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Relative response of sicklepod to and residual activity of some preemergence herbicides

John N. Burch

To the Graduate Council:

I am submitting herewith a thesis written by John N. Burch entitled "Relative response of sicklepod to and residual activity of some preemergence herbicides." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Robert M. Hayes, Major Professor

We have read this thesis and recommend its acceptance:

Elmer L. Ashburn, Larry S. Jeffery

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Carl W. Minkel

The Graduate School

RELATIVE RESPONSE OF SICKLEPOD TO AND RESIDUAL ACTIVITY OF SOME PREEMERGENCE HERBICIDES

A Thesis

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Master of Science

Degree

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John N. Burch

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ABSTRACT

Sicklepod (*Cassia obtusifolia* L.) is a very difficult weed to control. It is not known whether sicklepod can be more effectively controlled by herbicides used in corn (*Zea mays* L.), those used in cotton (*Gossypium hirsutum* L.) or those used in soybeans [*Glycine max* (L.) Merr.]. Research was conducted to evaluate the relative response of sicklepod to several preemergence herbicides used for broadleaf weed control in corn, cotton or soybeans. Residual activity of these herbicides was also determined to discern possible carryover injury to rotational crops.

Experiments were conducted at one location in 1982 and two locations in 1983 to evaluate sicklepod response to atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine], cyanazine {2-[[4-chloro-6-(ethylamino)-*s*-triazin-2-yl]amino]-2-methylpropionitrile}, simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine], fluometuron [1,1-dimethyl-3-(α,α,α,-trifluoro-*m*-tolyl)urea], diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], norflurazon [4-chloro-5-(methylamino)-2-(α,α,α,-trifluoro-*m*-tolyl)-3(2*H*)-pyridazinone], and metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one]. Residual activity was determined using both field and greenhouse bioassays.

The order of herbicidal effectiveness for sicklepod control among the herbicides commonly used in corn was: atrazine > simazine ≥ cyanazine. The order of herbicide effectiveness for the herbicides commonly used in cotton was: fluometuron > diuron = norflurazon > cyanazine. Of the herbicide treatments available for use in soybeans,

a single preemergence application of metribuzin was not as effective as the metribuzin system which consists of a preemergence application of alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] plus metribuzin followed by toxaphene (chlorinated camphene, 67 to 69% chlorine) plus crop oil early postemergence followed by metribuzin plus 2,4-DB [4-(2,4-dichlorophenoxy)butyric acid] applied late postemergence.

The only treatments that consistently provided season long control were atrazine at 4.48 kg ai/ha, atrazine at 3.36 kg ai/ha and atrazine plus simazine at 2.24 plus 1.12 kg ai/ha.

Alfalfa (*Medicago sativa* L.), crimson clover (*Trifolium incarnatum* L.), and wheat (*Triticum aestivum* L.) were susceptible to residual injury from the highest rate of atrazine. Wheat was more susceptible to norflurazon residual injury than the other rotational crops. Vetch (*Vicia villosa* Roth.) was the most tolerant crop tested in regard to residual injury from any of the herbicides studied. In the greenhouse, cucumbers (*Cucumis sativus* L.) were more susceptible to residual herbicide injury than the cover crops in the field. Where little or no injury to cucumbers was observed from residues in soil samples taken from treated field plots, no residual injury to cover crops was observed in the field.

If corn is to be grown on an area infested with sicklepod, at least 3.36 kg ai/ha of atrazine or a herbicide combination containing at least 2.24 kg ai/ha atrazine will be necessary to provide acceptable sicklepod control. A higher potential for residual injury to subsequent crops exists as atrazine rates are increased. If cotton is to be grown, fluometuron at 1.68 kg ai/ha provides the best control of sicklepod;

however, subsequent postemergence herbicide applications or other methods of weed control must be employed to give adequate season long control. Metribuzin at 0.56 kg ai/ha provides excellent control of sicklepod for 2 to 3 weeks in soybeans, but for season long control the metribuzin system should be used. There was no residual injury to cover crops from these soybean treatments.

Land infested with sicklepod can be more economically and effectively managed if corn is grown rather than cotton or soybeans.

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CHAPTER I

INTRODUCTION

Sicklepod is a serious problem weed throughout the southeastern United States (27). It is known by several other common names such as coffeeweed, coffee bean, sickleweed and sickle senna (24,31) and is sometimes referred to as *Cassia tora* L. Even after Linnaeus separated the species in 1753, Bentham in 1871 and others have classified and discussed them as being synonyms for the same plant. This investigation was conducted with sicklepod, *Cassia obtusifolia* L., as described by Singh (59).

Sicklepod is very difficult to control because of its tolerance to adverse environmental conditions, its tolerance to many of the herbicides presently available used to control broadleaf weeds and its tendency to germinate and emerge throughout the growing season. Sicklepod is increasing in importance in Tennessee in corn, cotton and soybeans (27). The relative effectiveness for sicklepod control of the preemergence herbicides used in these crops is not presently known. These herbicides differ in residual activity on subsequent crops. Therefore, research was conducted to 1) determine the relative response of sicklepod to several preemergence herbicides commonly used for weed control in corn, cotton or soybeans and 2) evaluate the residual activity of these herbicides on subsequent cover crops.

CHAPTER II

LITERATURE REVIEW

Sicklepod is responsible for major crop yield losses throughout much of the Southeast (27). This summer annual, a nonnodulating member of the Leguminosae family, is found in at least 47 countries and on all five continents (35). There are conflicting reports as to the origin of sicklepod. Freeny (29) states that sicklepod was probably introduced into the United States sometime before 1800 as a contaminant in cottonseed. Singh (59) on the other hand reported that sicklepod originated in America and then spread to the rest of the world. Nevertheless, sicklepod has been present in the Southeast for many years but only recently has it become a major problem in many rowcrops.

Sicklepod is a very vigorous plant reaching heights of over 2 meters (31). It produces large quantities of seeds which insure a good supply for several seasons after a single seed crop (19). A heavy infestation of sicklepod in cultivated crops has been reported to produce 900 kg/ha of seed (23) and a single plant may produce over 8000 seeds (28). These relatively large seeds have very hard impermeable seed coats and will germinate and emerge under a wide range of environmental conditions. Sicklepod can germinate over a temperature range of 18 to 39C (60,61) and under relatively low soil moisture conditions (the same percentage of sicklepod germination occurred at negative 10 bars of osmotic pressure as soybean germination at negative 3 bars) (36). It can remain viable in soil for more than 5 years (26). Seedlings can emerge from a soil depth of 15 cm (14,60). Limits of seedling growth are only slightly narrower than those for germination (40,60). Sicklepod can grow well over a pH range of 4.6 to7.9 (20,23). Sicklepod is very tolerant to potassium deficiencies and is somewhat tolerant to phosphorus deficiencies (37). Another characteristic of sicklepod that aids in its survival is leaf folding. These endogenously controlled diurnal rhythic movements cause a sevenfold variation in the percent of exposed leaf area (41). This folding of leaves occurs most often at night and during periods of drought and therefore decreases the amount of transpiration. Leaves also expand more fully during periods of cloud cover than when exposed to full sun. Chemical spray interception and retention can be affected by these leaf movements and should be a consideration when applying postemergence herbicides (41).

There is strong evidence that sicklepod contains an allelopathic substance. This substance is exuded from the plant and is also present in plant residues and is leached out during decomposition. It has been shown to inhibit the germination of cotton and oats (*Avena sativa* L.) and it delays the germination of ball clover (*Trifolium nigrescens* Viv.) and corn. This allelopathic substance also inhibits growth of *Rhizoctonia* spp., a serious cotton seeding disease; therefore, sicklepod infestations may improve cotton seedling survival. Germination of wheat, soybeans and sicklepod are unaffected by this phytotoxic substance (23).

Increased soybean production has been accompanied by increased use of some herbicides used in soybeans that have little or no activity on sicklepod. This has aided the spread of sicklepod. For example, postemergence applications of bentazon [3-isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] give excellent control of many broadleaf weeds including cocklebur (*Xanthium pensylvanicum* Wallr.). Heavy infestations of cocklebur suppress the growth of sicklepod; therefore, controlling cocklebur with bentazon makes conditions more favorable for the spread of sicklepod (44,45). Mechanical equipment (especially combines) has greatly enhanced the spread of sicklepod throughout infested fields, from infested to non-infested fields, and from year to year. Mechanical equipment can also act as a seed scarifying device which enhances germination (33).

In 1980 sicklepod was present in 13 southeastern states, was a problem in 11, and was increasing in severity in 12 (61). It is currently one of the most troublesome weeds in corn, cotton, peanuts (*Arachis hypogaea* L.) sorghum [*Sorghum bicolor* (L.) Moench] and soybeans in the Southeast. It is a very costly weed and is increasing rapidly in economic importance in Tennessee (27). Sicklepod is more troublesome in soybeans than in any other Tennessee crop.

Adequate herbicidal selectivity between soybeans and sicklepod is lacking. Full season interference from heavy infestations of sicklepod causes a 30 to 50% soybean yield loss (32,48,50). Sicklepod plants in the row do not reduce yield as much as those between the rows; specifically, plants 15 to 30 cm from the row can reduce yield by twice as much as those in the drill (62). Full season sicklepod control is not necessary to obtain maximum soybean yields. If soybeans are kept free of sicklepod for 4 weeks after planting, sicklepod plants which emerge later will not reduce yields under normal growing conditions (48,62). If sicklepod plants are allowed to mature, sicklepod seed production can occur. Problems such as increased harvesting losses and a higher percentage of foreign matter in harvested soybeans will also exist.

Cotton is more responsive to sicklepod than soybeans. Heavy infestations of sicklepod can reduce cotton yield by as much as 80% (16). The problem of trash is of greater concern in cotton than in other crops (18).

Sicklepod can cause serious problems even after the crop harvest is completed. If sicklepod is allowed to mature, its seeds are often a contaminant in the harvested crop seed. This promotes the spread of the weed through crop seed used for planting and through animal waste if fed as whole grain. Sicklepod causes poisoning to many animals if consumed. Corn contaminated with 5% sicklepod seed and fed to chickens reduced egg production, discolored egg yolks and resulted in other physical symptoms of poisoning (51). Sicklepod seeds are the most toxic part of the plant but other plant parts are also toxic and in many instances cause more trouble than seeds simply because of the nature and quantity of toxin. Where sicklepod comprises a high percentage of hay, silage or greenchop, large amounts of sicklepod may be consumed when fed to animals. In one study, 21 of 300 head of Holstein cattle died within 10 days of being fed 50% sicklepod (leaves, stems and seeds) in greenchop and several others were adversely affected but eventually recovered (47). Severe reductions in milk production have been reported in dairy herds when fed rations containing sicklepod (49).

Sicklepod is known to be a secondary host of the fungus *Collectotrichum fragariae* that causes anthracnose of strawberry (*Fragaria X ananassa* Duch.) which has caused extensive damage in Florida. Therefore, control of sicklepod could aid in preventing the spread of strawberry anthracnose (24,38).

Generally, reduction of crop yield losses is the main thrust of a weed control program; however, with sicklepod other factors such as seed production, foreign matter, toxicity, harvesting losses, and its being a pathogenic host should be considered when choosing and implementing a system of control.

Sicklepod control in agronomic crops has been extensively researched (17,30,31,44). Most of the research has been directed toward control in soybeans (19,50,58,67).

Present sicklepod control methods in soybeans consist of selective preemergence herbicides that allow a height differential in favor of the crop in order that post-directed sprays can be applied with minimum injury to the crop. Also the differential in development between these species allows soybeans to exert a certain amount of control pressure on sicklepod through competition for water, nutrients and light. One of the few weaknesses of sicklepod is its lack of shade tolerance (67).

Some preemergence herbicides used in soybeans which provide partial control early in the season are alachlor, chloroxuron {3-[p-(p-chlorophenoxy)phenyl]-1,1-dimethylurea}, metribuzin, metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide], and vernolate (S-propyl dipropylthiocarbamate). Herbicides that have some activity on sicklepod when applied postemergence include 2,4-DB, chloroxuron, dinoseb (2-sec-butyl-4,6-dinitrophenol), naptalam (N-1-naphthylphthalamic acid), linuron, metribuzin, paraquat (1,1'-dimethyl-4,4'-bipyridinium ion), acifluorfen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid} and toxaphene (1,45,58). Toxaphene is effectively used for control of the initial flush of sicklepod as an over-the-top postemergence spray. Its effectiveness diminishes rapidly once the sicklepod pass the cotyledon (VC) leaf stage. Toxaphene has no residual herbicidal activity. Toxaphene is more active on sicklepod than acifluorfen and causes no soybean injury (43). The supply of toxaphene is limited since the Environmental Protection Agency has banned the production of toxaphene and has restricted its use on sicklepod through 1986 (63).

Another possible way of achieving early selective control of sicklepod in soybeans is being developed using the fungus *Alternaria cassiae*. Sicklepod seedlings in the cotyledon to first-leaf (V1) stage are most susceptible to the pathogen. In green house studies, 96% control of sicklepod occurred within 14 days after inoculation when plants were treated at the first-leaf stage. Only 15 to 18% control occurred when the seedlings were inoculated in the second-(V2) or third-leaf (V3) stages (66). Control of sicklepod from *Alternaria cassiae* was not as high under field conditions as in a controlled environment. Thus far the only plants found to be susceptible to the fungus are sicklepod, coffee senna (*Cassia occidentalis* L.) and showy crotalaria (*Crotalaria spectabilis* Roth.) (65). Another pathogen that has shown promise as a biological control agent is tobacco etch virus which restricts the production of viable seeds (25).

Cultural control practices may also be implemented to aid in the control of sicklepod. Sicklepod growth slows when temperatures are below 24C (67). Earlier planting dates can aid in establishing soybeans before heavy sicklepod pressure occurs. This can be very beneficial since only 35 to 40% of the photosynthetically active radiation is available in the row under a 5-week old soybean canopy (31). Narrower row spacing results in earlier canopy closure and maximum crop competition with sicklepod (67). Timely cultivation alone has provided up to 93% control of sicklepod in soybeans and should be a major consideration when developing a system of control (48).

Effective sicklepod control measures in cotton consist of a preemergence herbicide such as fluometuron, diuron, prometryn [2,4-bis (isopropylamino)-6-methylthio)-s-triazine], or norflurazon, followed by one or more postemergence applications of DSMA (disodium methanearsonate), methazole [2-(3,4-dichlorophenyl)-4-methyl 1,2,4-oxadiazolidine-3,5-dione] or other appropriate herbicide to small (less than 5 cm) sicklepod plants (17,30).

In corn, adequate control can be obtained with atrazine, simazine or cyanazine applied preemergence at higher than normal rates followed by timely cultivations and post-directed applications of linuron or ametryn [2-(ethylamino)-4-(isopropylamino)-6-(methylthio)-s-triazine] when needed (31). Postemergence applications of 2,4-D [(2,4-dichlorophenoxy) acetic acid], dicamba (3,6-dichloro-o-anisic acid), or some of the triazines are also effective (40).

The initial and residual control of sicklepod exerted by herbicide treatments is of primary interest, but the carryover effect on subsequent crops is also a major concern. This is especially true since there has been an increased interest in legume cover crops for erosion control, for addition of organic matter and as a nitrogen source (22,46). Atrazine, simazine and norflurazon are of principle concern because of their persistence in the soil and the sensitivity of many rotational crops (52,56).

