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INFLUENCE OF CULTURAL PRACTICES ON THE SUNFLOWER SEED WEEVIL IN SOUTH DAKOTA

BY

JOE V. GEDNALSKE

A thesis submitted
in partial fulfillment of requirements for the
degree of Master of Science
Major in Entomology

South Dakota State University
1983

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THE SUNFLOWER SEED WEEVIL IN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

David D. Walgenbach
Thesis Advisor

Date

Maurice L. Horton
Head, Plant Science Department

Date

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INTRODUCTION

The sunflower, *Helianthus annuus* L., has become an important crop in South Dakota during the past ten years. Production has increased from 17,000 hectares in 1972 to 250,036 hectares in 1982 (Anonymous 1982). The major sunflower production area is in the northeastern one-quarter of the state. Nearly one-quarter million hectares have been grown annually in this area during the last four years. Because of the density and frequency of sunflower production, sunflower insect pests have caused major economic problems in the northeast quadrant of South Dakota.

The two species of sunflower seed weevils found in South Dakota, *Smicronyx fulvus* (LeC.) and *Smicronyx sordidus* (LeC.) have a wide distribution, which extends from the western Appalachian highlands across the plains region to the Pacific mountain system (Anderson 1962). Anderson (1962) reported *S. fulvus* specimens in Fall River County. Kirk and Balsbaugh (1975) reported that specimens of *S. fulvus* and *S. sordidus* had been collected throughout South Dakota on *Helianthus* species. Oseto and Braness (1979a) observed *S. fulvus* adults feeding and mating on wild *Helianthus annuus* L., *H. maximilani* S., *H. petiolaris* N. and *H. tuberousus* L. They recovered larvae from *H. annuus*, *H. maximilani*, and *H. petiolaris*.

The weevils apparently moved readily to domestic sunflowers when production began on a large scale basis in the 1970's. Seed weevils have attained economic levels in South Dakota since 1978 (Walgenbach personal communication). In 1981 70 percent of the sunflower acres were treated once and 15 percent twice for seed weevil control. The control cost was estimated at three million dollars (Gednalske and Walgenbach 1982). In 1982 the treated acres increased to 85 percent, with 20 percent being treated twice (Walgenbach personal communications). Aerial application of parathion has been the most frequently used treatment, and is a highly toxic chemical to insects and mammals.

Published information on the biology and control of seed weevils has been limited. Attempts at chemical control were initiated as early as the mid 1930's by Satterthwait (1946). He experimented with calcium arsenate, lead arsenate, sodium fluoride, pyrethrum, tale, hydrated lime, and gypsum, applied with a hand bellows. He reported unfavorable results for all treatments. Additional chemicals were evaluated by Muma et al. (1950), also with poor results. More recently Oseto and Braness (1979a) reported success in reducing seed weevil damage with treatments of phosmet, endosulfan, fenitrothion, and methidathion.

Although he reported no results, Satterthwait (1946) suggested that since seed weevil larvae overwinter in the soil, fall plowing may afford control. Satterthwait also screened several varieties of sunflowers for resistance to seed weevils. In his studies for varietal resistance, he indicated that earlier blooming varieties had a smaller percentage of the seed infested by weevils than later blooming varieties.

The purpose of this study was to evaluate cultural methods for sunflower seed weevil control. Procedures examined included the influence of tillage methods, crop rotation, date of planting, hybrid maturity, and degree-day units on emerging seed weevil populations. Tillage practices done as both fall and spring treatments including discing, chisel plowing, nobel blading, and moldboard plowing were examined for their effect on larval position in the soil, time of adult weevil emergence, and the number of adults emerging from the soil. Crop rotations were investigated for possible influence on weevil mortality and time of adult emergence. Sunflower planting date and hybrid maturity were compared to seed weevil ovipositional patterns. Degree-day accumulations were utilized for potential predictive values in assessing adult weevil emergence.

