bu/acre		0	0	12	26	40	54	68	82

[a] P. L. Brown, *personal communication.*
[b] Brown et al (4).

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Management Production in Montana

Table 2. Improvements in production efficiency at monitoring sites in north-central Montana during 1981 and 1982

Production efficiency[a]	Monitoring sites (%)[b]	
	1981	1982
90% or more	42	65
80–89%	22	23
70–79%	6	12
Less than 70%	30	0

[a] Actual yield/potential yield.
[b] 1981 = 31 sites at 17 locations; 1982 = 34 sites at 16 locations.

Table 3. Yield-limiting factors and percentage of monitoring sites in which yield-limiting factors were identified

	Monitoring sites with measurable yield loss (%)					
	Barley		Spring wheat		Winter wheat	
Yield-limiting factors	1981	1982	1981	1982	1981	1982
Crop management[a]	30	13	50	11	46	33
Climatic conditions[b]	10	0	0	10	15	0
Weed competition or herbicide injury	10	0	67	22	15	11
Insect damage[c]	10	0	17	0	0	0
Disease[d]	20	13	50	0	46	0

[a] Variety selection, fertility, planting date, row spacing, etc.
[b] Poor precipitation distribution, frost, snow, ice, etc.
[c] Wireworm, wheat stem sawfly, wheat stem maggot.
[d] Dryland root rot, wheat streak mosaic, Cephalosporium stripe, bacterial leaf blight, scald, net blotch, loose smut, stripe rust.

which included stored soil water (plant-available) and growing-season precipitation (Table 1). These estimates assume optimum growing conditions with 1) adequate fertility, 2) no disease, weed, or insect problems, 3) selection of an adapted variety, and 4) no adverse weather conditions during critical stages of crop development. A minimum of 10 cm (4 in.) of plant-available water is required to support the vegetative growth necessary for grain yield. Each additional 2.5 cm (1 in.) of water is then assumed to be converted into 6 hl/ha (7 bu/acre) of winter wheat or barley and 3.5 hl/ha (4 bu/acre) of spring wheat (P. L. Brown, *personal communication*; 4).

Stored soil water was estimated in the spring when winter wheat broke dormancy and at planting for spring grains. The Brown soil moisture probe is a 105-cm (3.5-ft) steel rod with a small sampling bit at one end. It is vigorously pushed into the soil without turning. The probe penetrates soil with enough water to support plant growth but is stopped by dry soil. Moist soil depth and soil texture were determined, and these two parameters were combined to ascertain the centimeters (inches) of plant-available water stored in the soil profile (4,5).

Growing-season (1 May—31 July) precipitation data were collected starting the day soil moisture determinations were made. Rainfall occurring after 31 July usually does not contribute to crop yield and therefore was not included.

Although this approach appears to be oversimplified, 3 years of field evaluations indicate it can provide a reasonable estimate of attainable yield over a wide range of environments in Montana. More important to the ICM program, comparing actual yield to potential yield gave estimates of production efficiency and allowed assessments of yield losses from disease.

Production Efficiency

Evaluation methods. In 1981, 31 monitoring sites were established in five counties of north-central Montana: Cascade, Chouteau, Hill, Pondera, and Teton. Monitoring sites were field locations of 8–40 ha (20–100 acres) representing a range of cropping practices common to the region. To explain differences between actual yield and potential yield, each site was characterized by collecting a variety of information before, during, and after the growing season. Before the season, soil fertility and soil water levels were measured. Crop management information—fertility program, variety, planting date, seeding rate, etc.—was supplied by the producers. Distribution of growing-season precipitation, crop growth stages, and pest occurrence and severity data were collected during the season by regularly scheduled field monitoring.

Disease data collected during each field visit included diseases present, percentage of field occurrence, severity range for individual plants, and other pertinent information, such as amount of residue or disease distribution. Diagnoses were confirmed in the laboratory by the plant pathology staff at Montana State University in Bozeman.

Disease assessment methods (rating scale and time of rating) for calculating potential yield loss varied with the disease. Leaf diseases were rated according to James (6). Since James does not include barley net blotch and bacterial leaf blight of wheat, we used the rating methods for barley scald and bacterial black chaff of wheat. The classification of Atkinson and Grant (1) was used to evaluate wheat streak mosaic losses, and percent yield loss from

Cephalosporium stripe was estimated as 75% of the percentage of whiteheads in the field. Potential yield multiplied by the percent yield loss determines loss in hectoliters per hectare (bushels per acre) (R. H. Johnston and D. E. Mathre, *personal communication*). The scale of Ledingham et al (8) was used to determine the severity of dryland root rot caused by *Bipolaris sorokiniana* (Sacc.) Shoem.

At crop maturity, six 1.4 m^2 (16 ft^2) plots were hand-harvested to estimate actual yields. Protein, test weight, kernel weights, plants per unit area, fertile tillers per plant, and kernels per head were determined as possible indicators of inadequate fertility and of moisture or pest stress during grain fill. Actual and potential yields were compared to determine percent production efficiency.