There are many factors affecting the longevity of herbicides in the soil. Increasing the rate of herbicides extends the residual activity. Increasing soil pH by liming significantly increases atrazine efficacy and longevity (39,42). Since surface pH tends to decrease under no-till culture, atrazine is detoxified more rapidly under no-till than conventionally tilled culture (21). Soil containing a higher percentage of organic matter does not have as much atrazine or simazine residual activity as one with lower organic matter (64). An increase in soil compaction increases the persistence of some soil applied herbicides (53). Amount and intensity of rainfall increases chemical dissipation. Temperature can have a significant impact on the amount of degradation. Other soil and environmental factors can influence the persistence of preemergence herbicides.

Atrazine and simazine have been reported to carryover on rotational crops (54,56). In the South, injury to subsequent crops from these and other herbicides most often occurs during dry years (56). Atrazine carryover in the northern states is more commonplace than in the southern states (56). Simazine is more persistent in the soil than atrazine (54,56,57); however, atrazine is more active on sicklepod. In a study by Saghin and Choudhasy (54) atrazine applied at 12.5 kg/ha in the spring to a clay soil with 2.2% organic matter and pH of 8.0 to 8.4 gave only slight injury to wheat and vetch planted in the fall. In the same study, simazine caused similar injury on vetch at 5.0 kg/ha. Simazine at 12.5 kg/ha completely killed both wheat and vetch. Alfalfa has also been found to be sensitive to atrazine and simazine (57). Alfalfa, red clover (_Trifolium pratense_ L.) and sweet clover [_Melilotus officinalis_ (L.) Lam.]

have similar tolerances to atrazine (34). Brinkman et al. (15) concluded that if spring planted small grains are to be grown in soil with an anticipated atrazine carryover problem, barley (*Hordeum vulgare* L.) would be preferable to wheat. Injury to rotational crops may also occur from interactions between chemicals, such as the synergistic effects of sub-toxic concentrations of EPTC (S-ethyl dipropylthiocarbamate) and atrazine on alfalfa and wheat (68).

Many herbicide labels restrict the crop that can legally be planted within 1 year after the herbicide application (2,6,7,10). Others allow for cover crops to be seeded but not grazed or harvested for feed or food. These labels also warn that some crop injury may occur (9,11,12). Some labels impose no restrictions concerning subsequent crops after the initial crop is harvested (3,4,5,8).

One of the most practical ways of minimizing injury from chemical residues is by rotating to tolerant crops (57). Mixing the soil by plowing or disking is another way to reduce residual activity (52). Irrigation, band applications, or addition of deactivators to the soil, seed or roots are other ways of reducing residual injury to subsequent crops (57).

CHAPTER III

MATERIALS AND METHODS

A. Relative Response of Sicklepod to Preemergenge Herbicides

1. Field response

Experiments were conducted in 1982 at West Tennessee Experiment Station at Jackson and in 1983 at Milan Experiment Station at Milan and Middle Tennessee Experiment Station near Spring Hill to determine the relative response of sicklepod to several preemergence herbicides frequently used in corn, cotton or soybeans. Each location had a dense, uniform, natural population of sicklepod. No crops were planted in the test areas, since crop tolerance to the herbicides studied was well established. Herbicide applications were made using a hand-carried CO_2-pressurized sprayer calibrated to deliver 187 L/ha of spray solution. Visual estimates of sicklepod control were made periodically throughout the growing season using a scale where 100% indicated complete control and 0% indicated no control as compared to the untreated areas. Plot design was a randomized complete block with four replications. The least significant difference (LSD) procedure was used to compare treatment means at the 0.10 probability level.

The metribuzin system for sicklepod control in soybeans which consists of a preemergence application of alachlor plus metribuzin followed by an early postemergence application of toxaphene plus crop oil followed by a subsequent postemergence application of metribuzin plus 2,4-DB (13) was evaluated at all three experiment sites.

The 1982 experiment was conducted at Jackson on a Collins silt loam (Aquic Udifluvent, coarse-silty, mixed, acid, thermic) with 1.1% organic matter. Plot size was 2 m by 12 m with and untreated area 1 m by 12 m between plots. Herbicide treatments evaluated are listed in Table 1. Preemergence herbicides were applied on May 13. The early postemergence application was made on May 24 to sicklepod at the cotyledon stage. Subsequent postemergence applications were made on July 2 to sicklepod with five true leaves. Rainfall of 5.6 cm occurred within 2 weeks after application of the preemergence herbicides and 23.6 cm occurred within 8 weeks.

In 1983 experiments were conducted on a Grenada silt loam (Glossic Fragiudalf, fine-silty, mixed, thermic) with 1.0% organic matter at Milan and a Braxton cherty silty clay loam (Typic Paleudalf, fine, mixed, thermic) with 1.0% organic matter at Spring Hill. Plot size at Milan was 2 m by 12 m with 3 untreated plots located within each replication. At Spring Hill, plot size was 2 m by 12 m with an untreated area 1 m by 12 m between plots. Herbicide treatments evaluated in 1983 are listed in Table 2. Two experimental herbicides, DPX F 6025 (common and chemical name not released at time of print) and imacaquin (proposed common name--formerly known as AC 252,214) [2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)-3-quinolinecarboxylic acid] were also evaluated. Preemergence applications at Milan and Spring Hill were made on May 25 and June 2, respectively. Early postemergence applications to sicklepod at the cotyledon stage were made on June 22 at Milan and June 27 at Spring Hill. Subsequent postemergence herbicide applications were made on August 1 at Milan to sicklepod with six to eight true leaves and July 14 at Spring Hill to sicklepod with five true leaves. Rainfall of 7.7 cm occurred at Spring Hill within 2 weeks after preemergence applications and 16.4 cm occurred

Table 1. Herbicide treatments evaluated for activity on sicklepod and residual activity on rotational crops in 1982 at Jackson.

Treatment	MOA[a]	Rate (kg/ha)
Atrazine	Pre	2.24
Atrazine	Pre	3.36
Atrazine	Pre	4.48
Simazine	Pre	1.12
Cyanazine	Pre	2.24
Atrazine + simazine	Pre	1.12 + 1.12
Atrazine + simazine	Pre	2.24 + 1.12
Atrazine + cyanazine	Pre	1.12 + 1.12
Atrazine + cyanazine	Pre	0.67 + 1.57
Atrazine + cyanazine	Pre	1.12 + 2.24
Fluometuron	Pre	1.68
Diuron	Pre	1.12
Norflurazon	Pre	1.68
Diuron + norflurazon	Pre	1.12 + 1.68
Metribuzin	Pre	0.56
Alachlor + metribuzin + toxaphene + crop oil + metribuzin + 2,4-DB [b]	Pre Post --VC Post --V5	2.24 + 0.43 + 2.24 + 0.5% + 0.28 + 0.22

[a] Method of application: Pre = preemergence; Post -- VC = postemergence at cotyledon stage; Post--V5 = postemergence at fifth true leaf stage.

[b] Metribuzin system

Table 2. Herbicide treatments evaluated for activity on sicklepod and residual activity on rotational crops in 1983 at Milan and Spring Hill.

Treatment	MOA[a]	Rate (kg/ha)
Atrazine	Pre	2.24
Atrazine	Pre	3.36
Atrazine	Pre	4.48
Simazine	Pre	2.24
Cyanazine	Pre	2.24
Atrazine + simazine	Pre	1.12 + 1.12
Atrazine + simazine	Pre	2.24 + 1.12
Atrazine + cyanazine	Pre	1.12 + 1.12
Atrazine + cyanazine	Pre	1.12 + 2.24
Fluometuron	Pre	1.68
Diuron	Pre	1.12
Norflurazon	Pre	1.68
Fluometuron + norflurazon	Pre	1.12 + 1.68
Diuron + norflurazon	Pre	1.12 + 1.68
Metribuzin + norflurazon	Pre	0.43 + 1.12
Metribuzin	Pre	0.56
Alachlor + metribuzin + toxaphene + crop oil + metribuzin + 2,4-DB[b]	Pre Post--VC Post--V5 to V8	2.24 + 0.43 + 2.24 + 0.5% + 0.28 + 0.22
Imacaquin	Pre	0.43
Imacaquin	Pre	0.28
Imacaquin	Pre	0.13
DPX F 6025	Pre	0.13
DPX F 6025	Pre	0.07

[a] Method of application: Pre = preemergence; Post--VC = postemergence at cotyledon stage; Post--V5 to V8 = postemergence at fifth to eighth true leaf stage.

[b] Metribuzin system

within 8 weeks. At Milan, no rainfall occurred until 5.1 cm fell 3 weeks after preemergence applications. By 5 weeks after application, 18.8 cm of rainfall had occurred. However, no rainfall occurred during July, August or the first half of September.

2. Greenhouse response

An experiment was conducted at Jackson and repeated at Knoxville during separate time intervals using soil from untreated areas at the Jackson site to compare the preemergence herbicides in regard to concentration required to control sicklepod. Sicklepod was seeded into soil containing atrazine, cyanazine, simazine, diuron, fluometuron, or norflurazon at 0.1, 0.2, 0.4, 0.8, 1, 2, or 4 parts per million on a weight basis (ppmw) or metribuzin at 0.1, 0.2, 0.3, 0.4, 0.5, 1, or 2 ppmw. Visual evaluations were made frequently during the next 6 weeks.

B. Residual Activity

1. Greenhouse bioassays

Greenhouse bioassays were conducted to evaluate the residual activity of herbicides applied in 1982 and 1983. Bioassays were conducted on soils from all locations mentioned earlier plus an Armour silt loam (Ultic Hapludalf, fine-silty, mixed, thermic) with 1.0% organic matter at Spring Hill which received atrazine preemergence at 1.7, 2.8, 3.9 or 5.0 kg/ha on May 12, 1982.

In the fall after herbicide applications in the spring, approximately 500 g of soil was taken from the top 8 cm of each plot. The following day cucumbers were planted as an indicator crop (55). Similar samples were taken at depths of 0 to 8 cm, 8 to 16 cm, 16 to 24 cm, 0 t o 16 cm, and 0 to 24 cm from plots receiving the highest rate of atrazine at each location. Standards were established by treating samples of each soil taken from untreated areas with 0.1, 0.2, 0.4, 0.6, 0.8, 1, 2, 3, or 4 ppmw of atrazine. Frequent visual evaluations were made during the 3 weeks following emergence and thinning of the cucumbers.

2. Field bioassays

Field bioassays were conducted at the same locations as the relative response experiments to evaluate the residual activity of the herbicides. Indicator crops were alfalfa, crimson clover, hairy vetch and wheat. Each cover crop was planted perpendicular to the herbicide treatments in each replication.

In 1982 at Jackson the alfalfa, crimson clover and vetch were planted on September 10 and the wheat on October 1. Visual evaluations of herbicidal injury were made during the fall and following spring.

In 1983 at Milan the alfalfa, crimson clover, vetch and wheat were planted on October 14. Alfalfa, crimson clover and vetch were planted on September 9 at Spring Hill and wheat was planted on October 14. Visual evaluations of herbicidal injury were made during the fall.

CHAPTER IV

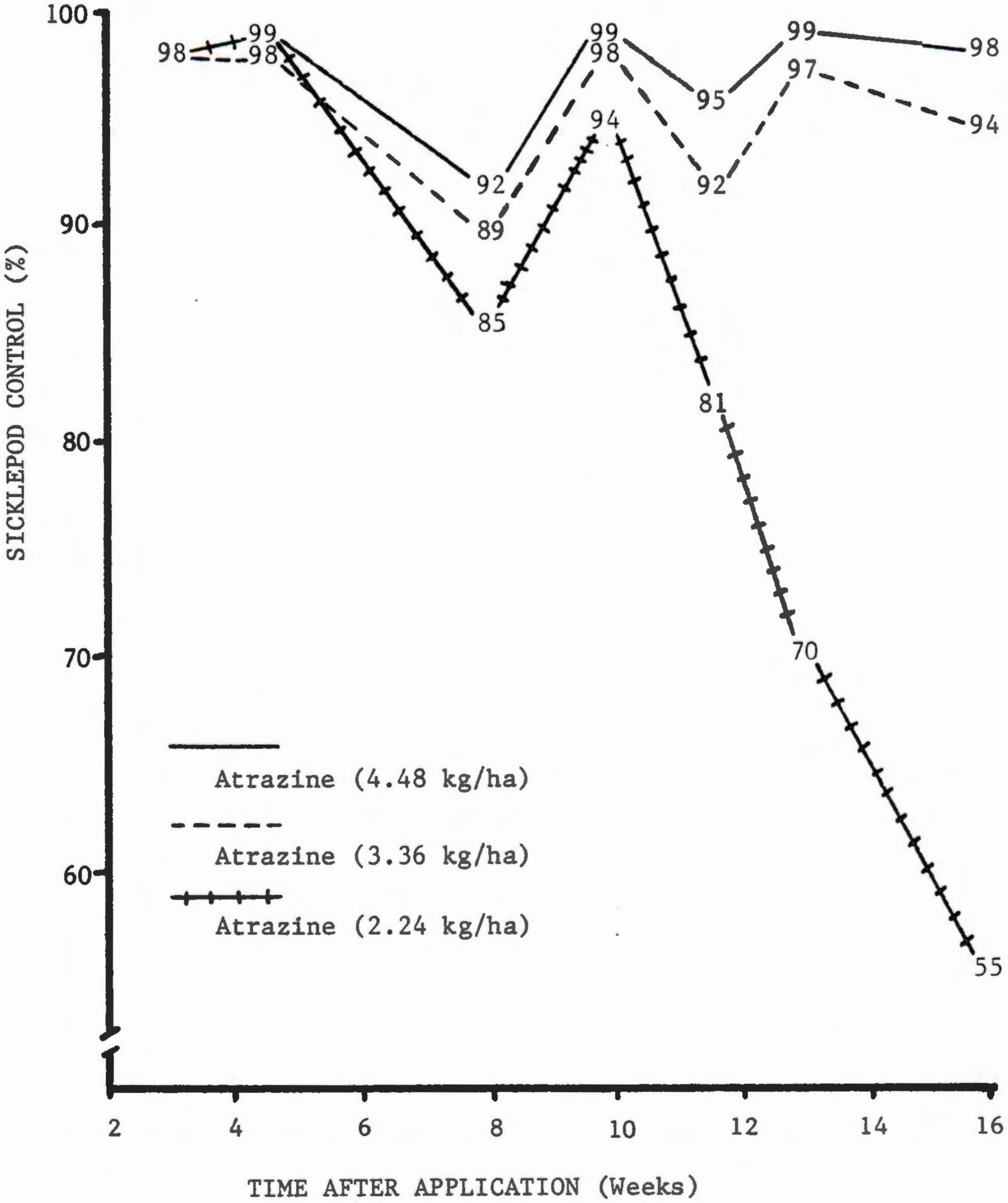
RESULTS AND DISCUSSION

A. Relative Response of Sicklepod to Preemergence Herbicides

1. Field response

Among the treatments evaluated at Jackson in 1982 which are commonly used in corn, the highest level of sicklepod control was achieved with atrazine applied at 4.48 kg/ha, atrazine at 3.36 kg/ha and atrazine plus simazine at 2.24 plus 1.12 kg/ha. Atrazine at 2.24 kg/ha provided excellent sicklepod control early in the season but by 11.5 weeks after application had dropped well below the higher rates (Figure 1). The other herbicide treatments where a total of 2.24 kg/ha of triazine herbicide was applied gave less sicklepod control than 2.24 kg/ha atrazine by 10 weeks after application. Sicklepod control with cyanazine at 2.24 kg/ha began to decline the quickest and by 8 weeks after treatment was less than that provided by any other treatment that contained 2.24 kg/ha total triazine (Figure 2). It was not until 11.5 weeks after application that atrazine plus cyanazine at 1.12 plus 2.24 kg/ha provided less sicklepod control than either atrazine plus simazine at 2.24 plus 1.12 kg/ha or atrazine at 3.36 kg/ha (Figure 3). Simazine at 1.12 kg/ha gave only about 30% sicklepod control through the first 4 weeks after application and dropped to 0% control soon thereafter.