LITERATURE REVIEW

A. History and Biology

The sunflower seed weevil *Smicronyx fulvus* (LeC.) was first reported as an economic pest by Forbes (1915). He stated that damage by seed weevils stopped the production of sunflower in Illinois. Cockerell (1915) also noted that *S. fulvus* was very common on commercial sunflower in Colorado, but was not a serious pest.

Satterthwait (1946) described two seed weevils *Demoris fulvus* (LeC.) and *D. constrictus* (Say) (later determined to be *Smicronyx fulvus* and *Smicronyx sordidus*) as among the worst pests of cultivated sunflower in the United States. He credited seed weevils for the decline of sunflower production in Illinois and Missouri in the 1930's. Muma et al. (1950) recognized *Demoris fulvus* and *D. constrictus* as a limiting factor to commercial sunflower production in Nebraska. He reported both species to be prevalent on wild as well as commercial sunflower varieties.

Anderson (1962) reclassified all forms of weevils in the genus *Desmoris* to the genus *Smicronyx*. He also identified the gray weevil as belonging to the species *sordidus* rather than *constrictus*. *S. Sordidus* was reported by Anderson as being the most widely spread species in the genus *Smicronyx*.

Phillips et al. (1973) listed *S. sordidus* as a potentially damaging insect pest of sunflower in Texas. In his survey in 1970, he found up to 97,812 weevils per hectare, or approximately 1 weevil per plant.

In 1974 S. fulvus was discovered infesting cultivated sunflower in North Dakota. The seed weevils have attained economic levels since that time (Oseto and Braness 1979a).

In the late 1970's seed weevils reached economic levels in South Dakota. In 1981 70 percent of the sunflower hectareage required insecticidal treatment (Gednalske and Walgenbach 1982).

A paucity of research information exists on the biology of the sunflower seed weevil. Information is limited to studies on D. fulvus and D. constrictus by Satterthwait (1946) and more recently by Oseto and Braness (1979a) on S. fulvus.

Satterthwait (1946) described S. fulvus adults as a bright rufous, or iron rust colored weevil about 2.5 mm in length. S. Sordidus is slightly larger and gray in color.

Seed weevils overwinter as 5th instar larvae, most of them in the soil, although a few will overwinter in the seed. Oseto and Braness (1979b) gave a detailed description of the 5th instar larva and pupa of S. fulvus. They describe the larva as 2.31-3.04 mm in length; robust, moderately curved; abdominal segments narrowed posteriorly, and thoracic and abdominal segments white in color. As pupation occurs the body elongates and the white color darkens to fusco-testaceous prior to eclosion.

The larvae pupate in the soil and adults emerge from late June to late August. Oseto and Braness (1979a) reported a 14 day pupal period, while Satterthwait (1946) described an eight day pupal stage. Upon eclosion in the soil, adults burrow to the soil surface and move to wild or commercial sunflower plants. Charlet and Oseto (1982) indicated that *S. fulvus* adults are likely to congregate on the borders of large commercial fields. Their study showed that damage from seed weevils decreased as the distance from the field edge increased. Based on percent of damaged seed, damage declined more than 10 percent from the field edge to 15 meters into the field. Adult weevils feed on sunflower stems and leaf petioles until buds appear. Feeding is then concentrated on the involucral bracts of the buds leaving pin-point feeding scars. This feeding has not been considered damaging to the developing head. At the onset of anthesis weevils begin feeding on pollen and developing seeds. Following a preoviposition period of approximately two weeks, females oviposite in feeding scars on developing seeds (Oseto and Braness 1979a). However, recent evidence indicates this period is much shorter (Oseto personal communication). Oviposition takes place when plants are at anthesis substage 4.0 to 4.5 (growth stages described by Siddiqui et al. 1975). Oviposition follows seed filling from the edge to the center of the sunflower head (Putt 1940).

The oviposition period lasts about 20 days and a single female will lay about 20 eggs. Normally a single egg is laid in a seed, however, Oseto and Braness (1979a) reported that 19 percent of the seed they examined contained more than one egg. When the sunflower plant is beyond substage 5.0, adults are no longer attracted to the head because of depleted pollen, and the hardened achenes prevent oviposition (Oseto and Braness 1979a).