Results. No effort was made during the 1981 growing season to change farming practices; development of a data base on production and pest problems was the main intent. The goal in 1982 was to eliminate or reduce the problems identified in 1981. Growers were encouraged to utilize plant-available water through recropping and to improve fertility. Changes in crop rotations, planting dates, and variety and herbicide selection were implemented to reduce disease, insect, and weed problems.

In 1981, production efficiencies were less than 70% in 30% of the monitoring sites. Only 42% were producing at 90% or more efficiency. In 1982, a 23% increase in sites producing at 90% or more efficiency resulted from implementation of ICM. No sites were below 70% (Table 2).

Yield-limiting factors. For each field in which the potential yield was not attained, the crop/pest data and field management summaries were reviewed to determine yield-limiting factors. These included inappropriate variety selection, inadequate fertility, plant diseases, insect damage, weed competition, and herbicide damage (Table 3). Field observations often indicated well before the end of the season that potential yields would not be attained.

Only when potential and actual yields were compared did the producers fully realize the extent of yield loss from pest problems and inefficient crop management practices. Traditionally, most producers compare their yields with previous yields of their own or their neighbors—all of which could be examples of low production efficiency. Producers were unaware of pest problems, especially diseases, because field monitoring was not a common practice. Most pest and production limitations could be overcome with information already available to the farmer.

Fig. 1. Crop/fallow farming in north-central Montana.

Fig. 2. Surface accumulation of sodium, calcium, and magnesium salts associated with perched water table of saline seep.

The 1983 ICM Program

The 1981–1982 ICM program had demonstrated a method for evaluating yield and the need for total crop management in north-central Montana. In 1983, the number of cooperating producers in this region was reduced and the program expanded to include seven northeastern counties: Daniels, Dawson, McCone, Richland, Roosevelt, Sheridan, and Valley. Reducing the number of cooperators in the north-central counties allowed more time for field days and producer education (Fig. 3).

The yield evaluation and field scouting methods used during 1981–1982 were used in the northeastern counties, again with the main intent the first year being to develop a regional data base on production and pest problems. Only 53% of the cooperators were producing at 90% or more efficiency, 7% at 80–89%, 27% at 70–79%, and 13% at less than 70%. Yield-limiting factors similar to those in the north-central counties included inadequate fertility, uncontrolled weeds, and crop stress due to precipitation distribution. Few diseases were observed. Despite drought conditions in some counties, the ICM program demonstrated an accurate method for evaluating crop yields, and producers were provided with ideas for sound management practices and encouraged to monitor their fields.

How Diseases Limit Yield

Identifying and solving disease problems proved to be an excellent example of the use of total crop management. In 1981, diseases limited yield in 20% of the barley fields, 50% of the spring wheat fields, and 46% of the winter wheat fields. The following is an example of how diseases can reduce winter wheat yield, water use, and nitrogen efficiency.

A cooperator in Pondera County planted Winoka winter wheat 9 September 1980 in a field with a crop history of winter wheat/fallow for the previous 7 years. Comparing actual yield to potential yield indicated a production efficiency of only 52%. Each yield-limiting factor was identified and, when possible, a yield loss assessment value was assigned. Table 4 shows the potential and actual yields and the losses associated with variety selection and diseases.

Records showed that after anthesis, bacterial leaf blight (*Pseudomonas*

Fig. 3. Information delivery to growers during a summer field tour.

Table 4. Difference between potential yield and actual yield and primary yield-limiting factors for a winter wheat field in Pondera County, Montana, during 1981

Measure	Yield comparisons			Yield-limiting factors			
	Potential yield	Actual yield	Difference	Variety	Cephalosporium stripe	Bacterial leaf blight	Total yield reduction
hl/ha	60.4	31.5	28.9	5.0	15.9	5.7	26.6
bu/acre	68.6	35.8	32.8	5.7	18.0	6.5	30.2

syringae pv. *syringae* Van Hall) caused complete necrosis of the flag leaf of every plant in the field (Fig. 4). Winoka is very susceptible to bacterial leaf blight, and yield losses at this level of infection have been reported in Montana (12). Yield loss could have been minimized by planting a recommended variety, such as Centurk, which is moderately resistant to *P. s.* pv. *syringae* (3) and has a higher yield potential for the cooperator's area (7).

In the same field, Cephalosporium stripe (*Cephalosporium gramineum* Nis. & Ika.) was responsible for 35% prematurely ripened whiteheads (Fig. 5). This level of severity reduced yield by 15.7 hl/ha (18 bu/acre). The cooperator's winter wheat/fallow cropping scheme was conducive to this disease, and for effective control, winter wheat should be excluded from the rotation for at least 3 years (10).