All of the herbicides studied which can be used for weed control in cotton provided similar sicklepod control through the first month. Activity from cyanazine at 2.24 kg/ha, diuron at 1.12 kg/ha, and norflurazon at 1.68 kg/ha declined during the second month while fluometuron at



LSD (0.10) 2 9 9 14 13 15 12

Figure 1. Sicklepod response to various levels of atrazine at Jackson in 1982.

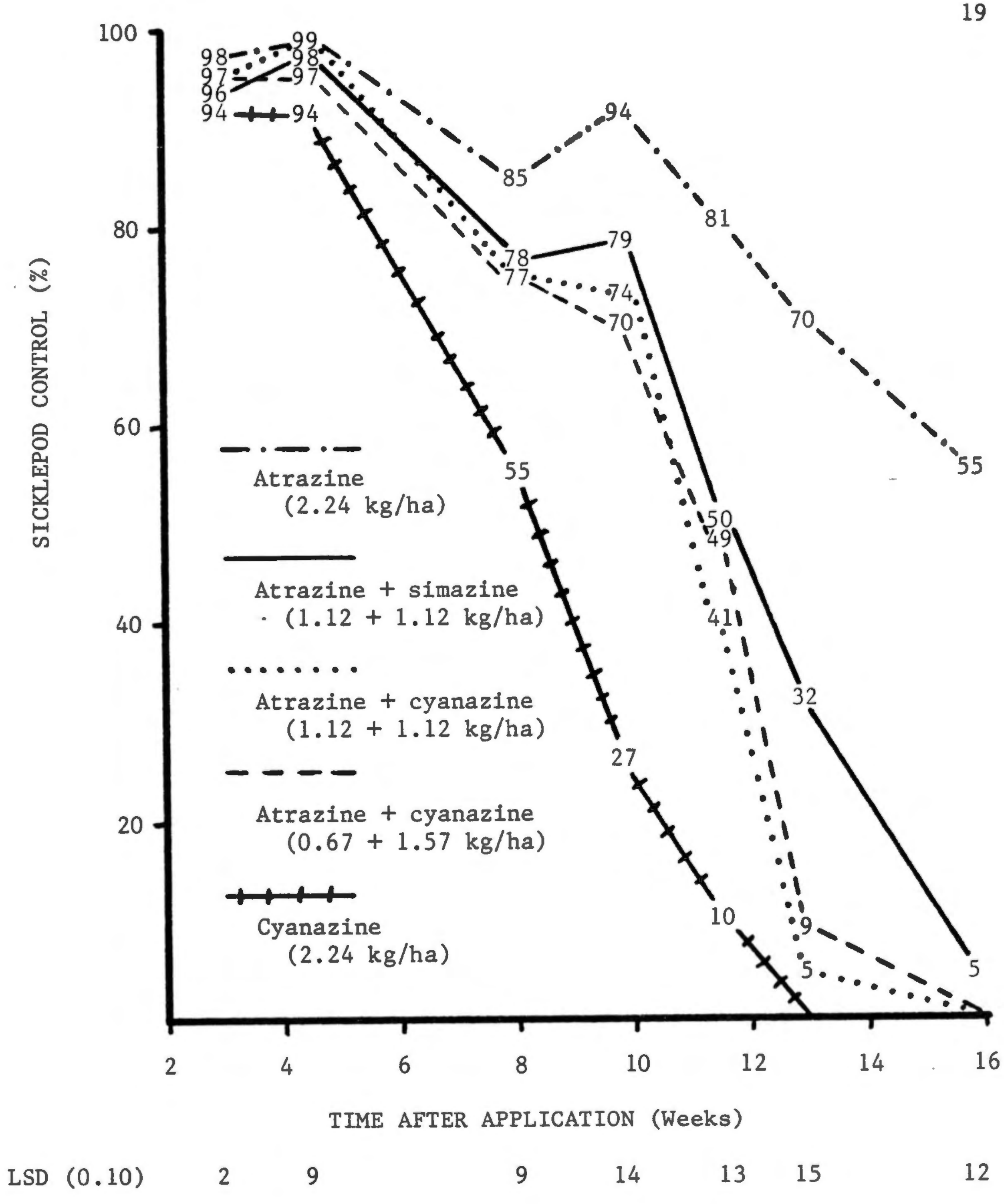
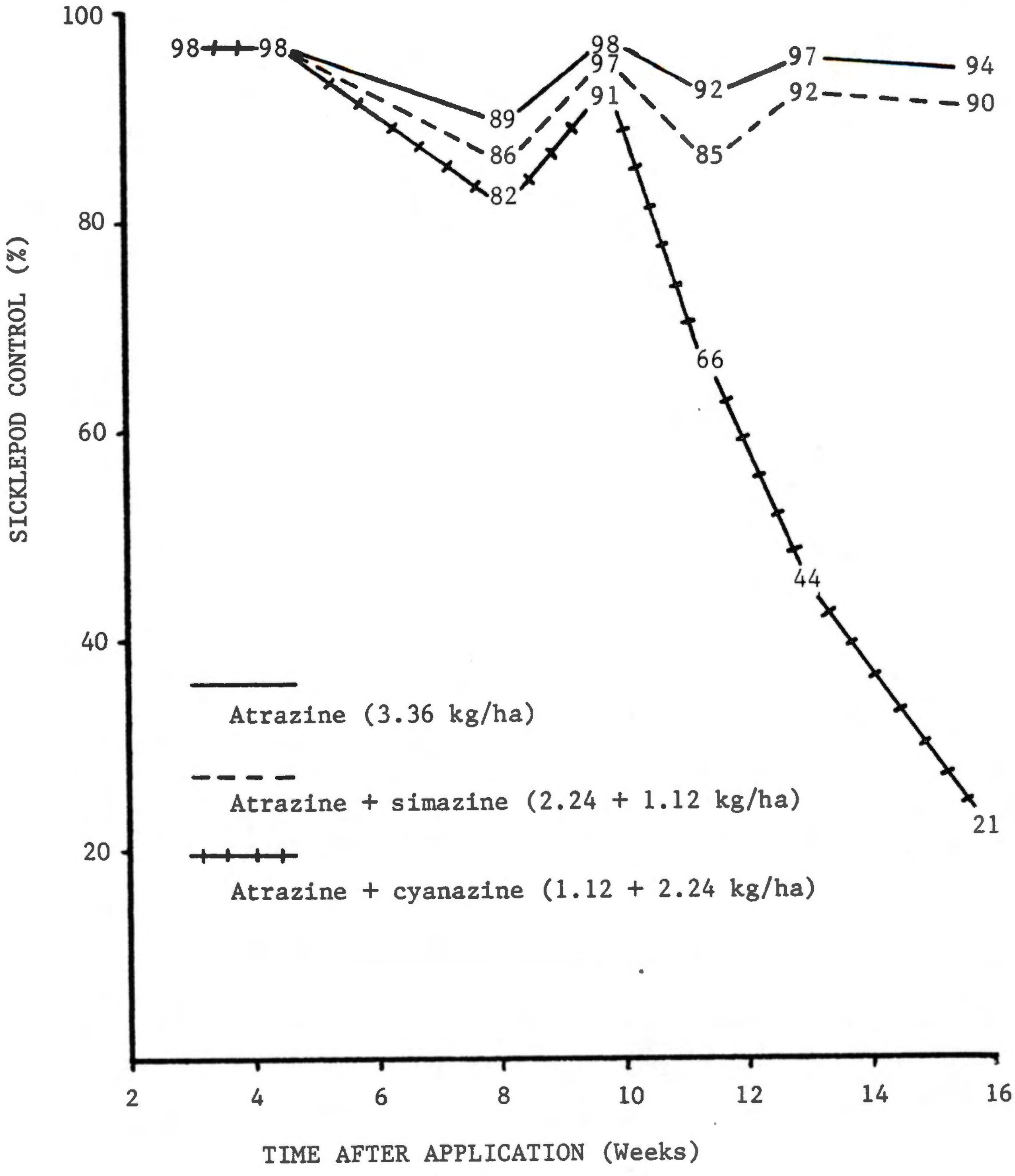


Figure 2. Sicklepod response to treatments containing 2.24 kg/ha total triazine herbicide at Jackson in 1982.



LSD (0.10) 2 9 9 14 13 15 12

Figure 3. Sicklepod response to treatments containing 3.36 kg/ha total triazine herbicide at Jackson in 1982.

1.68 kg/ha continued to control sicklepod for more than 2 months (Figure 4). Sicklepod control with diuron plus norflurazon at 1.12 plus 1.68 kg/ha was equal to that provided by fluometuron at 1.68 kg/ha through 8 weeks. After 8 weeks, sicklepod control by fluometuron at 1.68 kg/ha was somewhat higher than that provided by the diuron plus norflurazon combination (Figure 5).

Metribuzin alone at 0.56 kg/ha and the metribuzin system which consists of a preemergence application of alachlor plus metribuzin at 2.24 plus 0.43 kg/ha followed by and early postemergence application of toxaphene plus crop oil at 2.24 kg/ha plus 0.5% v/v followed by a subsequent postemergence application of metribuzin plus 2,4-DB at 0.28 plus 0.22 kg/ha provided equal control through the first 4.5 weeks. After 4.5 weeks, control from metribuzin alone dropped far below that provided by the metribuzin system (Figure 6).

At Milan, atrazine applied at 4.48 and 3.36 kg/ha and atrazine plus simazine at 2.24 plus 1.12 kg/ha provided the highest level of sicklepod control. Sicklepod control from atrazine at 2.24 kg/ha began declining sharply 9 weeks after application and remained lower than that provided by the other two rates of atrazine for the remainder of the season (Figure 7). Among the treatments that contained 2.24 kg/ha of total triazine, the trend was for atrazine at 2.24 kg/ha to provide better control than atrazine plus simazine at 1.12 plus 1.12 kg/ha which provided better control than atrazine plus cyanazine at 1.12 plus 1.12 kg/ha which provided better sicklepod control than did either simazine or cyanazine at 2.24 kg/ha (Figure 8). In general, treatments containing 3.36 kg/ha of total triazine gave better control than did treatments containing 2.24 kg/ha total triazine. Trends among the 3.36 kg/ha triazine treatments were for 3.36 kg/ha of atrazine