According to Satterthwait (1946) eggs are .45 to .66 mm in length, elliptical, and white with a transparent shell. The eggs hatch within the seed in approximately one week (Oseto 1979).

The larvae feed within the sunflower seed consuming one-third to one-half of the content before cutting a circular opening in the hull and dropping to the soil. This feeding reduced seed weight by 31 percent, and oil content by 25 percent in a study by Oseto and Braness (1980). However, these figures may vary dependant on seed size.

The larvae undergo five developmental stages. The first four instars take place within the seed in 7-14 days according to Oseto (1979). No other information is available on the weevils at this stage of its life cycle.

The fifth instar larvae undergo diapause in the soil beneath the sunflower head. Oseto and Charlet (1981) described the distribution of the overwintering larvae beneath the drooping sunflower head. Their study indicates that the majority of the weevil larvae were concentrated in the soil directly beneath the sunflower head, showing little latteral movement in the soil. Oseto and Braness (1979a) reported larvae to depths of 28 cm and indicated that larvae move vertically in the soil at various times of the year. They found larvae at the 28 cm level in mid-January when soil temperatures at that level were 1°C and moved to the 2.5 cm level at 6°C. Oseto and Braness also indicated a combined mortality rate for larvae and pupae of about 40 percent.

B. Control Methods

Observations of natural control of *S. fulvus* by chalcid and braconid parasitoids were made by Bigger (1930, 1931, 1932). He believed

Microbracon mellitor (Say) to be an important parasite because it appeared to be in biological synchrony with *S. fulvus*, and it was most abundant in areas where sunflowers had been grown for a number of years. Satterthwait (1946) reported finding *Microbracon mellitor* in 65 percent of the heads he had examined in 1939. Oseto and Braness (1979a) noted finding two braconid parasites, *Bracon mellitor* and *Neoliolus curculionis* and a pteromalid, *Trimeromicras* sp. in North Dakota sunflower fields. To date no one has made an attempt to assess the importance of these natural enemies in the control of sunflower seed weevils in the northern great plains.

Resistant varieties were investigated by Satterthwait (1946) as a means of seed weevil control. He screened open pollinated and inbred lines from 1936 to 1940 for resistance to seed weevil infestations. He isolated two sunflower lines he believed to be resistant to infestations. In one test these lines averaged 5 percent infestation, while average seed infestations in the planting were 75 percent. No further work has been reported on the development of resistant varieties.

Chemical controls were initiated in the 1930's by Satterthwait (1946). His trial included calcium arsenate, lead arsenate, sodium fluoride, pyrethrum, talc, hydrated lime and gypsum. None of these chemicals provided adequate control. Satterthwait blamed the long bloom period for the lack of control.

Muma et al. (1950) tested benzene hexachloride and DDT for seed weevil control in Nebraska. His test showed that DDT was not an effective control. Benzene hexachloride reduced weevil populations on heads for a short time. However, it did not reduce the percentage of infested seeds. Proper timing of insecticide applications was listed as a means of improving control.

Oseto and Braness (1980) tested endosulfan, fenitrothion, phosmet, and methidathion for efficacy on _S. fulvus_ adults. The results of their study showed that two applications of any of the tested insecticides significantly reduced damage when compared to controls.

No literature is available on tillage or cultural control of sunflower seed weevils, with the exception that Satterthwait (1946) suggested that fall plowing may offer some control. However, tillage and adjustments of planting date have proven to be valuable control aids with other insects.

Cultural control is the first line of defense against the pink bollworm, _Pectinophora gossypiella_ (S.), a major pest of cotton (Toscano et al. 1979). Crowder and Watson (1976) stated that the plowing-under of crop residue was one of the usual practices for control of pink bollworm in Arizona. Watson and Larson (1968) showed that the type of tillage following a cotton crop affected the number of pink bollworm emerging from the soil the following year. In this study deep plowing delayed and reduced emergence.

