Chemical fallow in Montana

by Robby Lee Brattain

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agronomy
Montana State University

Abstract:
Chemical fallow systems using atrazine (2-chloro-4-(ethylamino) -6-(isopropylamino)-s-triazine) were evaluated. Soil residue bioassays for atrazine were conducted at different time periods. Atrazine persistence was correlated with moisture, soil pH, soil organic matter, soil clay content and soil calcium content to devise a method for predicting atrazine residues in field soils. Precipitation and soil pH were the most important factors governing the rate of atrazine degradation. Soils with pH 8.0, or greater, need approximately 43.8 cm of precipitation to completely degrade 0.84 Kg/ha of atrazine. Soils of pH 7.0 to 8.0 and 6.0 to 7.0 must receive 41.1 and 39.6 cm, respectively, to degrade 0.84 Kg/ha of atrazine.

Bioassay techniques for measuring atrazine soil residues were compared. Standard greenhouse pot assay, cone-container assay, petri dish assay, Stanford-DeMent assay and Chlorella algae assay were compared for accuracy, and or time and space requirements. The standard pot and cone-container assays were accurate but required 21 days for completion. The Chlorella algae assay while initially more expensive, was accurate and required only two to three days for completion.

The tolerance of 19 barley, 10 spring wheat, three spring durum and 15 winter wheat cultivars to atrazine soil residues was evaluated. Barley and spring wheat were the most and least tolerant crops to atrazine, respectively. 'Klages' and 'Wapana' were the most tolerant barley cultivars. 'Olaf' and 'Crosby' possessed the highest tolerance among the spring wheat and durum cultivars, respectively, while 'Lancer', 'Winalta' and 'Cheyenne' were the most tolerant cultivars of winter wheat.

Glyphosate (N-(phosphonomethyl)glycine) was applied at different stages of weed growth to evaluate the effect of delaying application on control of weeds. Soil moisture measurements were taken to measure soil moisture loss due to weed growth on fallow ground. By delaying application, more glyphosate is needed for control of existing vegetation and there is a substantial loss of subsoil moisture from weed growth.

Information tours were held at ten locations in Montana in 1980. Tours were based on chemical fallow advantages and disadvantages and economic status of chemical fallow. Tours were directed to inform farmers, commercial applicators, county agents and herbicide dealers.

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Date March 5, 1981

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Approved:

Chairman, Examining Committee

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INTRODUCTION

It is common practice to alternate production of cereal crops with summer fallow in semi-arid regions. Fallow is defined as land cultivated but not seeded for one or more seasons to kill weeds, enrich the soil and conserve moisture (127). Approximately 39 million acres of cropland are summer fallowed annually in the United States (127).

Many terms are associated with fallow: bare or black fallow, summer fallow, stubble mulch tillage, chemical fallow and ecofallow. Tilled fallow systems may lose 75% or more of the moisture that the soil receives (127). While only 25% of the total moisture is saved, it is generally adequate for grain production in semi-arid areas.

Chemical fallow involves the use of herbicides to kill weeds during the fallow season, allowing minimum or no tillage. This provides minimal destruction to crop residue on the soil surface which reduces erosion and increases moisture conservation in most soils.

Chemical fallow systems have several advantages:

1. Increased surface residue which results in:
   a) reduced erosion.
   b) increased snowfall retention.
   c) increased rainfall penetration.
   d) increased soil moisture levels.
   e) insulation of crop seedlings.
2. Weed control is achieved when tillage is not possible.
3. Reduced energy, labor and machinery costs.

The importance of chemical fallow systems has been increased due to recent economic factors. The high cost of petroleum products, machinery, and machinery repairs has dramatically increased the cost of summer fallow tillage. Small grain producers in Montana are seeking alternate means of fallowing such as chemical fallow systems.