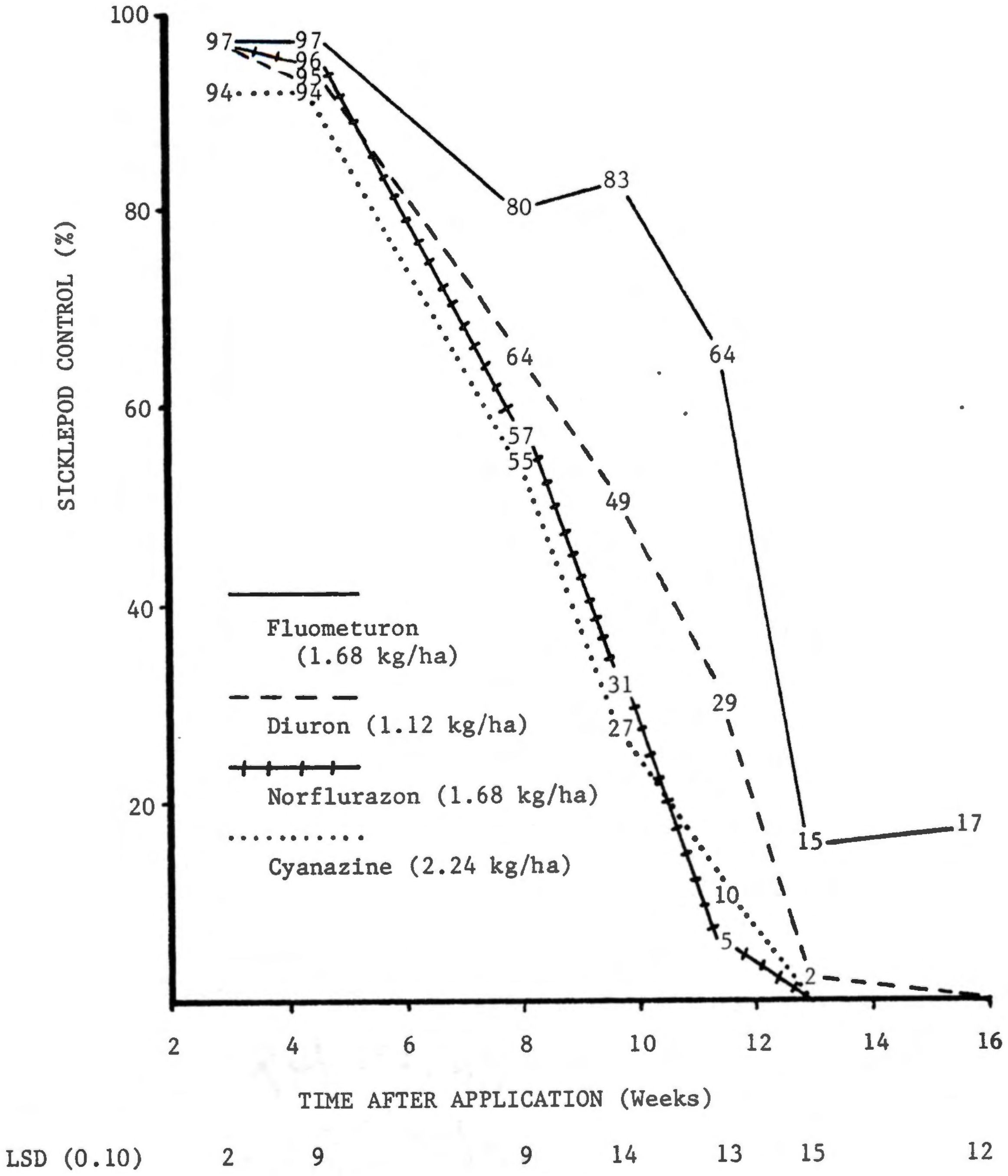
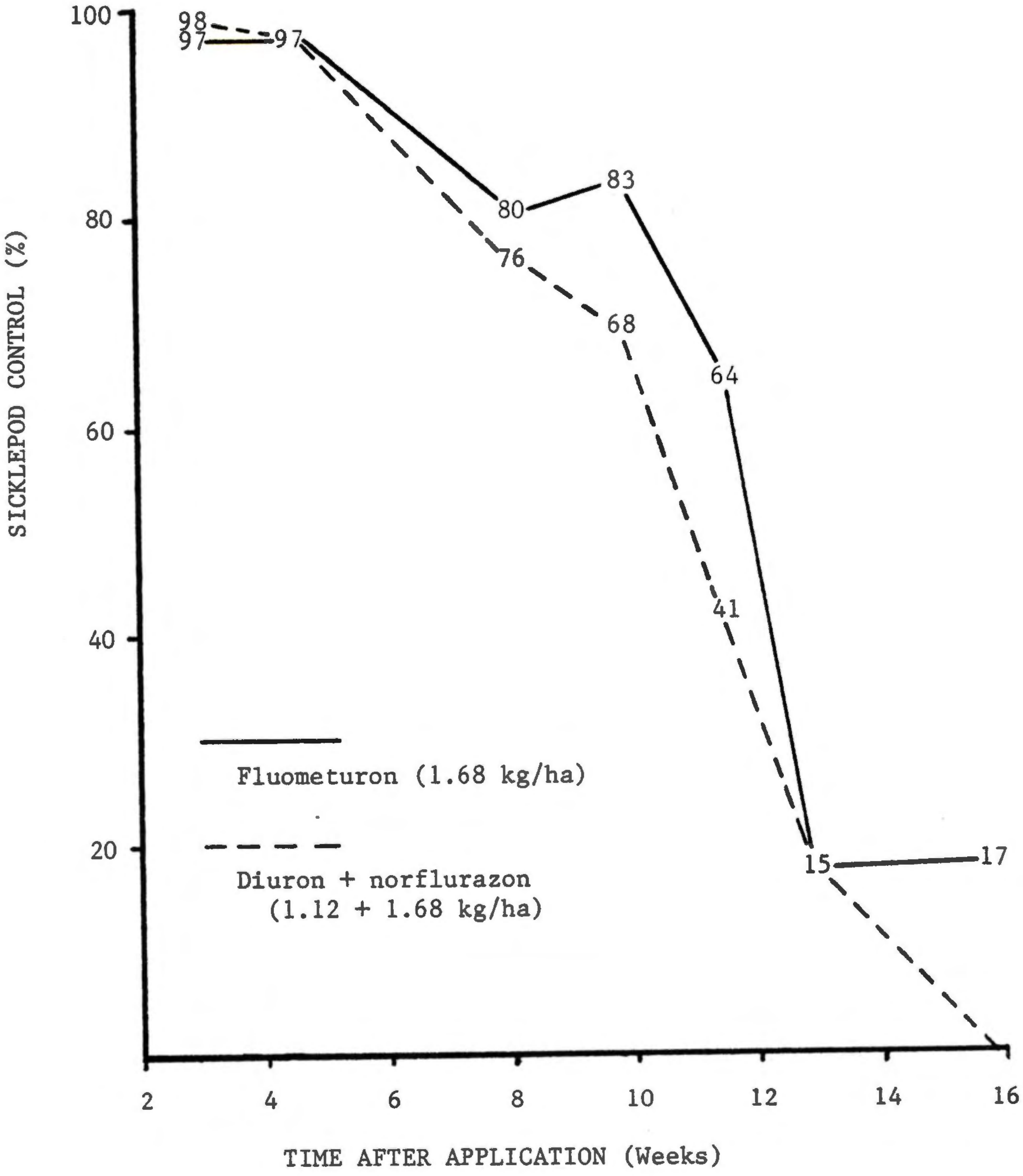
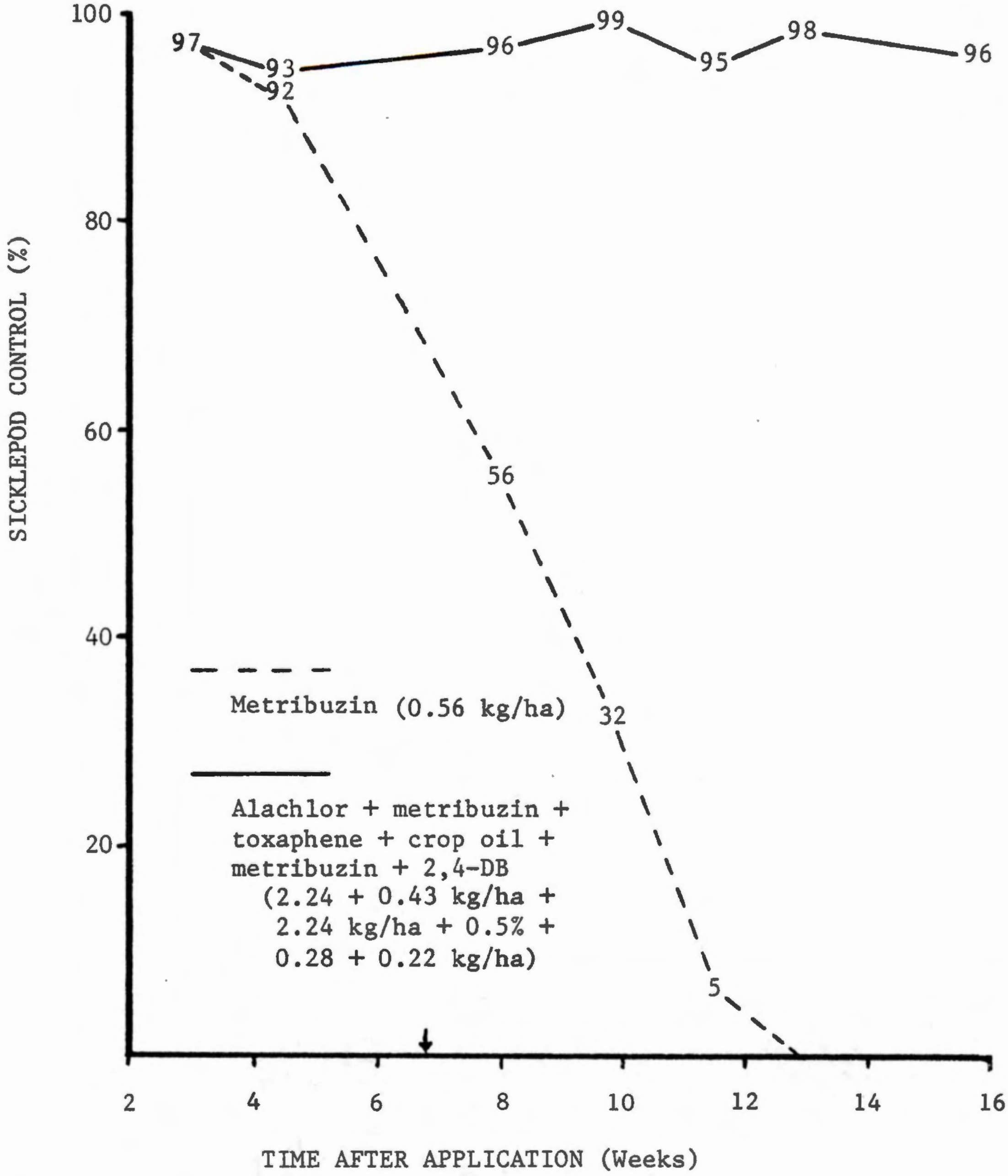


Figure 4. Sicklepod response at Jackson in 1982 to herbicides commonly used in cotton.



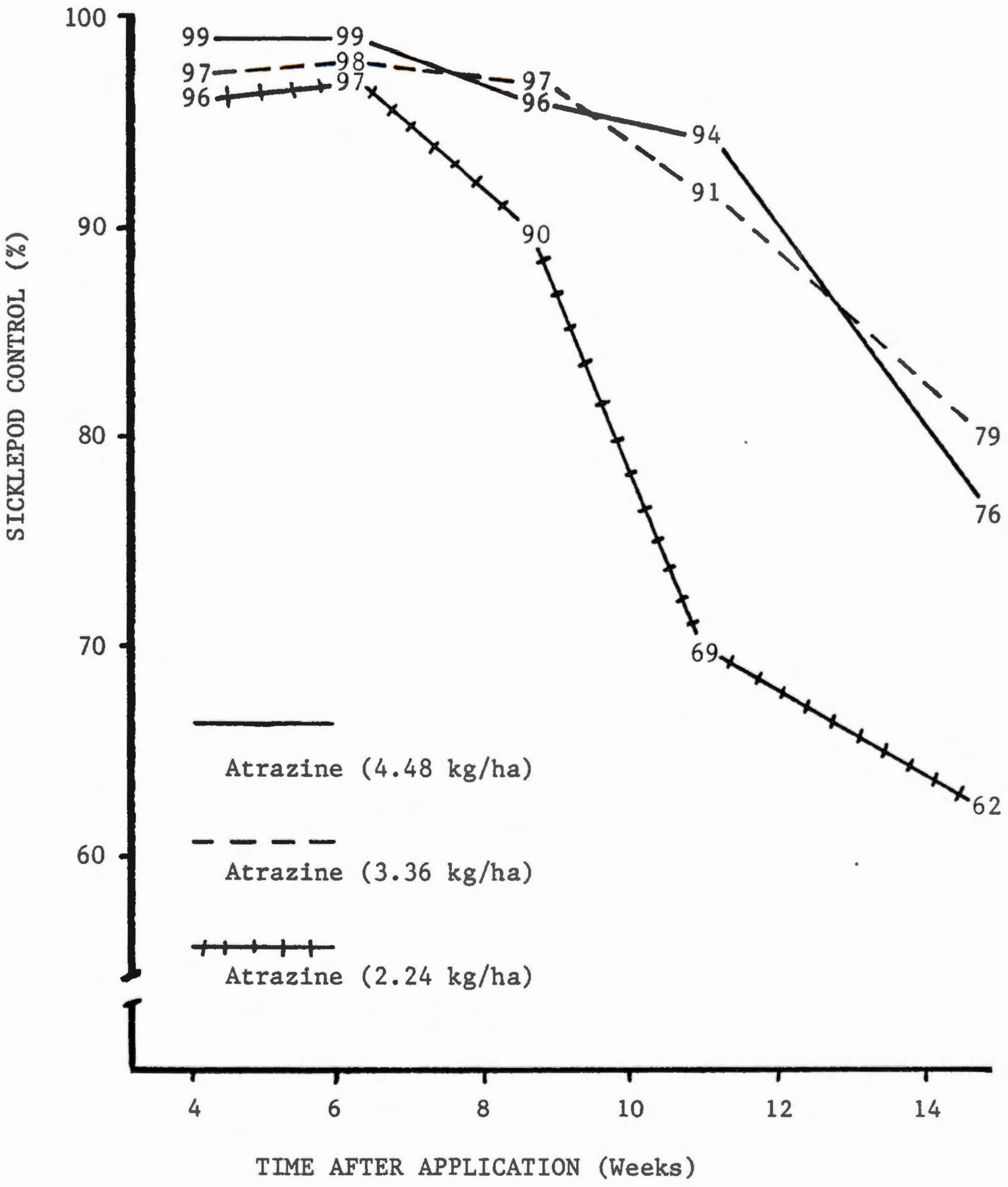
LSD (0.10) 2 9 9 14 13 15 12

Figure 5. Sicklepod response to fluometuron and diuron plus norflurazon at Jackson in 1982.



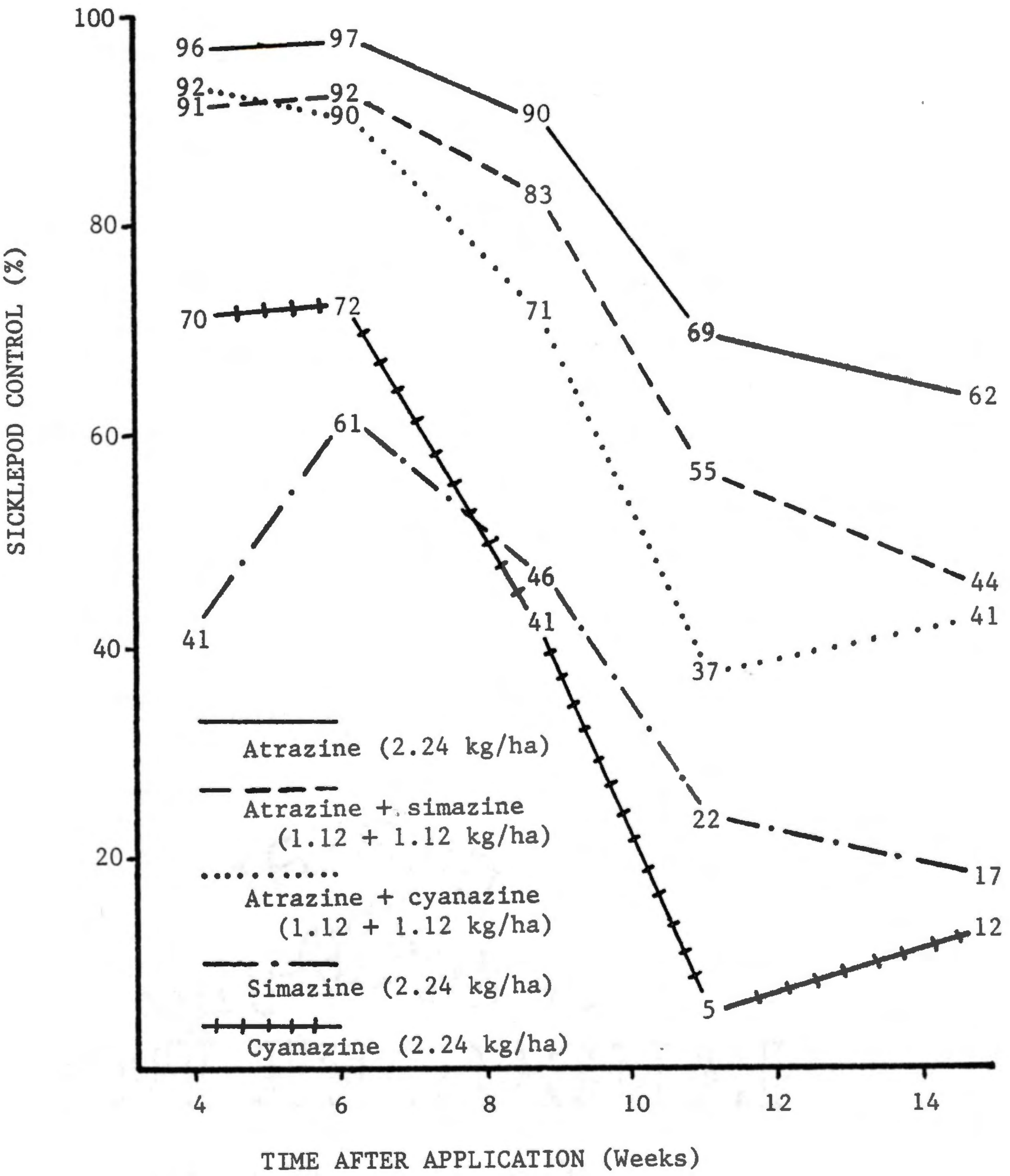
LSD (0.10) 2 9 9 14 13 15 12

Figure 6. Sicklepod response at Jackson in 1982 to herbicides commonly used in soybeans. (↓ - Postemergence application of metribuzin plus 2,4-DB).



LSD (0.10)	15	13	16	18	18

Figure 7. Sicklepod response to various levels of atrazine at Milan in 1983.