Leibee and Horn (1979) found that plowing and discing increased mortality of cereal leaf beetles, _Oulema melanopus_ (L.), by 100 and 93.8 percent respectively. Their study also suggested that one component of mortality due to tillage may be related to the repositioning of the insect to a greater distance below the soil surface.

Huddleston et al. (1972) found that sorghum midge, Contarinia sorghicola (Coq.), damage could be controlled by adjusting the date of planting. Their research indicated that sorghum planted so that blooming occurred prior to mid-August would escape midge damage.

Campbell and Van Duyn (1977) investigated the use of tillage in controlling a soybean stem borer, Dectes texanus texanus, an insect which also infests sunflowers in South Dakota. Their data indicated that burial of this insect larvae by deep plowing or row bedding reduced populations by 20 to 50 percent. Adult emergence was significantly reduced when stubble was buried 2 inches or more. Adult emergence decreased with an increase in depth of burial. Less than 36 percent of adults emerged from the soil when buried 2 inches, and less than 15 percent emerged when buried to 4 inches.

METHODS AND MATERIALS

1980-81 Field Study

A. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil.

A 0.5 hectare plot was selected at the James Valley Research Center near Redfield, South Dakota. The plot area was previously in sunflowers that had weevil infestations of 15-20 adults per head, based on survey counts at 80 percent bloom. Additional plot criteria were uniformity of the sunflower plant population, and severity of larval seed weevil infestations. The seed weevil larvae tunneled from the seed and dropped to the soil in late September and the field was harvested October 20, 1980.

Fall tillage treatments were performed on November 4, 1980. The tillage treatments included discing, chisel plowing, moldboard plowing, nobel blading, and an untilled control in a randomized complete block design with three replications. Treatments consisted of one pass with a 4.9 m tandem disc having 40.5 cm diameter blades that penetrated to a depth of 15 cm; one pass with a 2.5 m wide chisel plow with 8 shanks spaced 30.5 cm apart with penetration to a depth of 20 cm; one pass with a 3 bottom moldboard plow with 35.6 cm rollover shares turning soil to a depth of 20 cm; and one pass with a nobel blade with a 2.1 m sweep operated at a depth of 15 cm. Treatments were 27.4 m in length and approximately 5 m wide perpendicular to previous sunflower rows.

Spring tillage treatments were conducted April 15, 1981 in the same manner as fall treatments. The spring treatments had only two replications because of space constraints.

On April 30, 1981 a light discing to a depth of 10 cm was applied across treatments on one-third of the plots in preparation for wheat seeding. Wheat was seeded with a 3 m wide John Deere grain drill with 15.2 cm spacing at a rate of 2 bu per hectare on May 1. The remaining two-thirds of the plot received similar discing for preparation for sunflower planting and herbicide incorporation on May 15. The sunflowers were planted at a rate of 39,500 seeds per hectare in 91.4 cm rows with a 4 row John Deere finger planter. Trifluralin was applied at 1.74 liters per hectare to the sunflower plot for weed control. On June 17 one-half of the sunflower plot was cultivated with a single row cultivator disturbing the soil between the rows to a depth of approximately 7.5 cm.

Six emergence traps were placed in each subplot on June 17. Each 9.1 x 5 m subplot contained one tillage treatment overlaid by one crop. Traps were placed in previously marked rows relating to the position of the drooping sunflower heads of the previous sunflower crop as described by Oseto and Charlet (1981). Location of larvae were confirmed through soil sampling.

Traps were constructed from 18.9 liter polyethylene pails with 10 cm of the basal portion removed. The traps were 28.6 cm in diameter at the top, 27.7 cm in diameter at the base, and 25.4 cm in height. The traps were forced into the soil approximately 10 cm and covered with a 10 x 10.5 cm mesh Lumite® Saran screen, secured to the trap with a rubber band. Each trap covered 602 sq. cm of soil surface.