Chapter 1

LITERATURE REVIEW

A. Early History of Chemical Fallow (to 1960)

Chemical fallow research in Montana began in 1947 (10) when T. S. Aasheim attempted to reduce the number of tillage operations with 2,4-D to maintain protective crop residues on the soil surface. Timmons (10) reported that chemical fallow plots outyielded cultivated plots in Kansas in 1947.

Barnes et al., (11) compared the effects of fallowing techniques on soil water. Chemical fallow was compared with no tillage, subsurface cultivation, and spring plowing followed by subsurface cultivation. Chemical fallow treatments allowed maximum water infiltration (1.52 in/hr). Ninety-five percent of the water volume infiltrated the chemical fallow during the last 30 minutes of the hour duration. Chemical fallow water infiltration was 216% more than the infiltration of plowed soil and 250% more than the infiltration of subsurface cultivation. Barnes (11) attributed the difference in infiltration to the stubble residue eliminating water runoff.

Baker et al., (10) conducted chemical fallow studies in Montana from 1951 to 1955 and found that weed control by chemical treatments lasted longer than control by cultivation. Yields were not reduced by chemical fallow. It was concluded that chemical fallow was more expensive than cultivation. Cost of fallowing was usually reduced when tillage and application of 2,4-D were combined. Chemical fallow supplemented with tillage resulted in firm seedbeds which aided seeding procedures.

Research in the early 1950's indicated that chemical fallow had great potential if lower costs and more consistent weed control were achieved. Decreased cultivation conserved soil moisture and reduced soil erosion.

Wiese and Army (129) in 1957 compared storage of soil moisture following disking, sweep plowing, and chemical fallow. Total moisture in a four-foot soil profile was not affected significantly by any of the treatments. All methods were considered inefficient for moisture storage. Chemical fallow treatments had better erosion control and moisture levels equal to subsurface cultivation. Wiese and Army (129, 131) concluded that if consistent weed control was achieved, soil moisture levels would be higher under chemical fallow treatments.

By 1960, the advantages of chemical fallow included: 1) reduction in operation costs, 2) retention of crop residue, and 3) increase in precipitation retention. However, an inexpensive, consistant, broad spectrum herbicide was needed (39).

Research prior to 1960 showed slight increases in soil moisture conservation in chemical fallowed land (10, 11, 95, 129). In 1960, Wiese and Army (130) observed that a disked soil surface dried more rapidly than chemically fallowed plots because wind speed and evaporation of soil water were greater on bare fallow. Additionally, temperature of the upper six inches of soil was higher under bare fallow which increased evaporation where runoff was prevented, moisture storage for chemical fallow and stubble mulch was equal, indicating that bare fallow under normal field conditions stored less moisture due to runoff (131).

Maintaining surface residue increases soil moisture in the surface two inches of soil and decreases soil crusting (5). The effects of surface plant residue decreased with profile depth. Soil depths below two inches were not influenced significantly by surface residue. Chemical fallow maximized standing stubble which remained intact. The stubble impeded air movement at the soil surface and reduced evaporation. It was concluded that surface residues increase soil moisture reserves especially if precipitation is received frequently.

The development of paraquat (1,1'-dimethyl-4,4' bypyridinium ion) in 1963 was a significant advancement for chemical fallow since it provided broad spectrum grass control (52). Grasses are the primary weeds in many areas and are often hard to control. Areas treated with paraquat were especially resistant to soil erosion due to plant residue.

Fenster (43) concluded that some herbicides such as atrazine and prometon persist too long for chemical fallow cropping systems. Wicks (121) found that chemical fallow reduced dry soil aggregation, nitrification rate, soil nitrate levels, and nematode populations. He concluded that the limitations of chemical fallow systems are inconsistent weed control, herbicide cost, and crop injury from herbicide residues.

B. Recent History of Chemical Fallow (1960-1975)

By the late 1960's, the benefits from maintaining surface crop residue were widely known (132). Erosion control had been a major concern and several studies indicated that chemical fallow maximizes control of soil erosion (3, 4, 15, 16, 65). Hyder and Everson (67) successfully utilized chemical fallow procedures for both seedbed preparation and the rehabilitation of abandoned cropland previously vulnerable to erosion. Bennett (16) tested chemical fallow systems for erosion control on hillsides and found a large reduction in soil erosion.

