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WEED AGGRESSIVITY IN AGRONOMIC CROPS

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Introduction

The quantity of herbicides applied in crops has disturbed environmentalists for many years and several environmental groups have voiced distress about the impact of herbicides on water quality, the food supply, and human health. These concerns are causing administrators, scientists, and farmers to search for farming practices and research programs that can effectively balance agri chemical usage with the protection of national resources, food supplies, and human health (Anonymous, 1989a; Anonymous, 1989b). "Society will become more environmentally sensitive, and agricultural practices will become more environmentally friendly. Pesticides that cause unacceptable environmental damage or threaten health will be withdrawn. During the next 20 years many of today's chemical pesticides will become obsolete. Certain environmentally friendly herbicides, like glyphosate, will still be used, often in combination with biotechnology, to replace less friendly herbicides" (Schneiderman and Carpenter, 1990). "Environmental pressures have led to a growing demand for an overall reduction in the use of pesticides and, in countries such as Denmark, Sweden, and the Netherlands, sucha reduction has become formal government policy" (Thomas, 1990). New research programs must be initiated that include on-farm studies of farming systems and the development of computer software and systems to aid farmers in the management and decision making needed to adopt alternative systems (Anonymous, 1989b).

Weed Competition

Weed competition is a complex phenomenon governed by various biological, environmental, and proximity factors. Emergence characteristics, growth rates, and other components of plant size and function influence the process of competition (Harper, 1977; Radosevich, 1986). The proximity factors of plant density, spatial arrangement, and proportion of species also are important considerations when studying interactions among neighboring plants (Harper, 1977; Radosevich, 1986; Radosevich, 1987).

Predicting crop yield reductions from weeds has focused traditionally on low weed infestation densities to identify the economic threshold levels (minimum densities) which justify expenditures for weed control (Aldrich, 1987). Economic threshold level and area of influence measurements have provided the basis
for developing weed competition indices farmers can use to decide if weed control is warranted (Coble, 1985; Dew, 1972; Schweizer and Dexter, 1987). A competitive index, derived from yield density relationships, and selected for weed density as well as weed species, is more likely to reflect the competitive ability of a particular weed infestation than an index obtained from plant weights in the growing crop (Wilson and Wright, 1990). However, economic threshold level and area of influence do not adequately measure plant growth factors, i.e. light, water, nutrients, O₂ and CO₂, involved in competition. Under irrigated conditions, light may be the most important growth factor impacting crop stress from weeds since nutrients and water stress can be managed. Environmental conditions usually preclude competition for O₂ and CO₂ (Trenbath, 1976).

Weed-crop competition focuses on interactions in which some growth factor is in insufficient supply to meet the needs of each plant. During the growing season, competition is seldom restricted to a single growth factor because of the interrelationships between competition and plant growth form and rate. Competition begins at the point when environmental resources (principally water, nutrients, and light) cease to meet the needs of two or more plants in an area. Weeds commonly take up added nutrients (fertilizer) more rapidly and in larger quantities than do crops (Alkamper, 1976). Attempts to provide enough of a competed-for growth factor to meet the needs of both the crop and the weeds are impractical. A relatively scarce supply of a growth factor encourages earlier onset of competition for that factor.

The aggressivity (competitiveness) of weeds are mainly determined by growth characteristics inherent to each weed species and partially by environmental constraints. Differences among weed species in their relative competitiveness for individual growth factors also may contribute to some variability in results of threshold-level and area-of-influence studies. Differences among weed species in their relative aggressivity have been reported for only four annual weeds. Ranked in order of aggressiveness were barnyardgrass > redroot pigweed > common lambsquarters > nightshade (Rousch and Radosevich, 1985). In Colorado, a computer-based weed management expert system for weed control in corn uses a subjective relative competitiveness index for 15 annual weed species (Schweizer, unpublished). These 15 species are categorized into three relative competitive groupings --- most competitive (common sunflower, Kochia, shattercane, and velvetleaf), intermediate (common lambsquarters, redroot pigweed, and wild proso millet), and least competitive (barnyardgrass, common purslane, foxtails, nightshades, sandbur, venice mallow, wild buckwheat, and wild oats). Knowledge of the aggressiveness of weed species in relation to each other and to that of the crop could result in optimal weed control practices. Benefits realized from the control of unaggressive weed species may be
minimal. Even though competition is a complex phenomenon, several concepts and principles can be examined that can be applied in weed management.