Traps were checked at 4 to 5 day intervals and the number of weevils recorded. Counts began at the appearance of the first weevils on July 8, and continued until emergence ceased on September 1. Weevils congregated at the top edge of the traps upon emergence allowing easy enumeration.

Adult weevil numbers were fitted to a logistic curve over dates of emergence. An analysis of variance was made on the total number of weevils trapped per plot, comparing effects of tillage and crops. A Waller-Duncan K-ratio T test was used to make comparisons of mean weevil emergence between tillage methods and between crops.

B. Effects of Tillage on Larval Distribution in the Soil.

To ascertain the effect of different tillage operations on the depth of larvae in the soil, the following study was conducted: On March 26, 1982 soil cores were taken in the fall tillage treatments with soil temperatures at 3°C. On April 23 soil cores were taken in spring tillage treatments with soil temperatures at 15°C. A 11.2 cm diameter hydraulic soil probe mounted on a truck was used to remove soil cores. Cores were taken to a depth of 22.5 cm and divided into upper, middle, and lower 7.5 cm sections. Fifteen cores were taken per plot in both fall and spring tillage treatments. The number of larvae collected per section of the core was recorded and subsequently used to determine the depth to which tillage operations moved the larvae. Seed weevil larvae were extracted from the soil cores using the procedure described by Heilman, Gednalske, and Walgenbach (1983). The effect of tillage treatment on the depth of larvae was analyzed with a Chi-Square analysis.

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Treatments were compared by calculating the percentage of larvae found in each of the three layers of the soil profile.

C. Timing of Seed Weevil Emergence Study.

In this study the relationships were examined between tillage treatments, cropping patterns, soil temperatures, sunflower anthesis, and time of weevil emergence. Comparisons were made between tillage treatments for their affect on time of seed weevil emergence and similar comparisons were made between the three cropping schemes.

Degree-day units were calculated based on soil temperatures, and compared to beginning and peak weevil emergence periods. Degree-day units were accumulated when the mean soil temperature for the day was greater than 50°F, and a unit was added for each degree over 50°F. Calculations were made for soil temperatures at 5, 10, and 20 cm depths. The only beginning threshold for degree-day accumulations on weevils in the Midwest is on the alfalfa weevil. Wedberg et al. (1977) listed 48°F as the beginning threshold for the alfalfa weevils in Illinois. Since seed weevils emerge slightly later than the alfalfa weevil, 50°F was chosen as the beginning threshold.

Time of weevil emergence was compared to expected bloom periods for different dates of planting for sunflowers. Bloom periods were predicted by using sunflower hybrid performance data for the time between planting and anthesis. A three year study by Robinson (1981) on sunflower varieties showed the time between planting to bloom to range from 66 to 74 days for 87 hybrids. U.S.D.A. 894 hybrid, one of the most frequently planted hybrids, averaged 68 days from planting to bloom.

Putt (1940) reported that inflorescence takes 9 to 10 days.

RESULTS AND DISCUSSION

1980-81 Field Study

A. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil.

Weevil emergence patterns during 1981 showed that the type of tillage following sunflower production had an affect on the number of weevils emerging from the soil the following year. The fall moldboard plow treatments caused a significant reduction in the number of weevils emerging from the soil compared to untilled plots, reducing emergence by 39.7 percent, whereas the other treatments had no detectable effect (Table 1).

Table 1. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the soil (Fall Treatments 1980-81).

Fall Treatments	Mean No. Weevils/Plot*	Percent Reduction Compared to Untilled
Untilled	44 a	-
Disc	42 a	0
Nobel Blade	41 a	0
Chisel	40 a	0
Moldboard Plow	27 b	39.7

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

The spring tillage treatments indicated a similar trend with the moldboard plow, reducing emergence by 31.9 percent from the untilled; however, there was not a significant reduction at the .05 level (Table 2). The spring applied chisel plow reduced adult weevil emergence 36.4 percent from the untilled; however, again chisel plow and untilled means were not significantly different. The disc and nobel blade treatments were not significantly different from the untilled and actually had slightly higher emergence means.

