Montana crop loss assessment in small grains

by Vickie Jeanne Parker

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
Weeds, diseases, and insect pests separately and collectively affect small grain yields. Yield effects caused by interactions among these pests are often unknown. The Montana crop loss assessment experiment was designed to measure yield constraints due to weeds, diseases, and insect pests. Significant interactions among weeds, diseases, and insect pests were shown during the three year study (1980-1982). Though yield constraints due to these pests vary with location and season, information and methodology from the crop loss assessment project may be useful for further studies on crop/pest interactions.

Crop loss assessment treatments included weed control, disease control, insect control, weed-disease control, weed-insect control, disease-insect control, weed-disease-insect control, and a check (no control). Pests were controlled by using herbicides, insecticides, fungicides, and bacterio-cides. Each treatment was replicated four times in 1980 and 1981, and eight times in 1982. Fumigation and fumigation plus weed-disease-insect control treatments were added in 1982. Pest populations were monitored, pest damage was measured, and yield component data were recorded.

In 1980, the weed-disease-insect control treatment resulted in a 44% spring wheat yield increase over the check at Bozeman, and a 21% and 45% increase at Conrad in 1981 and 1982 respectively.

In 1982, the disease control treatment produced 35 % fewer tillers/m sq. than the weed-disease-insect control treatment, even though stand counts were not significantly different among treatments. Yields of the disease control and insect control treatments were 35 % less than in treatments where both diseases and insects were controlled. Insect control treatment significantly increased volunteer barley dry weight over the dry weight in the check.

The nematode populations were 70% lower in the disease control plots than in the check plots. Nematode populations in the insect control plots were 70% higher than in the check plots.

Sawfly cutting was reduced by weed-insect control. Disease control resulted in significantly lower P. syringae infection than no disease control.

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ABSTRACT

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CHAPTER 1

INTRODUCTION

Montana small grain yields are affected by weeds, diseases, and insect pest populations. Weeds, such as wild oats, decrease yields by successfully competing with small grain crops for limited moisture, space, and nutrients. Diseases or insect pests can infest and destroy crops either sporadically or cyclically depending on the weather, the buildup of the disease or pest populations, and the farming practices which encourage or discourage the survival of the organisms.

The crop loss assessment experiment was initiated in Montana to identify effects on small grain yields caused by interactions of weeds, diseases, and insect pests. Biologically, the interactions among these pests cannot be easily separated from each other, but scientifically, their effects on yield are often examined separately.

The Montana crop loss assessment experiment evolved from questions such as the following: 1) If weeds significantly reduce yield and diseases significantly reduce yield, will the combination of weeds and diseases decrease yield additively? Synergistically? Or will the diseases infect the weeds, and, therefore, decrease the weeds' competitive ability, which would result in an increase in grain yields?

2) If a plant is infected by a disease, but the disease pressure does not visibly affect yield, how much weed pressure, insect pressure, or additional disease pressure would be necessary to noticeably affect yield? 3) If all stress caused by weeds, diseases, and insect pests is removed from the plant, will it produce more grain, or less? 4) Do chemicals affect crop yield when pest are not present, or are at very low populations?

A preliminary study in 1980 on crop loss assessment (W. Morrill, P. Fay, D. Sands, unpublished data) measured the effects of weeds, diseases, and insect pests on grain yield. Interactions among these factors as they affected yield were evaluated. Control of weeds, diseases, and insect pests resulted in a 44% yield increase as compared to the check.

Based on the work done in 1980, the objectives of this study were 1)to continue multidisciplinary research designed to enhance yield of small grains, and 2) to search for interactions among weeds, diseases, and insect pests.

Crop Loss Assessment Concept

Crop loss assessment illuminates opportunities for grain yield increases when adequate protection measures are used. Pest control programs (Chiarappa et.al. 1972) have been developed without full knowledge of the relevant economic factors involved.

Chiarappa et.al. (1975) pointed out the need for crop loss assessment projects to secure reliable information about yield constraints on which to base long term planning of research progams and allocation of resources. They stated that crop loss assessment data should substantiate evidence of pest problems already occurring. Through crop loss assessment, the relationship of pest infestation to crop damage and yield can be quantified (Irving, 1970). Plant protection scientists, economists, biomathematicians and ecologists must cooperate in a continuous multidisciplinary program to reduce crop losses and increase food production.

The parameters of crop loss assessment (Chiarappa et.al., 1975) include the level of weed/disease/insect pest infestations existing in a given field or area, and the quantity (or quality) of yield reduction resulting from that particular level of infestation. To obtain useful information, the researcher should 1) design a field experiment to appraise losses, 2) record field symptoms and the effect on the crop due to infection or infestation, 3) establish a quantitative relationship between the population densities and yield losses, and 4) determine methods to prevent or reduce losses.