The competitiveness of weed species is associated with such factors as weed duration, weed density, weed seed banks, and cultural practices.

Weed Duration. Duration of weed competition is often called the critical period. The "critical period of weed control" defines the time span when weeds present from the beginning of the crop cycle must be removed without yield loss by crops, or the point after which weed growth no longer affects crop yield (Nieto et al, 1968). The length of competition tolerated after seeding varies for crop and weed species, but most crops can tolerate early weed competition for 2 to 10 weeks after seeding without suffering a yield loss. For example, corn can tolerate green foxtail for 4 weeks (Sibuga and Bandeen, 1978) and giant foxtail 6 weeks (Knake and Slife, 1969) after seeding without a yield loss. Soybeans can tolerate common cocklebur for 4 weeks (Barrentine, 1974), yellow foxtail for 5 weeks (Staniforth and Weber, 1956), giant foxtail for 8 weeks (Knake and Slife, 1969), and velvetleaf for up to 12 weeks (Oliver, 1979) after seeding without a yield loss.

The weed-free period required after seeding before crop yields are reduced also varies for crop and weed species, but most crop yields are not reduced as long as the crop is kept free of weeds for 2 to 10 weeks after seeding. For example, corn and soybean yields are not reduced as long as annual weeds do not become established for 2 to 6 weeks after seeding (Zimdahl, 1980). Yield-reducing competition is likely to occur much earlier in the crop cycle if moisture, rather than light, is the primary limiting resource.

Weed Density. As weed density increases, crop yields decrease, but the weed density-crop yield relationship is usually sigmoidal rather than linear (Zimdahl, 1980). A study conducted in Illinois illustrates the sigmoidal relationship; however a number of other studies could have been cited. Smooth pigweed densities of 0, 1, 2, 4, 8, and 40 plants/40-inch spacing in corn reduced grain yield by an average of 5, 12, 15, 27, and 36%, respectively, over a 3-year period. The same smooth pigweed densities in soybeans reduced seed yield by an average of 18, 27, 32, 45, and 51%, respectively, over a 3-year period (Moolani et al, 1964).

Weed Seed Banks. Most annual weeds produce a prolific number of seeds each year. Stevens (1932) reported that a single, large-developed plant of barnyardgrass can produce 7,160 seeds, green foxtail 34,000 seeds, common lambsquarters 72,450 seeds, and redroot pigweed 117,400 seeds. Because annual weeds have a great capacity to produce seeds, it is not surprising that large
numbers of weed seeds are found in agricultural soils. In Minnesota, Robinson (1949) reported that the reservoir of seeds in soils at four locations ranged from 4 to 175 million/acre; and in England, Chancellor (1979) reported that the reservoir of seeds in soils at 32 locations ranged from 6 to 96 million/acre.

A large weed seed reservoir in soil can be reduced to a much lower level within 4 to 6 years where most annual weeds are controlled in rotational crops with herbicides and tillage (Roberts, 1968; Schweizer and Zimdahl, 1984a and 1984b). Initially, an intensive system of weed management has to be employed for at least 4 years to reduce the weed seed reservoir in the soil by 90% or more. Once the weed seed reservoir has been reduced to a low level (<20 million/acre), it can be maintained with a moderate level of herbicides and tillage. However, the number of weed seeds in soil will increase whenever environmental conditions prevent the timely application of herbicides and delay tillage; where new seeds are introduced in fields via wind, irrigation water, contaminated crop seed, or manure; or where some weed species become resistant to herbicides.