Table 2. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil (Spring Treatments 1980-81).

Spring Treatments	Mean No. Weevils/Plot*	Percent Reduction Compared to Untilled
Disc	52 a	0
Nobel Blade	50 a	0
Untilled	44 a b	-
Moldboard Plow	30 b	31.9
Chisel	28 b	36.4

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

The crop following sunflower did not have a measurable effect on weevil emergence. The three crops were not significantly different in the number of weevils emerging from the soil (Table 3).

Table 3. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil (Crop Treatments 1980-81).

Treatments	Mean No. Weevils/Plot*
Sunflower with Cultivation	41.5 a
Wheat	40.6 a
Sunflower	37.3 a

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

B. Effects of Tillage on Larvae Distribution in the Soil

The type of tillage used following sunflower had a significant effect [P ($x^2 \geq 70$) = .01] on the location of larvae in the soil in both spring and fall treatments.

In the untilled treatments, 95 percent of the seed weevil larvae collected were at the 0-7.5 cm depth, and none were found deeper than 15 cm in both spring and fall plots (Figures 1 and 2). There were no differences in the depth of larvae found in the fall and spring untilled areas even though the soil temperature at the time of sampling the fall treatments was 3°C, and was 15°C when spring treatments were sampled. This is in contrast to Oseto and Braness (1979a) who reported larvae at 28 cm when soil temperature was 1°C. They also indicated that larvae moved to the 2.5 cm depth in the soil when temperatures rose to 6°C.

The moldboard plow treatment placed the majority of the larvae below the 7.5 cm level in the soil (Figures 1 and 2). Over 50 percent of the larvae were collected at the 7.6-15 cm depth and 24 to 30 percent were deeper than 15 cm in the fall and spring moldboard plow treatments respectively. This indicates that the moldboard plow operated to a depth of 20 cm is successful in moving the larvae from the 0-7.5 cm depth as found in the untilled areas to below 7.6 cm.

The chisel plow treatment moved over 20 percent of the larvae deeper than 7.6 cm into the soil (Figures 1 and 2). The discing and nobel blade treatments showed less movement of the weevil larvae into the soil than did the chisel plow (Figures 1 and 2).

The chisel plow, disc, and nobel blade were operated at similar depth to the moldboard plow. However, this data indicates that only the moldboard plow has the ability to move the weevil larvae substantially