The potential yield of winter wheat for this monitoring site in 1982 was 63.6 hl/ha (73 bu/acre) and the actual yield, 49.4 hl/ha (56.7 bu/acre). Field observations and yield comparisons showed that diseases did not limit yield. The field monitored was adjacent to the 1981 winter wheat field but had a different cropping history: 1979 fallow/1980 barley/1981 fallow/1982 winter wheat. By planting barley in 1980, thereby excluding winter wheat for 3 years, the grower had unknowingly broken the disease cycle of *C. gramineum*. The ICM program used this field as an example of the beneficial results of crop rotation to control Cephalosporium stripe.

The primary yield constraint at this monitoring site in 1982 was inadequate soil fertility. Soil tests indicated 134 kg of nitrogen per hectare (120 lb per acre). Even with 100% efficiency of the available nitrogen, only 52.2 hl/ha (60 bu/acre) could have been produced. This assumes that each hectoliter (bushel) requires 2.6 kg (2 lb) of nitrogen (5).

An Increase in Leaf Diseases

Leaf spot diseases have become more prevalent in Montana with the increased use of recropping or reduced tillage, or both. In winter wheat fields monitored between 1981 and 1982, tan spot caused by *Pyrenophora trichostoma* (Fr.) Fckl. increased 47% and Septoria leaf spot caused by *Septoria* spp. increased 19% (11).

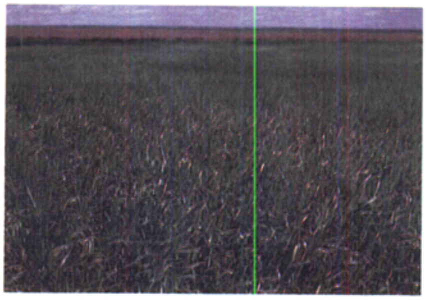


Fig. 4. Necrosis of winter wheat flag leaf caused by bacterial leaf blight.

Fig. 6. Spring barley planted no-till in barley stubble.

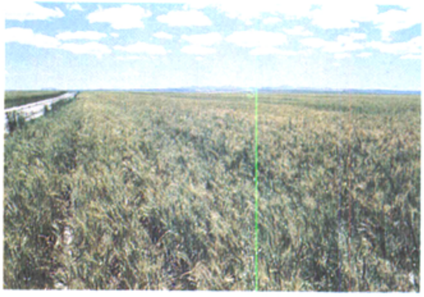


Fig. 5. Whiteheads in a winter wheat field severely infected by Cephalosporium stripe.

Fig. 7. Leaf symptoms in recrop, no-till barley infected by net blotch and scald.

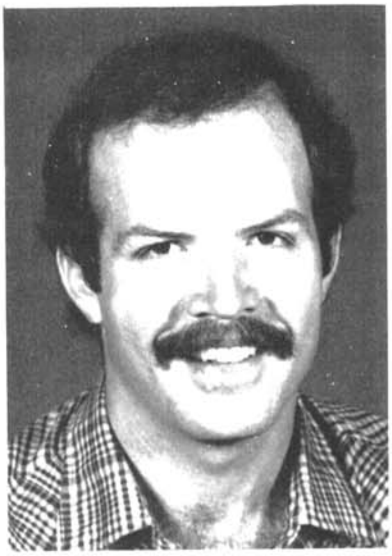
A specific example of leaf disease increase was documented in a field planted to barley for 3 years, beginning in 1981. The field had been in winter wheat/fallow rotation. As saline seep became more prevalent, recropping was initiated, resulting in increased residue accumulation (Fig. 6). The first barley crop in 1981 had minimal leaf disease, but increases in net blotch caused by *Pyrenophora teres* Drechs. and in scald caused by *Rhynchosporium secalis* (Oud.) J. J. Davis were observed in 1982 (Fig. 7). Although 75–80% of the plants were infected, flag leaf infection was less than 1%. In 1983, the percentage of plants infected remained high and flag leaf infection during kernel development was 10–25%. Because environmental stress was minimal, a yield loss was not detected.

The two factors important in increasing the amount of scald and net blotch inoculum associated with residue—previous crop disease severity and amount of residue on the soil surface (9)—were operative in this field. The obvious increase in leaf diseases and continuation of a reduced tillage program prompted the producer to plant winter wheat for 1983–1984. Field monitoring results were an important consideration in reaching this decision.

In Montana, leaf diseases of dryland spring wheat, winter wheat, and barley can best be controlled with cultural practices and selection of disease-resistant varieties. At present, economic returns for chemical applications do not justify their use under dryland conditions.

Investment in the Health of Future Crops

Montana's small grain ICM program has developed a practical approach to total crop management. The potential yield principle provides both a means of monitoring production efficiency and a simple crop loss assessment method for plant diseases. Because most disease problems cannot be solved in the year diagnosed, producers must plan ahead and select proper cultural practices. By solving one problem, they often solve other management or pest problems at the same time. Field monitoring for plant diseases was shown to be an investment in



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the health of future crops rather than a means for planning pesticide-based control programs.

Even with the low profit margin for dryland small grains in Montana, significant economic benefits can be realized using this integrated approach. Grower acceptance has been high because the program has emphasized total crop management and efficient utilization of plant-available water. The concept of integrated crop management has been translated into a practical system adapted to the needs of the producers.

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