Cultural Practices. Cultural practices such as planting date, row spacing, crop cultivar selection, crop rotation, tillage, and herbicide usage directly affect the extent to which weeds interfere with a crop. Velvetleaf emerging with soybeans planted in mid-May were twice as competitive as those emerging with soybeans planted in late June (Oliver, 1979). A 3-week head start by corn or soybeans markedly reduced the dry matter production of giant foxtail (Knake and Slife, 1965). Giant foxtail seeded into corn and soybeans 3 weeks after the crops were planted made only 1/5 the growth in corn and practically no growth in soybeans. Narrow-row spacings also have reduced weed competition in soybeans in Illinois (Wax and Pendleton, 1968), Kansas (Felton, 1976) and Nebraska (Burnside and Colville, 1964). Soybeans planted in 20-inch rows will reduce the weight of weeds by more than 3.5 times than those planted in 40-inch rows (Felton, 1976).

Mechanical Tillage

A computer based weed management expert system for corn production can be used successfully in large scale farmer trials to reduce the amount of herbicide required for sustainable corn production in conventional irrigated cropping systems in the Central Great Plains (Westra et al, 1990). New emphasis on alternative agriculture methods that eliminate or replace part of a herbicide program with mechanical tillage necessitates precision research to determine whether computer based weed management models can be adapted to provide weed management decisions for alternative farming systems. Additionally, few reports have been published on the effectiveness of mechanical
tillage to control weeds in row crops over the last 40 years, because weed control strategies developed since World War II for crop production have encouraged farmers to apply high rates of prophylactic soil applied herbicides in anticipation of weed problems. Little recent research has been directed toward many on-farm interactions integral to alternative agriculture, such as the relationship among crop rotations, tillage methods, and pest control (Anonymous, 1989b). Most of the recent information on weed control with tillage appears in popular farming magazines or in eleven case studies commissioned by the National Research Council [NRC] (Anonymous, 1989b). Five of the eleven NRC case studies dealt with crop and livestock farms, with corn and soybeans being the principal row crops. Weed control practices included rotating crops, tilling just before planting, delayed planting, rotary hoeing (before and/or at emergence), frequent cultivations (2-4 per season), and sometimes handweeding and/or postemergence herbicides. Weeds that emerged within the crop row were difficult to control when the weeds emerged simultaneously with the crop. Thus, if weeds are to be controlled within the crop row with mechanical tillage, better tillage methods must be sought.

One tillage method that may control weeds effectively within the row is an in-the-row cultivator. In preliminary studies in 1990, Schweizer (unpublished) found that after two cultivations, the weed populations in corn were reduced 98% with an in-the-row cultivator but not reduced at all with a standard row cultivator. Thus, the effects of alternative tillage systems on weed control and cultivation costs need to be determined in irrigated row crops.

Model Development

Weed management decisions are based on various types of weed thresholds: competition, economic, economic optimum, period, predictive, safety, statistical, and visual (Cussans et al, 1986; Dawson, 1986). Few weed management models have been developed. Economic weed threshold models have been developed for corn (Zea mays L.) (King et al, 1986), soybeans [Glycine max (L.) Merr.] (Mara and Carlson, 1983; Wilkerson et al, 1988), sugarbeets (Beta vulgaris L.) (Shribbs et al, 1990), and winter wheat (Triticum aestivum L.) (Doyle et al, 1986). Modeling is clearly underused as a tool in weed research because there seems to be a lack of appreciation for the advantages of modeling (Cousens et al, 1987). Modeling can enhance a research program by: a) acting as a framework to integrate available information on a particular topic, b) pinpointing critical gaps in research, c) increasing the speed with which understanding develops when used with an experimental program, and d) identifying critical experiments which make the most economical use of resources (Cousens et al, 1987).
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