Population density is measured in or on a given plant/crop/area by one of the following methods (LeClerg, 1971): 1) Actual counts of pest numbers, or weight or volume of specimens collected, 2) Visual rating of pest numbers in defined classes, 3) Actual counts of plant or crop units damaged or affected by pests, 4) Visual ratings of damaged plants or plant parts in classes defined by descriptive scales or diagrams. Crop variety, seeding rate, plot dimensions, part of plots harvested, number of replications, pest species present, time of initial infection or infestation, yield components, and any management problems should be recorded.

If these guidelines are followed, research in the development of crop loss forecasting systems and efficient pest management programs would be accelerated (Chiarappa et.al., 1975). For crops whose value does not warrant chemical application, crop loss assessment surveys are the basis for possible alternative solutions such as breeding resistant varieties or modifying cultural practices (James, 1974).

Insect Pests of Wheat

Aphids

Four species of aphids have been found in Montana small grain fields (Carroll, 1982):

Schizaphis graminum (Rondane) - greenbug

Macrosiphum avenae (Fitch) - English grain aphid

Rhopalosiphum padi (Linaeus) - Oat-bird-cherry aphid

Rhopalosiphum maidis (Fitch) - Corn leaf aphid.

These aphid species feed on the plants in stages from early tillering to ripening. They are also the vectors for barley yellow dwarf virus (BYDV).

Kieckhefer (1975) found that the greenbug, English grain aphid, and oat-bird-cherry aphid colonize spring wheat, barley, winter wheat, and rye, and the corn leaf aphid colonizes barley in the early growth stages. Apablaza (1967) reported that the greenbug and English grain aphid severely injure or kill seedlings of barley, wheat, and oats and cause reductions in kernel weight of harvested grain, even when the infested plants are advanced in maturity. He found that plants were not killed if greenbug infestation occurred 65 days after the date of seeding. Infestation occurring 35 days after seeding caused fewer tillers and lower kernel weights.

The English grain aphid killed all barley, wheat, and oats it infested at 7-27 days after seeding. The corn leaf aphid did not damage the small grains as severely as the above two species. The loss in grain yield depended on the weather, abundance of parasites and predators, and stage of plant growth at the time of infestation (Apablaza, 1967).

The English grain aphid overwinters in the egg stage on grasses and stubble. During the growing season it moves into the edges of the field. The English grain aphid feeds on the flag leaf before ear emergence and on the wheat head after emergence (Wratten, 1974). No significant differences were noted between spikelet numbers or number and weight of grains, but grain weight was reduced by 14%. Grain protein was also significantly reduced.

A heavy infestation of the English grain aphid during flowering reduced yield by up to 30% (Kolbe, 1969). Thousand kernel weight decreased when aphids exceeded 200 aphids/head.

Oat-bird-cherry aphids overwinter in the egg stage. Alate aphids disperse into the wheat fields in late May and feed on lower plant parts and bases of blades. As few as 39 aphids/shoot decreased yield significantly (Kolbe, 1969).

Metasystox or malathion applied early in the season effectively controlled oat-bird-cherry aphids (Kolbe, 1969). Phorate and Di-Syston seed treatments effectively controlled greenbug on spring barley six weeks following planting. These chemicals increased yield significantly over untreated checks even though plant stands were reduced significantly (DePew, 1964). Treated plots yielded 16 to 24 bu/acre, while untreated plots yielded 1.4 bu/acre.

Survey methods included the use of traps placed above the plant canopy and on the ground surface (Broadbent, 1948), sweep net samples, and visual counts and identification of aphid species on a weekly schedule from wheat emergence to harvest (Dean, 1973; Kieckhefer, 1975).

Wheat Stem Sawfly

Wheat stem sawfly, *Cephus cinctus* Norton, is native to wheat grasses, and has adapted well to cultivated grain fields. Parasites, which control sawflies in wheat grasses, have not successully moved into domestic grains (Davis, 1955; Holmes, 1953; Holmes et.al., 1963; Wallace & McNeal, 1966; Nelson & Farstad, 1953; Nielson, 1949; Somsen & Luginbill, 1956). Sawfly adults emerge from stubble in the late spring and move into wheat fields which are in the stem extension stages. The females oviposit into hollow areas throughout the wheat stem. The larvae hatch in one week and feed inside the stems until early August. At this time, the larvae move to the bases of the stems, and cut and plug the stubs (lower stems). They remain in these stubs throughout the winter (Criddle, 1923). Because the adult is the only stage of the insect which is outside the stem, and because the number of female adults does not indicate the number of larvae, due to multiple ovipositing and larval cannibalism, predicting the economic losses due to the wheat stem sawfly is difficult. Cut stems/unit area is an accurate estimate of the overwintering sawfly larval population (Criddle, 1923).