Soil moisture storage in a Washington study was 35% of the received precipitation with bare fallow compared to 43% of the received precipitation for chemical fallow in a three-year crop rotation system (3). In a two year crop rotation, nearly twice as much moisture (44%) was stored in a chemically fallowed system in contrast to conventional tillage (25%). Additional research was conducted to measure conservation of soil moisture using chemical fallow techniques (4, 37, 58, 59, 124).

Chemical fallow systems have often been reported to increase crop yields (1, 18, 44, 46, 56, 58, 98, 125, 126). Corn yields increased

625 Kg/ha as a result of reduced water stress on chemically fallowed land (66). Sorghum and winter wheat yields increased significantly under chemical fallow (123).

Early chemical fallow research indicated that weed control was more consistent following conventional tillage (43, 124). However, there were several studies which reported satisfactory weed control (37, 44, 73, 92). Fenster et al., (43) suggested that new herbicide formulations such as granular formulations might result in better weed control.

Fenster and Burnside (44) found weed control and wheat yields were highest on chemically fallowed land when compared to three tillage methods and six tillage dates. Eckert and Evans (37) found that weed seed production of downy bromegrass (Bromus tectorum L.) was reduced or eliminated by chemical fallow with atrazine. An increase in soil nitrate levels was also recorded.

Wicks et al., (124) evaluated several formulations of atrazine. When a wettable powder formulation of atrazine was incorporated, the density of seeded wheat plants per unit area was increased when compared to plots which were not soil-incorporated. Soil-incorporation of granular formulations of atrazine had no effect on wheat stands.

Chemical fallow herbicide residues frequently caused yield reductions and crop injury (38, 65, 66, 76, 117). Hutchings and Hicks (65) reported crop yield reductions from herbicide residues and competition which resulted from inconsistent weed control. Seedling vigor of wheat and barley seeded into chemical fallow was reduced by herbicide residues. Eckert (38) observed that planting in furrows removed atrazine residue from the seeded row. Disk furrows were as effective for reducing crop injury from herbicide residue as shovel-opener furrows. Warboys (117) reported that mulches of paraquat treated herbage adversely affected seedling growth and development.

Use of residual herbicides stimulated research on persistence of residues. Lavy (76) found that 2,4-D degraded rapidly under aerobic conditions and atrazine degradation decreased with soil depth. Atrazine treated soil samples placed at a depth of 90 cm contained phytotoxic residues after 41 months.

C. Present Research on Chemical Fallow (1975-1980)

Recent research efforts in Nebraska have identified several benefits of chemical fallow systems when compared to conventional tillage methods (72). Chemical fallow results in:

1) increased yields of sorghum and corn following chemical fallow.
2) equal or increased yields of winter wheat under chemical fallow.
3) production of two crops in three years rather than two crops in four years.
4) conservation of moisture as a result of cooler soil tempera-

tures, reduced evaporation, increased trapping of snow and rainfall, little or no water use by weeds and no loss of soil moisture from tillage. Tillage also promotes weed growth by moving dormant seed to soil depths favorable for germination. Klein (72) stated that chemical fallow systems led to more efficient crop production, reduced energy costs, decreased soil erosion and increased conservation of moisture.

Schroeder (101) reported chemical fallow systems conserved topsoil, soil moisture, fuel, and energy expenses. Additionally, labor, machinery use, and machinery repairs were reduced. Miller (83) also observed no-till farming increased soil moisture retention and reduced energy inputs. It was found that yields were increased by chemical fallow, especially during dry years.

Alternatives to fallowing may increase the number of productive acres. Arnold (6) suggests that where sufficient moisture exists for crop establishment, recropping with minimum tillage systems are feasible.