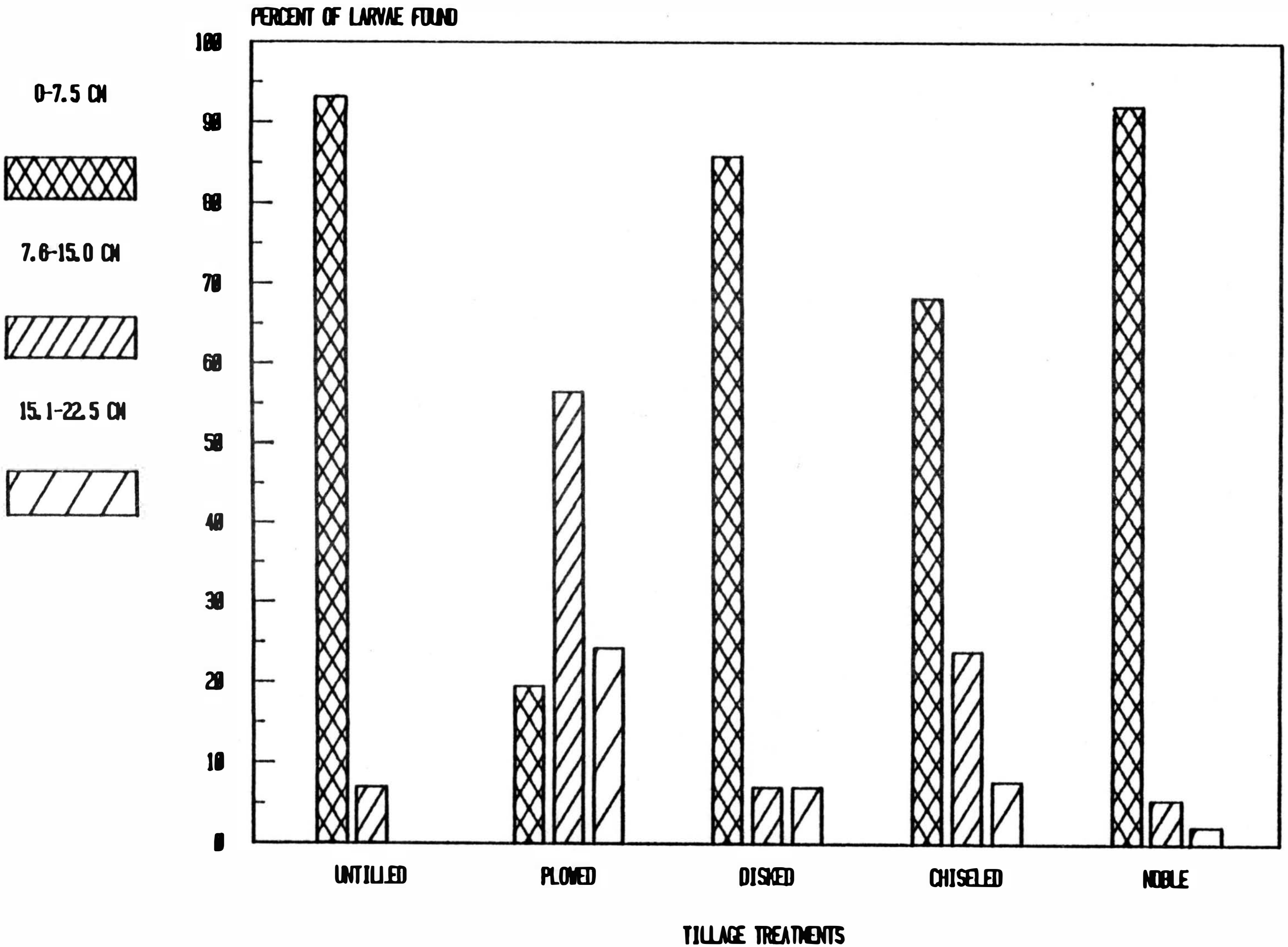

Figure 1. Influence of fall applied tillage treatments on the percent of larvae found at three levels of the soil profile, Redfield 1980-81.