LSD (0.10)	15	13	16	18	18

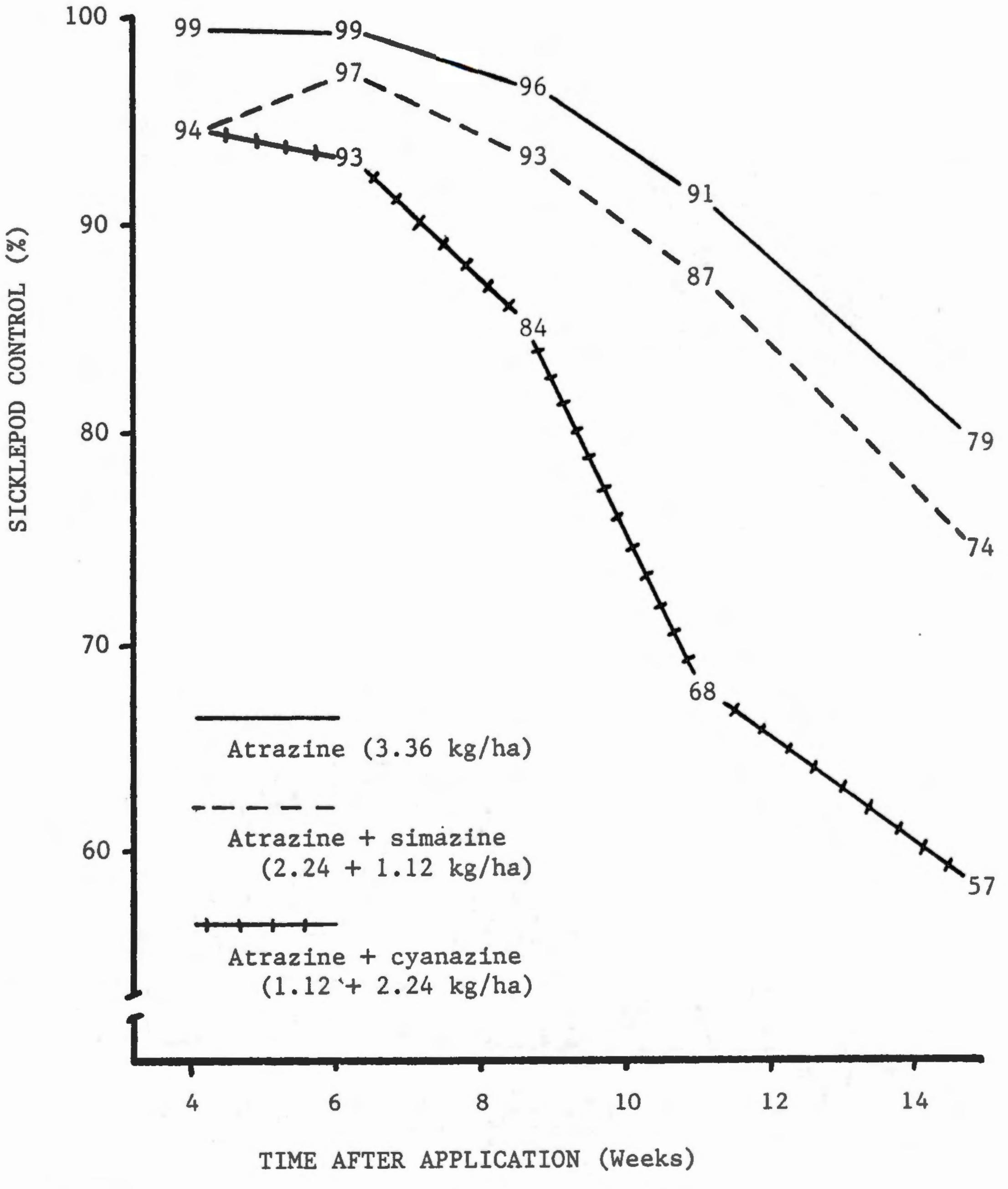
Figure 8. Sicklepod response to treatments containing 2.24 kg/ha total triazine herbicide at Milan in 1983.

to provide better control than atrazine plus simazine at 2.24 plus 1.12 kg/ha which provided better control than atrazine plus cyanazine at 1.12 plus 2.24 kg/ha (Figure 9).

At Spring Hill, no difference in sicklepod control occurred among atrazine applied at 4.48 kg/ha, atrazine at 3.36 kg/ha, and atrazine plus simazine at 2.24 plus 1.12 kg/ha; however, atrazine at 4.48 kg/ha did consistently provide the highest numerical level of control. There was no difference in sicklepod control between atrazine at 4.48 kg/ha and atrazine at 2.24 kg/ha until 14 weeks after application (Figure 10). The order of effectiveness for sicklepod control among the treatments containing 2.24 kg/ha total triazine was: atrazine at 2.24 kg/ha > atrazine plus simazine at 1.12 plus 1.12 kg/ha > atrazine plus cyanazine at 1.12 plus 1.12 kg/ha > simazine at 2.24 kg/ha > cyanazine at 2.24 kg/ha (Figure 11). The trend was for atrazine plus cyanazine at 1.12 plus 2.24 kg/ha to provide less control than the other two treatments containing 3.36 kg/ha of triazine; however, a significant difference did not occur until 10 weeks after application (Figure 12).

At Milan, among the herbicides commonly used in cotton, diuron at 1.12 kg/ha, norflurazon at 1.68 kg/ha and cyanazine at 2.24 kg/ha controlled less sicklepod than did fluometuron at 1.68 kg/ha (Figure 13). Control with diuron plus norflurazon at 1.12 plus 1.68 kg/ha or fluometuron plus norflurazon at 1.12 plus 1.68 kg/ha was equal to that with fluometuron at 1.68 kg/ha (Figure 14).

At Spring Hill, cyanazine at 2.24 kg/ha controlled less sicklepod than did the other cotton treatments. The trend was for fluometuron at 1.68 kg/ha to provide better control than norflurazon at 1.68 kg/ha or



LSD (0.10) 15 13 16 18 18

Figure 9. Sicklepod response to treatments containing 3.36 kg/ha total triazine herbicide at Milan in 1983.

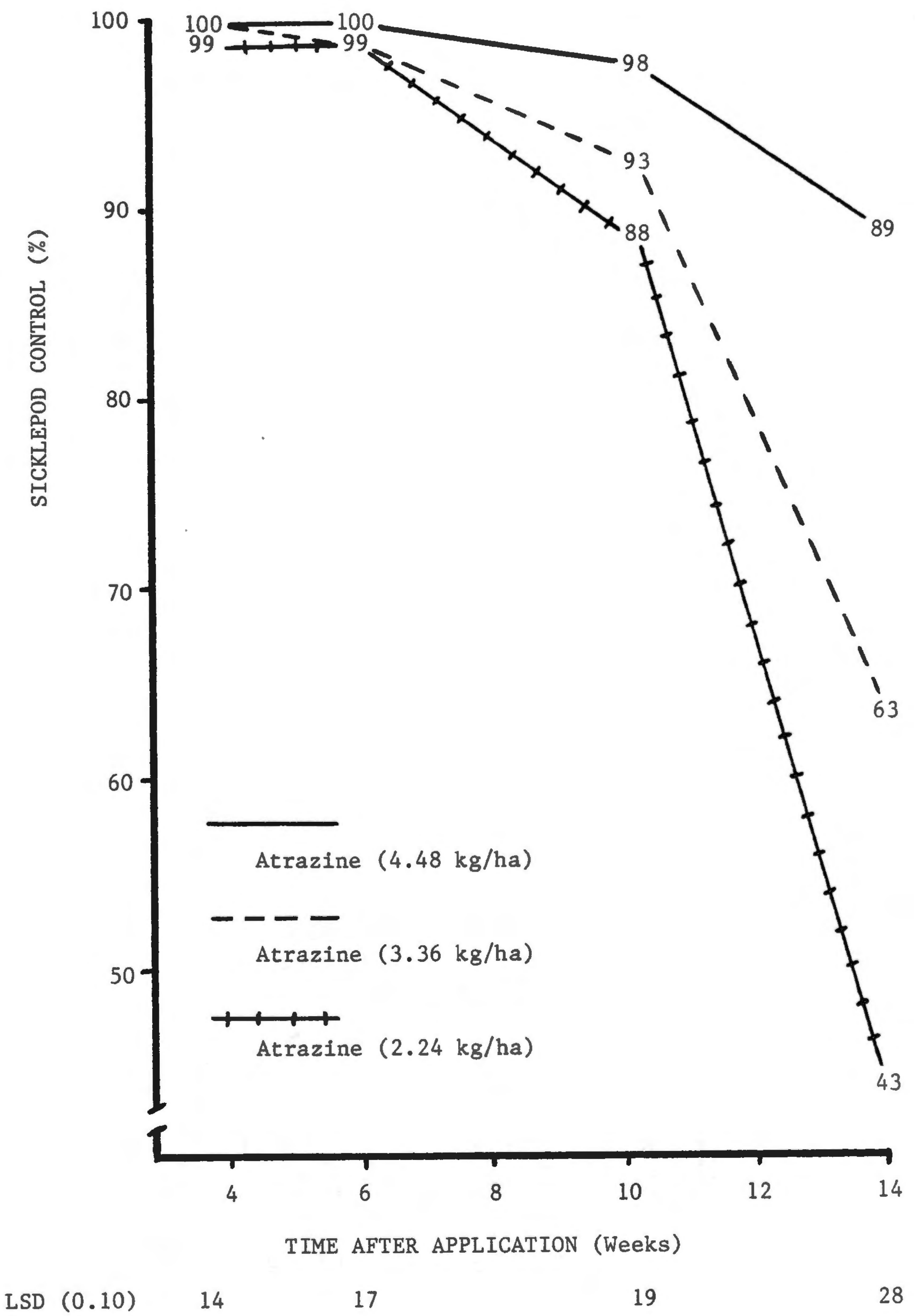
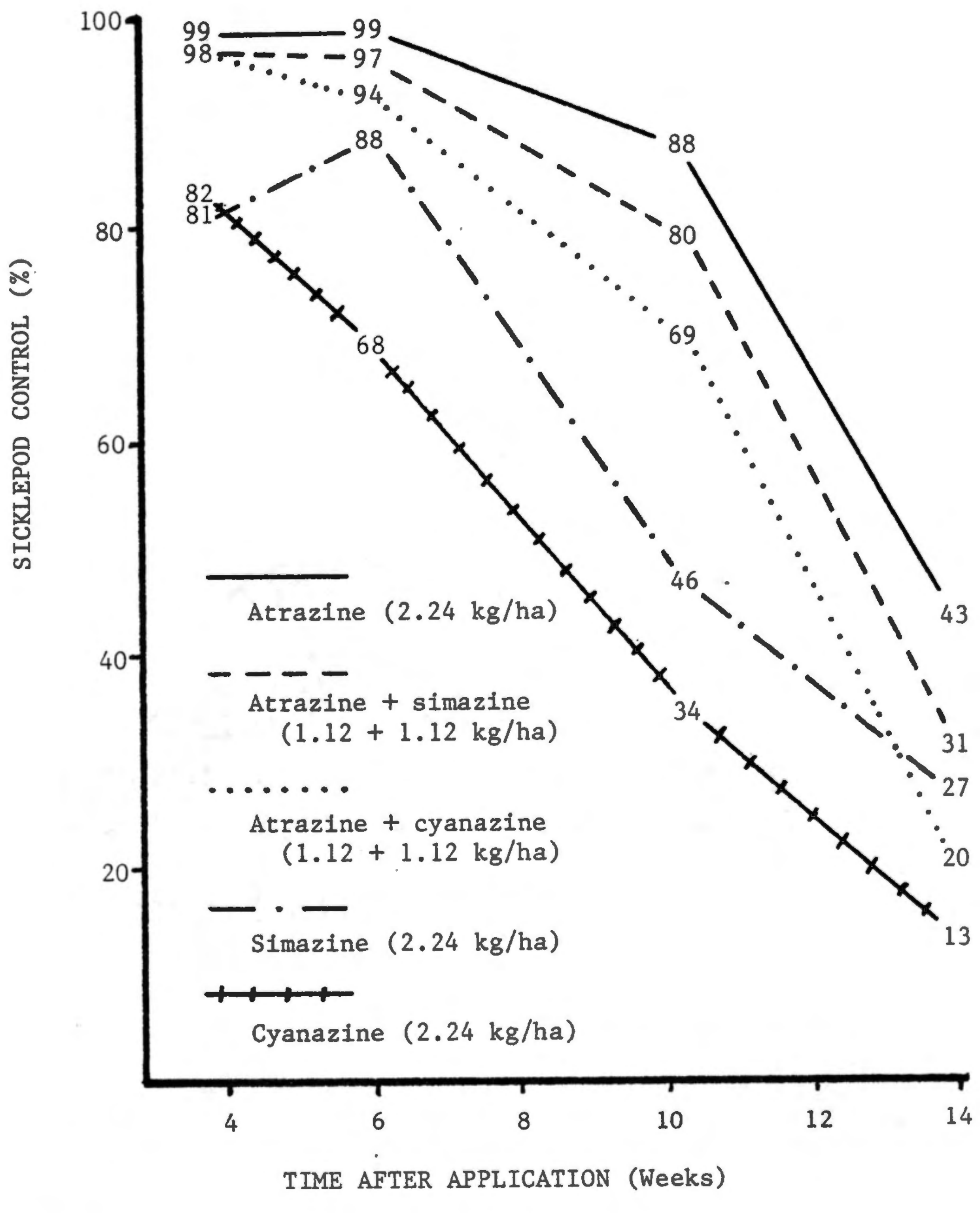
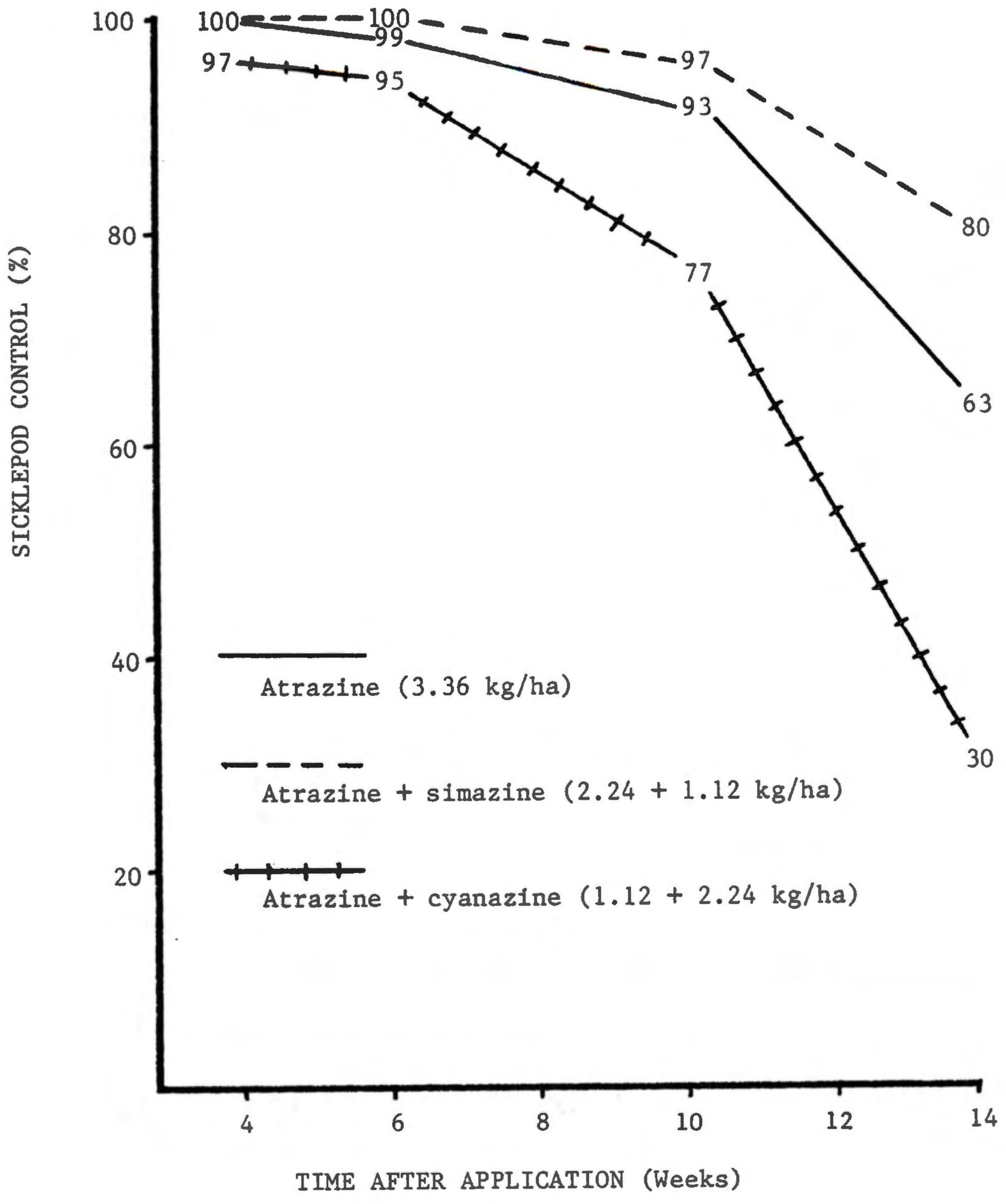


Figure 10. Sicklepod response to various levels of atrazine at Spring Hill in 1983.