Timing of herbicide application may be the most crucial factor for a successful chemical fallow program (72). Herbicide application must be precise since erratic weed control has been a major deterrent to adoption of chemical fallow (28). Humburg (62) concluded that herbicide choice, rate, time of application, and tank mixtures were key factors governing the success of chemical fallow.

Effects of chemical fallow and tillage on crop yield and crop quality were evaluated at Moccasin, Montana (75). There were no significant differences in yield, test weight, or protein between the two systems. Soils receiving chemical fallow herbicides remained soft and plastic allowing no-till seeding of winter wheat. Crop residues on the soil surface did not interfere with seeding.

Problems have been noted in no-till seeding. Plugging of drill openers and covering of seed with crop residue have been reported during seeding (45). Crop residues become brittle and fluffy during the weathering process which may promote the plugging of seed drills. Seeding of grain into heavy crop residue requires equipment that will not clog easily (45).

Additional benefits (72) from chemical fallow are as follows:

1) Weed growth is prevented. Conventional tillage controls weeds after they have used soil moisture and nutrients. Chemical fallow with soil active herbicides stops weed growth before soil moisture is utilized.

2) Surface crop residues are increased. Residue enhances rainfall infiltration, decreases erosion, and increases capture of rain and snow.

3) Higher yields in dry years have been reported. Extra moisture stored by chemical fallow will increase yields when moisture is a limiting growth factor. Research has indicated that

wheat yield increases of 200-335 Kg/ha are possible for each additional inch of accumulated moisture.

4) Reduction in tillage operations occurs. Growers have been able to eliminate as many as three to five tillage operations, saving considerable labor and fuel. Machinery wear is reduced. Fewer tillage operations result in less soil compaction, less damage to soil structure, and more surface residue.

5) Chemical fallow adds flexibility since weed control is possible when soils are too wet for tillage or producers are busy with other operations.

6) More nitrate nitrogen is accumulated.

Limitations of chemical fallow systems include:

1) Inconsistent weed control. An effective herbicide must provide consistent, broad spectrum weed control.

2) Residual crop injury from herbicides has hindered development of chemical fallow systems. Herbicide residues must dissipate below injurious levels prior to planting time of sensitive crops.

3) Planting equipment often functions poorly when heavy crop residues are on the soil surface resulting in poor crop stands.

4) Soil temperatures are lower at seeding time.

5) Insect and disease problems may arise.

D. <u>Research on Atrazine</u>:

The first triazine derivatives were synthesized in 1952 in the laboratories of J. R. Geigy and S. A. Basel in Switzerland. Atrazine was synthesized by reacting cyanuric chloride with one equivalent of ethylamine and isopropylamine in the presence of acid acceptors to produce (2 chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine)(Figure 1). Atrazine is classified as a photosynthetic inhibitor that blocks the Hill reaction(8).

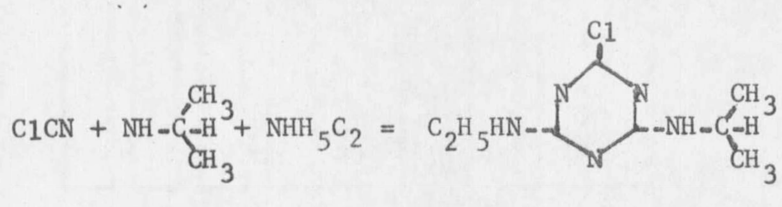

Figure 1. Synthesis of Atrazine.

Greenland (53) and Bailey (9) list seven factors which govern the adsorption of organic molecules onto soil colloids: 1) chemical character, shape and configuration of the molecule; 2) acidity or basicity of the molecule; 3) water solubility; 4) polarizability; 5) polarity; 6) charge distribution on cations; and 7) molecule size. Several of the factors listed above effect the fate of atrazine in field soils (8, 108).

Seven factors influence the fate and behavior of atrazine in soil: 1) microbial decomposition; 2) photochemical decomposition; 3) chemical decomposition; 4) volatilization; 5) leaching; 6) adsorption on soil particles; and 7) plant uptake.