Heptachlor applied to soil at planting resulted in high larval mortality if a light infestation occurred, and if sawflies were restricted to the lower nodes of the wheat stems (Holmes & Peterson, 1963). Wallace (1962) also reported effective control of sawflies (70 to 80%) by furrow application of heptachlor. Of seventeen chemical sprays, broadcast granules, and furrow treatments tested, furrow treatments were most effective, while sprays and broadcast granular treatments were ineffective (Wallace, 1962).

Hessian fly

Hessian flies, *Phytophaga destructor* (Say), are widely distributed in the wheat growing regions of the world. The female adults lay their eggs on wheat leaves, the eggs hatch, and larvae feed between the leaf sheaths and the stalks causing a weakening of the spring wheat stems and a decrease of 1000 kernel weight and grain quality (Pike and Antonelli, 1981). Controls include the application of insecticides (Morrill & Nelson, 1976). Sampling of damage is done by counting infested tillers/unit area (Brown, 1960).

Wheat Stem Maggot

Wheat stem maggot, Meromyza americana Fitch, infests all small grains and some grasses. The larvae feed within the stems which causes wheat heads to die before the grain is formed. Counting white heads of stems spirally cut is a sampling method (Allen and Painter, 1937).

Wireworms

Many species of wireworms are phytophagous on seeds, roots, and young seedlings of a variety of crops. Soil treatments have been used to protect vegetable crops against wireworms. The efficacy of seed treatments depends upon the species of wireworm involved, wireworm activity, the proportion of the population attracted to the seed, and the date of planting. Lindane had little effect on seed germination even when it was combined with certain fungicidal treatments (Lange et.al., 1949).

Weed Competition

Weeds in small grains have been the focus of research projects for many years. Friessen and Shebeski (1959) found that as few as 50 weeds/m sq. would decrease grain yield, and that, specifically, wild oats, wild mustards, wild buckwheat, and sowthistle were highly competitive with cereal crops.

Friessen et.al. (1960) stated that weeds caused a significant drop in yield and grain protein, but Bell and Nalewaja (1968) found no influence on percent protein due to weed pressure. Bell and Nalewaja (1968) did discover, however, that a wild oat density of 10 seedlings/m sq. caused a decrease in wheat yield of 1 to 3 bu/acre. Early control of wild oats is essential (Nalewaja & Arnold, 1970).

McNamara (1976) found a reduction in wheat yield, tiller number, and dry matter at plant maturity due to wild oat competition. Competitive effect increased with increased density. Hodgson (1963) found that in Montana wheat fields, 2 Canada thistle shoots/m sq. reduced yield by 15 % and that 25 shoots/m sq. reduced yield by 60%. Samples of weeds were taken from four 30 cm. sq. plots. A meter sq. area of the field was harvested for yield determination (Hodgson, 1963).

Diseases

Viruses

Virus diseases infecting spring wheat include barley yellow dwarf virus (BYDV) which is transmitted by aphids, and wheat streak mosaic virus (WSMV) which is transmitted by mites. Control of the virus depends greatly on control of the vector, or escape of the host plant from contact with the vector. Control of the vector by spraying insecticides seldom prevents virus introduction (Broadbent, 1969). By manipulating planting rate or the size of the field, the percent of total plants infected can be reduced.

Weeds, alternate or secondary hosts for insects, may be the key in many plant-virus interrelationships (Duffus, 1971). Early weed control is necessary because control of the weeds after vector populations have been established may force movement of the vector between hosts, and consequent virus spread.

Symptoms of BYDV and WSMV have been reviewed in the literature (Wiese, 1977; Smith, 1963). Smith stated that more aphids are necessary later in the growth stages of cereals to cause a similar degree of severity inflicted by fewer aphids earlier in the season. Panayotou (1979) reported that wheat yield was reduced more from a late infection. Gill (1980) confirmed Smith's findings with his report that later inoculation resulted in lower losses, but that grain size and milling properties were affected. In spring wheat, the stem extension growth stage is the most susceptible stage to virus infection.

Doodson and Sanders (1970) rated leaves showing BYDV symptoms as 0=no discoloration through 8=total necrosis. Monitoring of the BYDV vector movement may be done by visual examination of plants showing symptoms. Infected plants can be pulled and aphids counted. Sweeps of the field can be made to determine the aphid species present and the stage of maturity of the aphids (Gill, 1970).

Carbofuran was found to control mites, the vector of WSMV. Its application reduced the incidence of WSMV and increased grain yields (Harvey et.al., 1979). While neither a phytotoxic nor stimulating effect on plant growth was observed, carbofuran may have caused plants to produce more grain. Wheat streak mosaic virus incidence was determined by counting the number of infected plants in 9.2 meters of row.