LSD (0.10)	14	17	19	28

Figure 11. Sicklepod response to treatments containing 2.24 kg/ha total triazine herbicide at Spring Hill in 1983.



LSD (0.10)	14	17	19	28

Figure 12. Sicklepod response to treatments containing 3.36 kg/ha total triazine herbicide at Spring Hill in 1983.

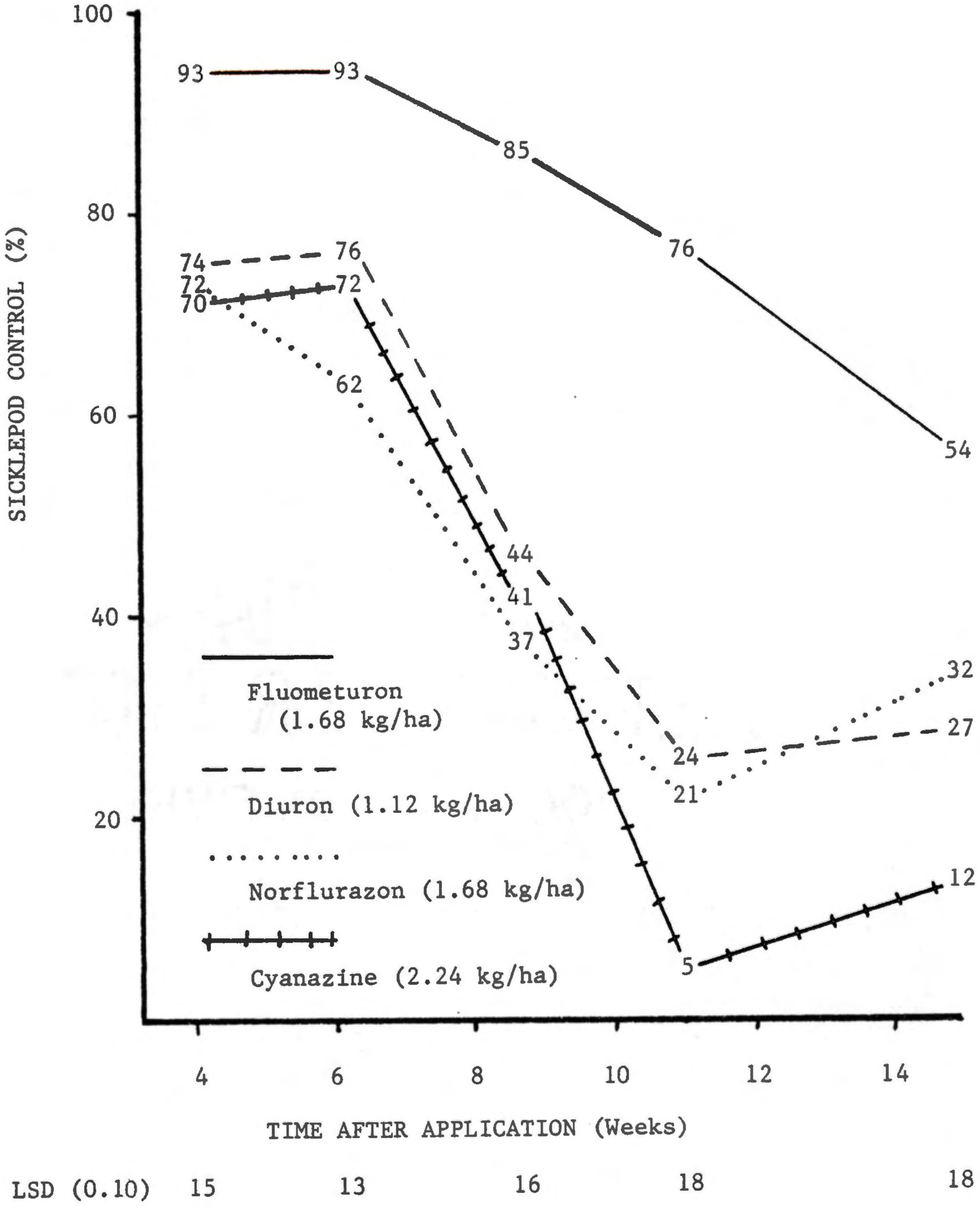
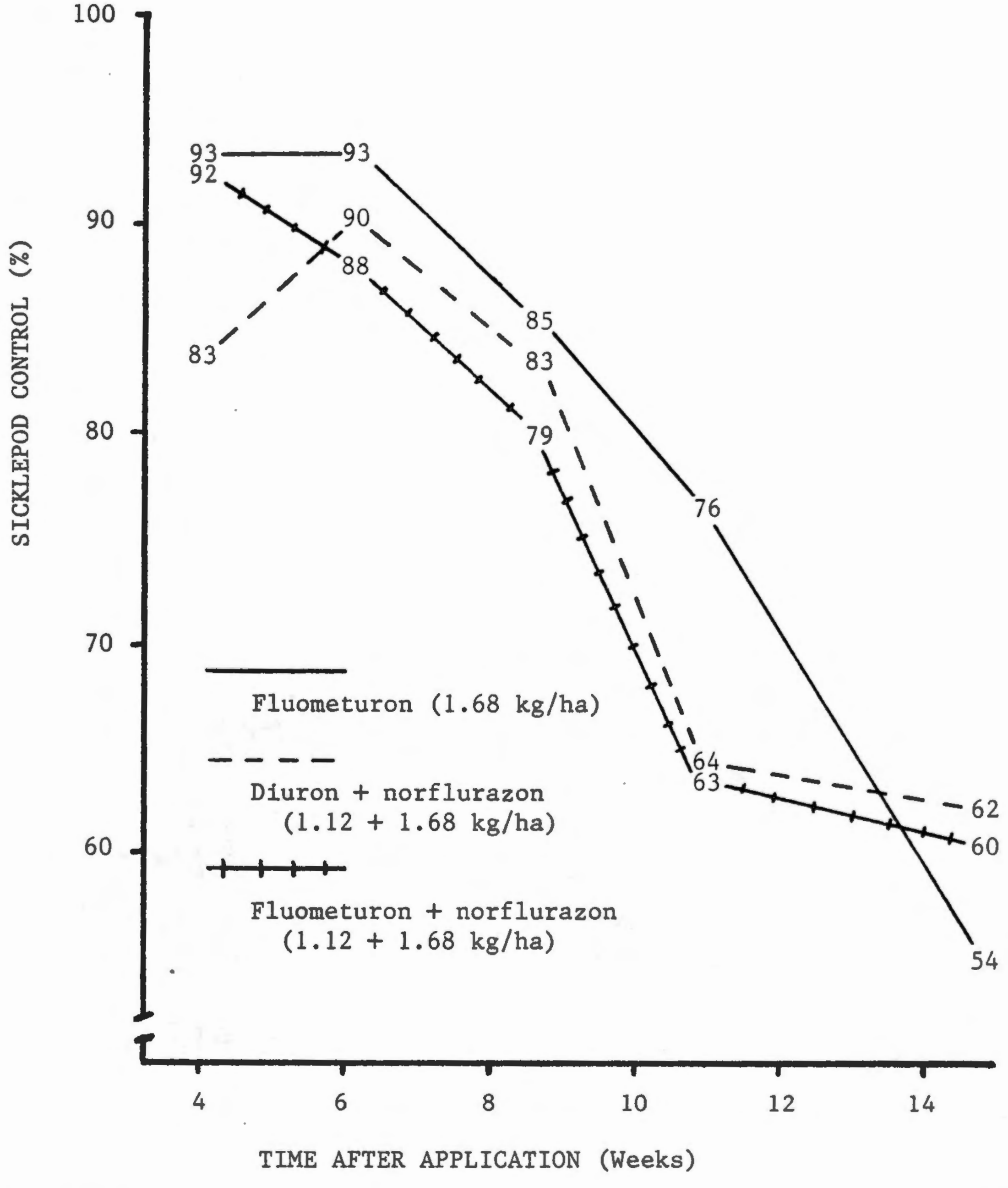


Figure 13. Sicklepod response at Milan in 1983 to herbicides commonly used in cotton.



LSD (0.10) 15 13 16 18 18

Figure 14. Sicklepod response to fluometuron, diuron plus norflurazon, and fluometuron plus norflurazon at Milan in 1983.

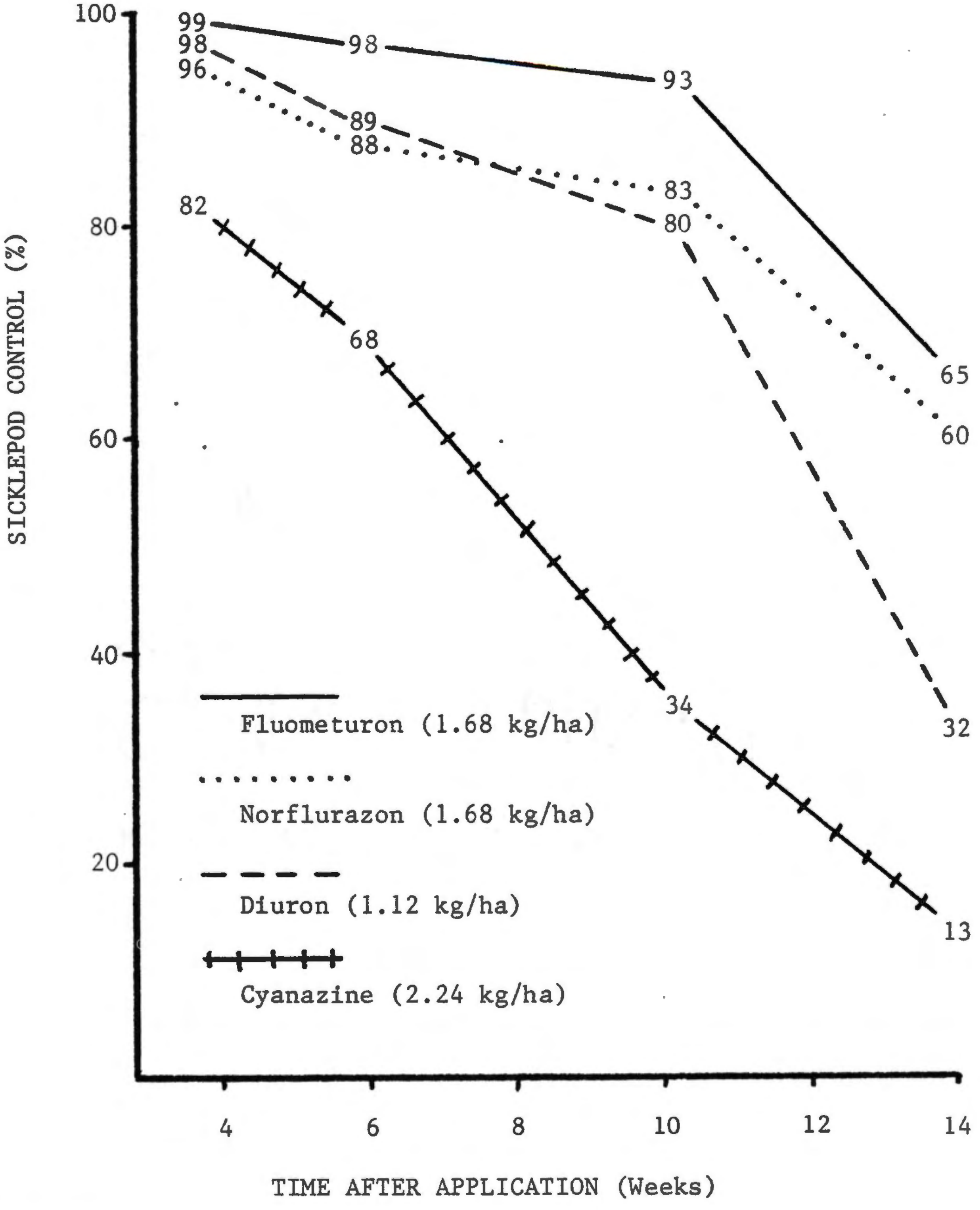
diuron at 1.12 kg/ha. By 14 weeks after application, diuron at 1.12 kg/ha had diminished in effectiveness and was poorer than fluometuron at 1.68 kg/ha or norflurazon at 1.68 kg/ha (Figure 15). It was not until 14 weeks after application that diuron plus norflurazon at 1.12 plus 1.68 kg/ha gave less control than fluometuron at 1.68 kg/ha or fluometuron plus norflurazon at 1.12 plus 1.68 kg/ha (Figure 16).

At Milan, all of the herbicide treatments evaluated for use in soybeans provided equal sicklepod control through the first 9 weeks. After 9 weeks the metribuzin system provided better sicklepod control than did metribuzin plus norflurazon at 0.43 plus 1.12 kg/ha or metribuzin at 0.56 kg/ha. The increased control from the metribuzin system was evidenced soon after the postemergence application of metribuzin and 2,4-DB (Figure 17).

The trend at Spring Hill among the treatments that can be used in soybeans was for the metribuzin system to provide better sicklepod control than metribuzin plus norflurazon at 0.43 plus 1.12 kg/ha which was better than metribuzin alone at 0.56 kg/ha. Metribuzin at 0.56 kg/ha provided significantly less control than did the other treatments during the middle of the season (Figure 18).

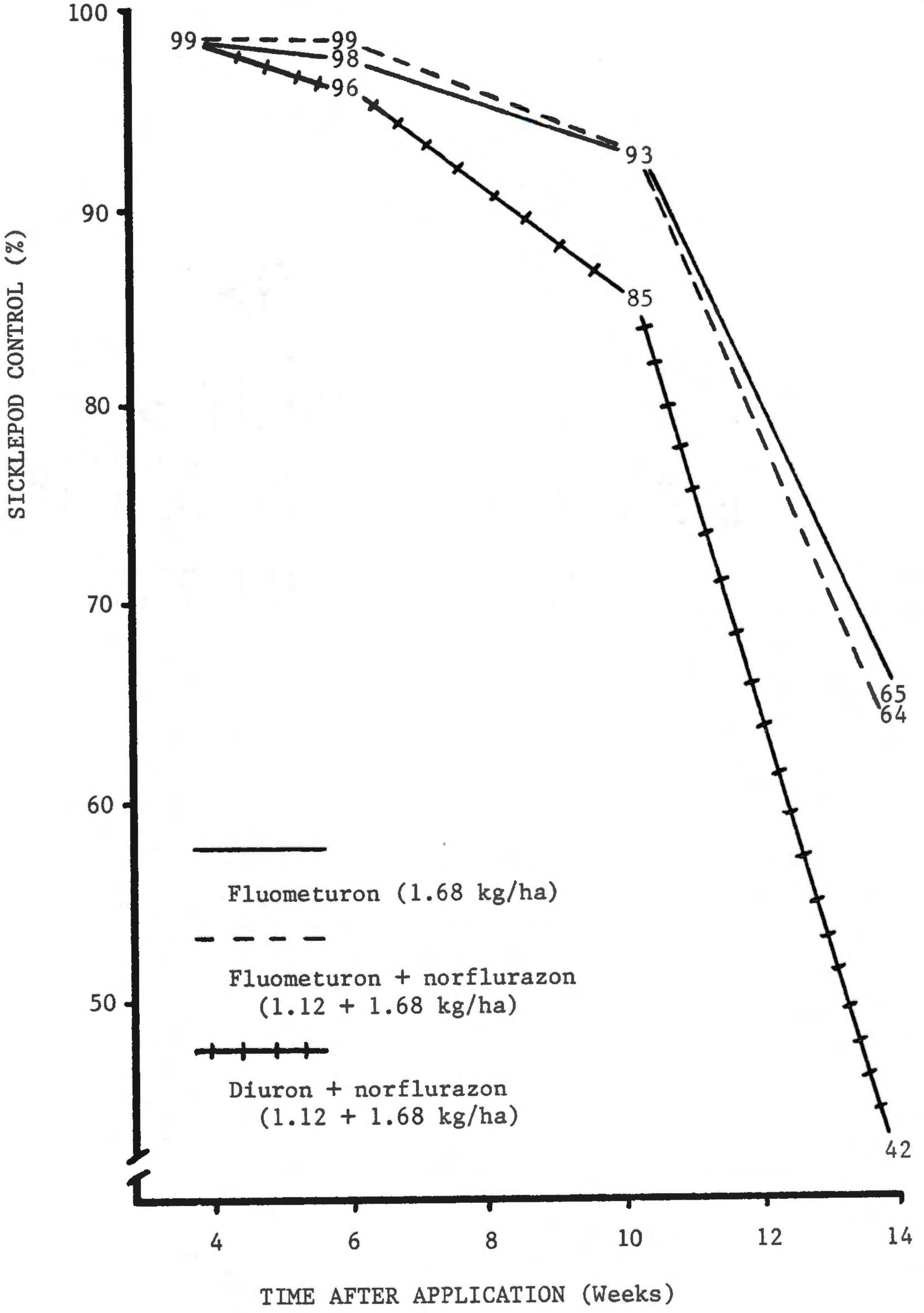
At Milan, the experimental herbicide DPX F 6025 tended to control more sicklepod than did imacaquin early in the season while the reverse was true toward the end of the season (Figure 19). These experimentals controlled less sicklepod than did the metribuzin system and in most cases provided less control than did metribuzin at 0.56 kg/ha.

At Spring Hill, imacaquin controlled more sicklepod than did DPX F 6025 with the trend being for the higher rates of imacaquin



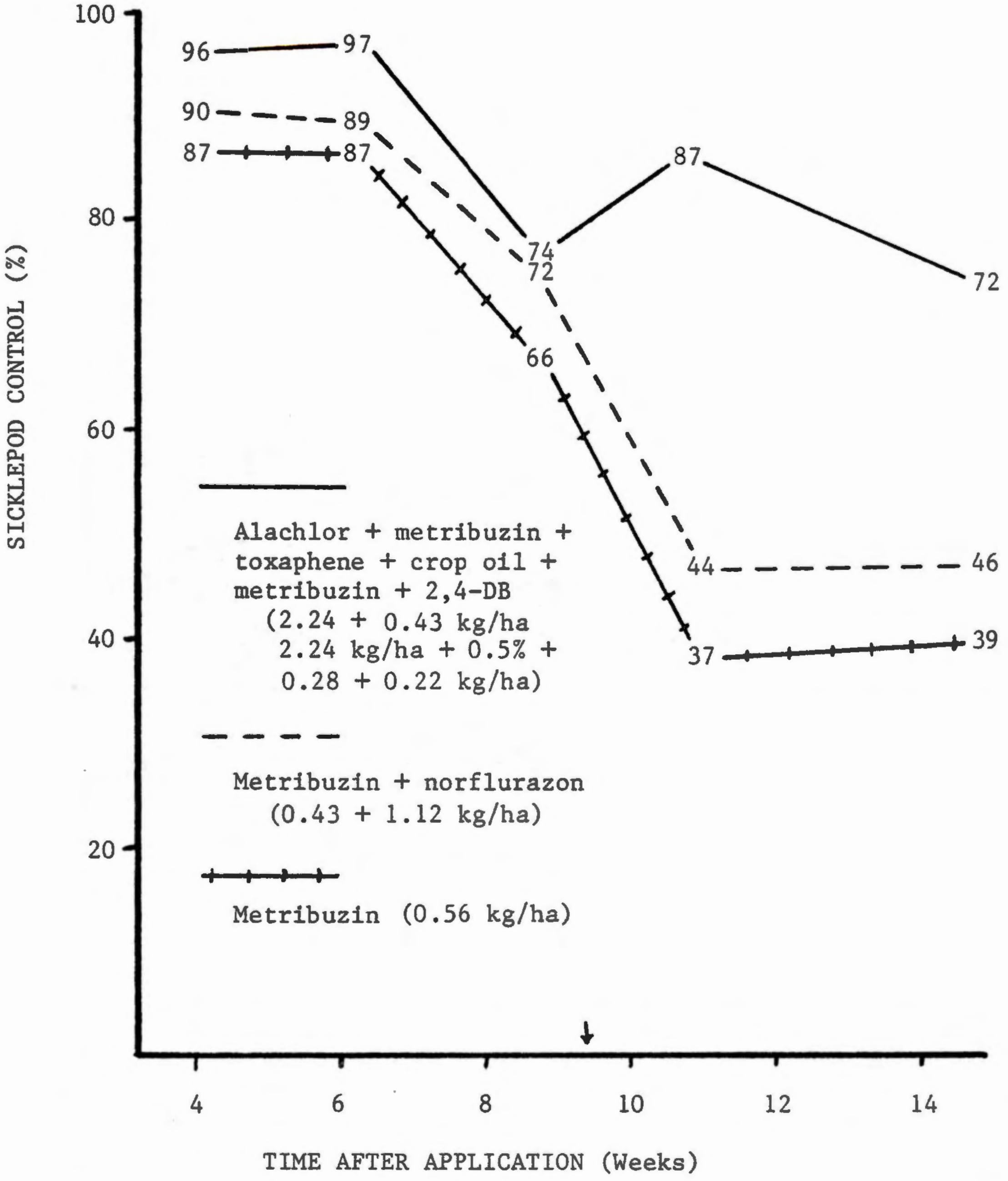
LSD (0.10) 14 17 19 28

Figure 15. Sicklepod response at Spring Hill in 1983 to herbicides commonly used in cotton.



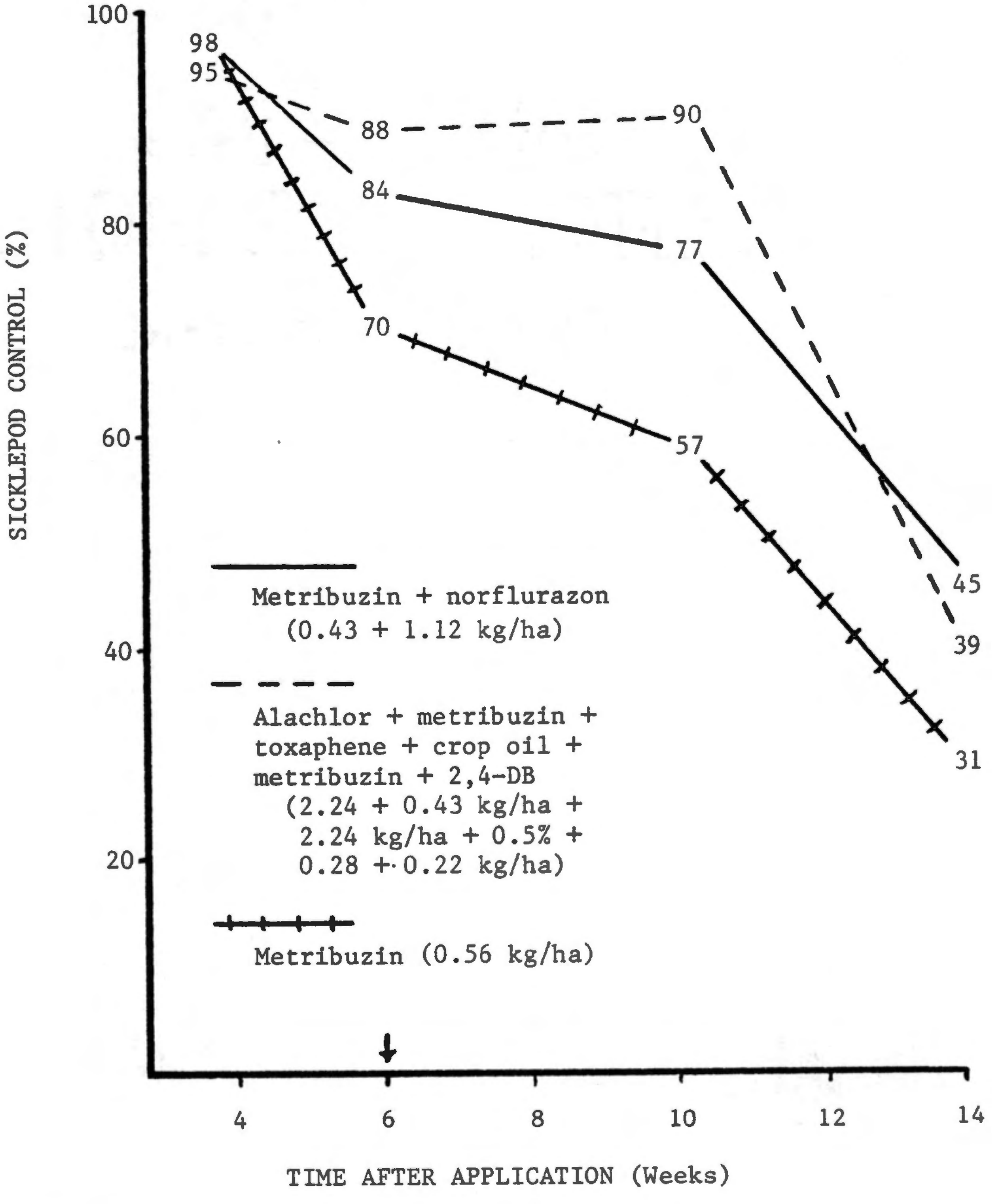
LSD (0.10)	14	17	19	28

Figure 16. Sicklepod response to fluometuron, diuron plus norflurazon, and fluometuron plus norflurazon at Spring Hill in 1983.



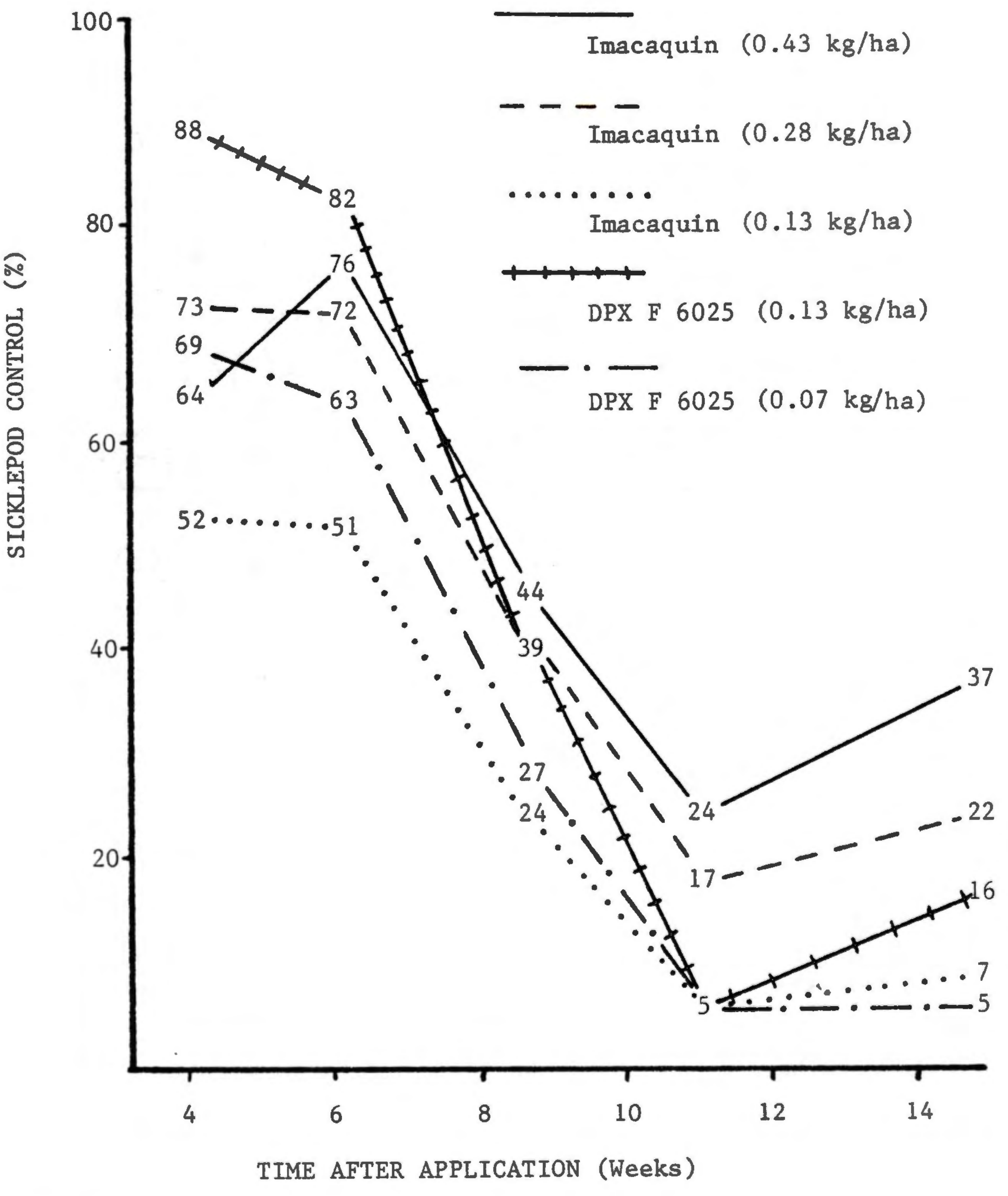
LSD (0.10) 15 13 16 18 18

Figure 17. Sicklepod response at Milan in 1983 to herbicides commonly used in soybeans. (↓ - Postemergence application of metribuzin plus 2,4-DB).



LSD (0.10)	14	17	19	28

Figure 18. Sicklepod response at Spring Hill in 1983 to herbicides commonly used in soybeans. (↓ - Postemergence application of metribuzin plus 2,4-DB).



LSD (0.10) 15 13 16 18 18

Figure 19. Sicklepod response to experimental herbicides at Milan in 1983.