Bacteria

Pseudomonas syringae decreases yields of semidwarf spring wheats and some winter wheats (Otta, 1974). Symptoms have been described in the literature (Otta, 1974; Sellam & Wilcoxson, 1976). Field evaluation of infection was done by Sellam and Wilcoxson (1976) after heading, when dry weather stopped the bacterial spread. They measured plant resistance to *P. syringae* by rating the percent of necrosis occurring on the upper three leaves. Resistance equalled small lesions, or 5 to 10% of the surface infected, moderataly susceptible equalled 10 to 15% of the leaf surface infected, and susceptible equalled more than 25% of the leaf surface blighted. Fryda and Otta (1978) isolated P. syringae from the upper leaves of wheat plants and determined it was from epiphytic populations from nearby weeds or crop plants. They surveyed P. syringae presence by sampling the first, second, and third wheat leaves of 1050 plants.

Fungi

Common root rot, Cochliobolus sativus, reduces the number of tillers/plant and the number of kernels/spike (Verma et.al., 1976). Sampling plants from each of 6 adjacent rows from 6-9 locations/field is the most efficient root rot surveying method (Stack & McMullen, 1977).

CHAPTER 2

MATERIALS AND METHODS

Experimental Year One - 1981

The experimental design was a randomized block containing eight treatments replicated four times. The experimental plots were planted at the Central Montana Agricultural Research Center near Moccasin, MT and at the Western Triangle Agricultural Research Center north of Conrad, MT. The treatments were weed (W) control, disease (D) control, insect (I) control, WD control, WI control, DI control, WDI control, and a check (no controls). Cultivars included Newana spring wheat and Hector barley. Each plot consisted of 8 border rows, 4 yield rows, and 8 working rows for a total of twenty 6.0 meter rows. The area per cultivar per location, therefore, was .33 acres.

The Moccasin plots were planted on 4/10/81 into moist fallow at a rate of 140 barley seeds/6 m row and 160 wheat seeds/6 m row. Conrad plots were planted on 4/24/81 (same rates as Moccasin) to a depth of 5 cm to reach the available soil moisture. Soil tests showed 75 lb. (34 kg)/acre NO3, and 30 lb. (13.5 kg)/acre additional NO3 was applied at

Moccasin. Soil tests at Conrad showed 32 lb. (14.4 kg)/acre NO3. Sixty lb. (27 kg)/acre additional NO3 was applied.

Weed Control (W)

Bi-monthly hoeing and hand pulling controlled weeds. At wheat maturity, a weed survey was taken in the four yield rows of each plot. Weed species were noted, and the number of each species was counted (Klingman, 1971).

Disease Control (D)

Seed of the disease control treatment was treated with 3 oz./100 lb (85g/45 kg) carboxin 30 days before planting. After emergence, the disease control plots were sprayed every two weeks with benomyl at the rate of 1 lb. (.45 kg)/acre active ingredients (AI), triadimefon at 1/4 lb. (.11 kg)/acre AI, manzeb at 2 lb. (.9 kg)/acre (80% AI), oxytetracycline hydrochloride at .04 oz. (1.1 g)/acre, and streptomycin at .13 oz. (3.7 g)/acre (three applications each).

In the first week of July, a foliar disease survey was conducted in the yield rows of all plots. The diseases were identified, and their frequency of occurance was rated using a standarized scale of 0=no disease present, 1=few plants infected and 2=very visible (Slykhius et.al., 1959).

Just before harvest, a root rot survey was conducted on 10 plants/plot pulled at random. The severity of lesions on the subcrown internode was rated on a scale of 0=no lesions to 4=completely black (Verma et.al., 1974).

Insect Control (I)

Seed of the insect control treatment was treated with 2 oz. (56.7 g)/bush lindane (18% AI) 30 days before planting. After emergence, insect control plots were sprayed every two weeks with acephate at the rate of 1/4 lb. (.11 kg)/acre AI. Carbofuran was sprayed at the rate of 1/4 lb. (.11 kg)/acre AI at the grain ripening stage.

Sticky traps (3 x 5 white card stapled lengthwise to a 40 cm wooden stake, and covered with Tack Trap) monitored the flying insects in every plot. The traps were changed every two weeks, and trapped insects were identified and counted.

Pitfall traps (Figure 1) also were placed in all plots to monitor the movement of ground insects. These were emptied every week, and the insects were identified and counted.

Insect damage, as it occurred, was identified. The number of white heads in each plot caused by wheat stem maggots was counted. After harvest, the number of stubs, in the four yield rows, containing wheat stem sawfly larvae was counted.