(0.43 and 0.28 kg/ha) to provide better and longer control (Figure 20). There was no difference in sicklepod control between the metribuzin system and imacaquin at 0.43 kg/ha (Figure 21).

2. Greenhouse response

Results of the greenhouse experiments to measure sicklepod response to herbicide concentrations were somewhat erratic; however, some trends existed. Sicklepod was controlled by lower concentrations of atrazine than of simazine or cyanazine which were approximately equal in sicklepod control. Sicklepod was controlled by slightly lower concentration of norflurazon than diuron. Diuron was slightly better than fluometuron which was far better than cyanazine. Sicklepod was controlled by lower concentrations of metribuzin than any of the other herbicides. Overall the order of herbicides in regard to sicklepod control was: metribuzin > norflurazon ≥ diuron ≥ fluometuron > atrazine > simazine = cynazine.

B. Residual Activity

1. Greenhouse bioassays

As determined by the cucumber bioassay, residual activity equivalent to 0.1 ppmw of atrazine was still present in August 1982 in soil taken from plots in Jackson treated with atrazine plus simazine at 2.24 plus 1.12 kg/ha in May 1982. Soil samples from plots that received 3.36 kg/ha atrazine had residual activity equivalent to 0.15 ppmw atrazine while those from plots treated with atrazine at 4.48 kg/ha had residual activity equal to 0.2 ppmw atrazine. Samples from all other treatments exhibited less injury than 0.1 ppmw atrazine.

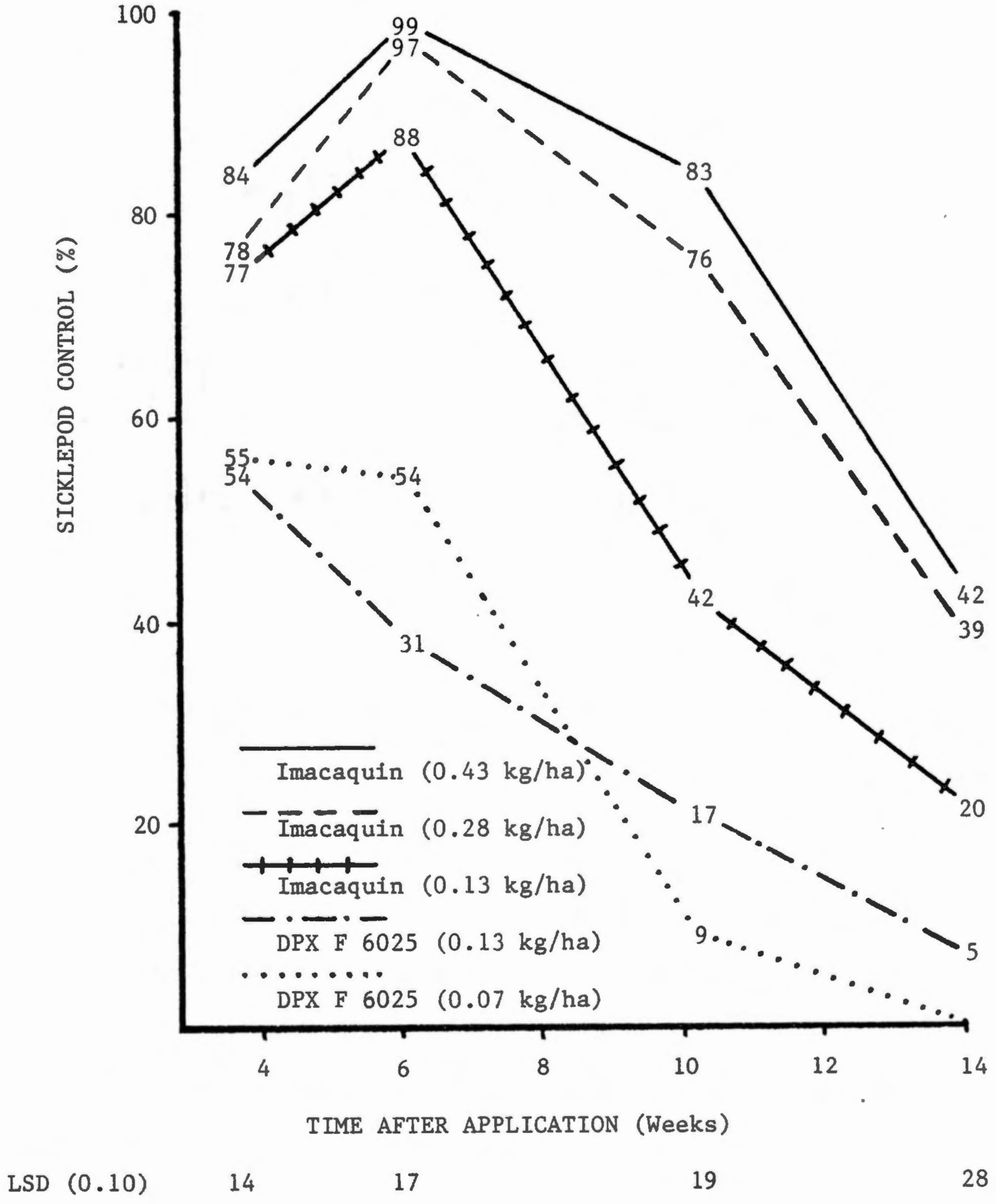


Figure 20. Sicklepod response to experimental herbicides at Spring Hill in 1983.

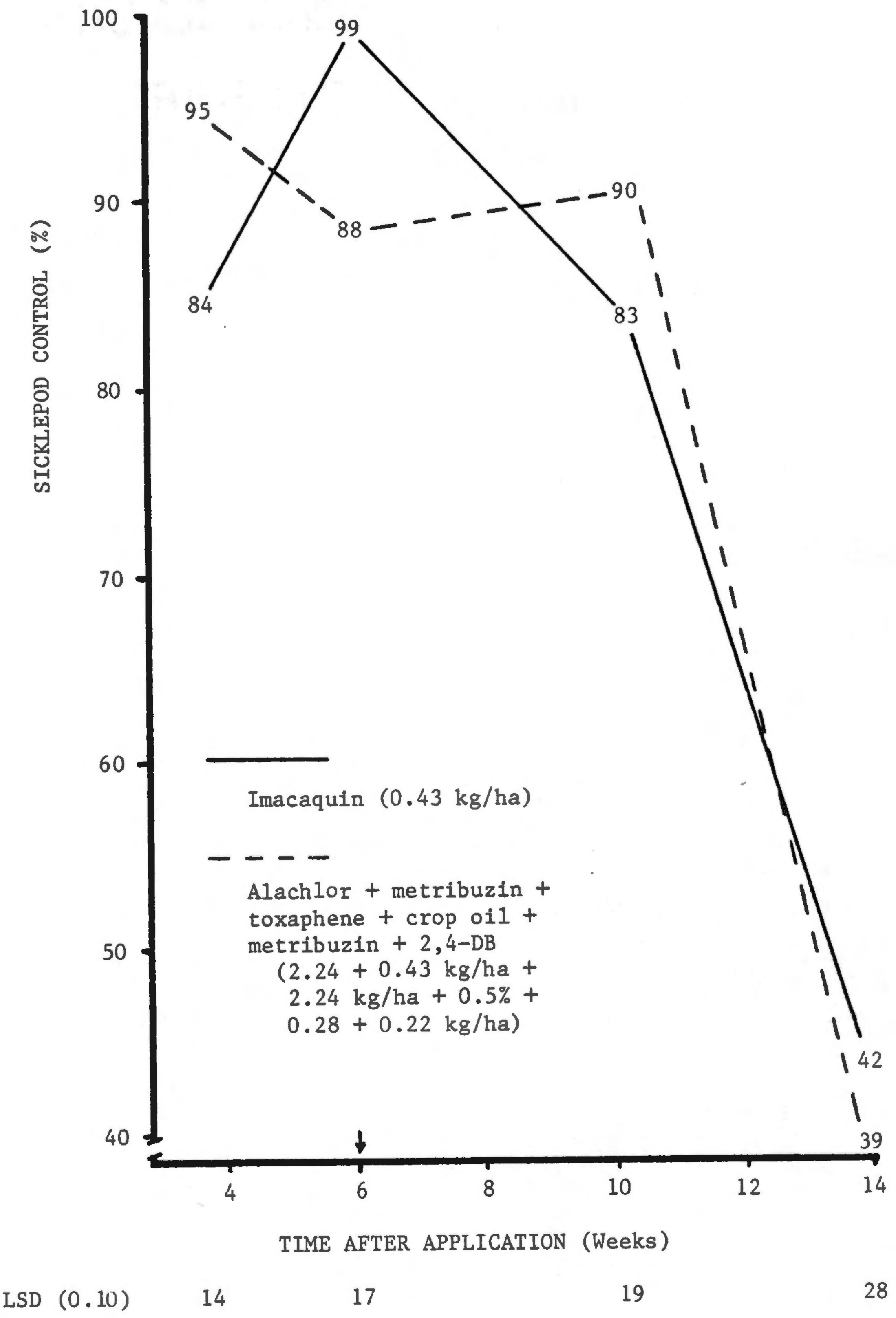


Figure 21. Sicklepod response to imacaquin at 0.43 kg/ha compared to that of the metribuzin system at Spring Hill in 1983. (↓ - Postemergence application of metribuzin plus 2,4-DB).

In the same year at Spring Hill, samples from plots that had been treated in May with 3.9 kg/ha of atrazine exhibited injury equivalent to 0.25 ppmw of atrazine in August and samples treated with 5.0 kg/ha had residual activity equal to 0.3 ppmw atrazine. Soil samples taken at the depths of 8 to 16 cm, 16 to 24 cm, 0 to 16 cm, and 0 to 24 cm from the plots that received 5.0 kg/ha atrazine exhibited less injury than 0.1 ppmw atrazine.

In 1983 at Milan, samples taken from plots treated with 4.48 kg/ha atrazine in late May had residual activity equivalent to 0.1 ppmw atrazine in September as determined by the cucumber bioassay. Herbicide residues from plots treated with diuron at 1.12 kg/ha, diuron plus norflurazon at 1.12 plus 1.68 kg/ha, or fluometuron plus norflurazon at 1.12 plus 1.68 kg/ha caused more injury to cucumbers than that caused by residues in the 4.48 kg/ha atrazine plots. Injury from residues in samples from all other plots was less than that from 0.1 ppmw atrazine.

Soil samples taken in September of 1983 at Spring Hill from plots treated June 2 with atrazine at 2.24 kg/ha or atrazine plus simazine at 1.12 plus 1.12 kg/ha had residual activity equivalent to 0.15 ppmw atrazine. Soil treated with atrazine at 3.36 kg/ha had residual injury on cucumber equivalent to that caused by 0.25 ppmw atrazine Soil treated with atrazine plus simazine at 2.24 plus 1.12 kg/ha had activity equal to 0.3 ppmw atrazine. Injury from samples taken from plots treated with 4.48 kg/ha atrazine or 2.24 kg/ha simazine corresponded to injury caused by 0.35 ppmw atrazine. Injury to cucumber from herbicide residues in samples taken from plots treated with diuron at 1.12 kg/ha or norflurazon at 1.68 kg/ha was similar to that caused by 4.48

kg/ha atrazine. Soil that had been treated with 1.68 kg/ha fluometuron or fluometuron plus norflurazon at 1.12 plus 1.68 kg/ha produced twice the injury to cucumbers as that of atrazine at 4.48 kg/ha. Soil samples from plots treated with diuron plus norflurazon at 1.12 plus 1.68 kg/ha were intermediate in residual activity between diuron at 1.12 kg/ha and fluometuron at 1.68 kg/ha. Residues from all other samples gave less injury than 0.2 ppmw atrazine.

2. Field bioassays

In 1982, very little residual injury to any of the cover crops studied occurred. Residues from 3.36 and 4.48 kg/ha of atrazine applied in May caused some injury to alfalfa, crimson clover and wheat planted in September with more injury occurring in plots treated with the higher rate. Residue from norflurazon at 1.68 kg/ha caused some injury to wheat in the fall. None of the herbicide treatments applied in May injured vetch seeded in the fall. In the spring of 1983, no visual evidence of phytotoxicity caused by the residues of any of the herbicides applied in May of 1982 was apparent on any of the crops seeded in the fall of 1982. Because no differences in crop stand or vigor were apparent, yield data was not taken.

At Milan in 1983, the most residual injury occurred to fall seeded wheat in plots that received 1.68 kg/ha of norflurazon in May. Wheat was first chlorotic and later died causing severe stand reduction and possibly subsequent crop yield loss. Residual activity from 1.68 kg/ha of norflurazon also injured crimson clover but the injury was not as severe as that to wheat. Wheat in the plots that received 4.48

kg/ha of atrazine was also injured but only slight stand loss occurred. Injury from residual activity of atrazine plus simazine applied at 2.24 plus 1.12 kg/ha was slightly less than that caused by atrazine at 4.48 kg/ha. No appreciable injury occurred to vetch from any treatment.

At Spring Hill in the fall of 1983, herbicide residues in plots that received treatments containing 1.68 kg/ha norflurazon in the spring injured wheat most severely. Residues in plots treated with metribuzin plus norflurazon at 0.43 plus 1.12 kg/ha caused injury to wheat that was slightly less than that caused by 1.68 kg/ha norflurazon. Stands of vetch, crimson clover and alfalfa were insufficient to make evaluations of residual injury.

CHAPTER V

SUMMARY AND CONCLUSIONS

In general, the preemergence herbicides used in corn controlled more sicklepod than did those used in cotton which controlled more sicklepod than did those used in soybeans. Atrazine applied at 4.48 kg/ha, atrazine at 3.36 kg/ha, and atrazine plus simazine at 2.24 plus 1.12 kg/ha kg/ha were the only treatments that consistantly provided effective season long control of sicklepod. Atrazine rate seemed to be the critical factor in herbicide combinations for sicklepod control in corn. Those combinations that contained at least 2.24 kg/ha atrazine gave the highest level of sicklepod control. Atrazine plus simazine at 2.24 plus 1.12 kg/ha had lower potential for injury to rotational crops than atrazine at 4.48 kg/ha. The order of herbicide effectiveness for sicklepod control among those herbicides used in corn was: atrazine > simazine ≥ cyanazine. The order of herbicide effectiveness for sicklepod control among herbicides used in cotton was: fluometuron > diuron = norflurazon > cyanazine. The metribuzin system provided better control of sicklepod than did a single preemegence application of metribuzin. Generally, sicklepod control and residual activity increased when two of the preemergence herbicides were combined.

Injury to subsequent crops from herbicide residues was the greatest with atrazine, simazine, and norflurazon and least with metribuzin and cyanazine. Herbicide residual injury can be reduced by mixing the soil which serves to dilute the chemical concentrations. If residual injury to cover crops is anticipated, one should consider planting vetch since it was more tolerant to the residues of the herbicide treatments evaluated than was alfalfa, crimson clover or wheat. Wheat was the most susceptible cover crop studied to injury from norflurazon residues.

Complete sicklepod control can be achieved in corn with a single preemergence application of at least 3.36 kg/ha atrazine or a herbicide combination containing 2.24 kg/ha atrazine whereas none of the preemergence herbicide treatments evaluated for use in cotton or soybeans provided complete season long control. The results of these experiments indicate that fields infested with sicklepod can be more easily managed if rotated to corn. In cotton, soybeans and sometimes corn, the preemergence herbicide is only part of a total sicklepod control system. One should consider the many cultural, mechanical and chemical methods of weed control available when developing a weed control program suited for situations where sicklepod is a problem.

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