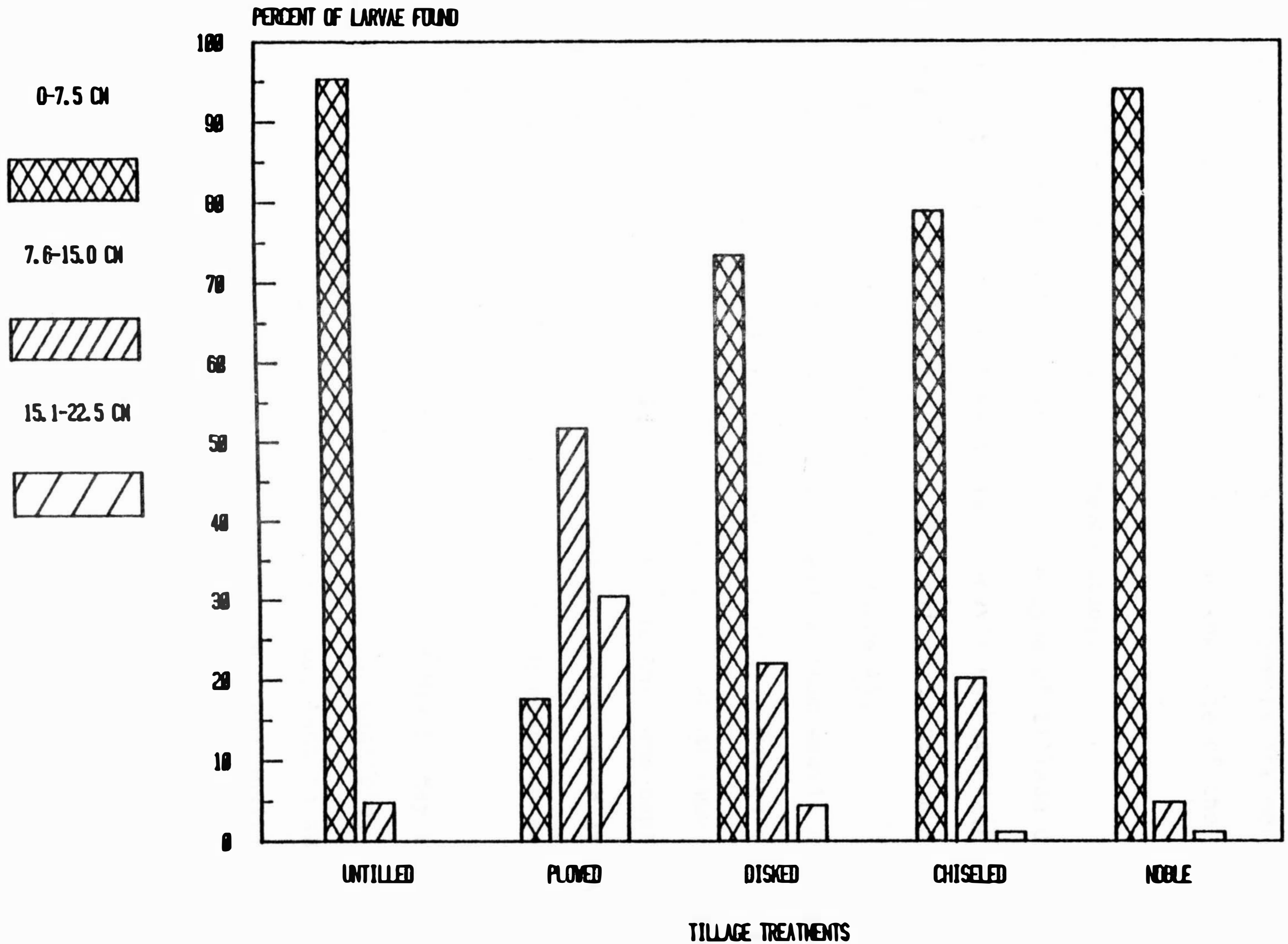

Figure 2. Influence of spring applied tillage treatments on the percent of larvae found at three levels of the soil profile, Redfield 1980-81.

deeper into the soil profile. This is likely due to the turning action of the moldboard plow, whereas the other implements are merely disturbing or slightly turning the soil at the site of the shank or blade.

C. Timing of Seed Weevil Emergence Study.

Data from 1981 indicated that the type of tillage did not have a significant effect on the time of adult weevil emergence (Figure 3). The crop following a sunflower crop also failed to have a significant effect on the time of weevil emergence (Figure 4).

Weevil emergence began July 8, and maximum weevil emergence occurred between July 30 and August 4 (Figure 5). Degree-day totals at initial emergence were 1081 at the 5 cm depth. At maximum emergence 1736 degree-day units had been accumulated at the same depth (Figure 5). Degree-day totals were approximately 200-300 units lower at the 10 cm depth, and another 150 units lower at the 20 cm depth on each study date (Figure 5).

The bloom period of sunflowers planted May 1, May 15, and June 1 was compared to time of weevil emergence data at Redfield, South Dakota in 1981 (Figure 6). This data is extremely important to sunflower producers when we consider that there is a 14 day preoviposition period for *S. fulvus* (Oseto and Braness 1979a). Since weevils are attracted only to sunflower heads actively shedding pollen (Oseto personal communication 1982), oviposition is unlikely in sunflowers planted in early May.

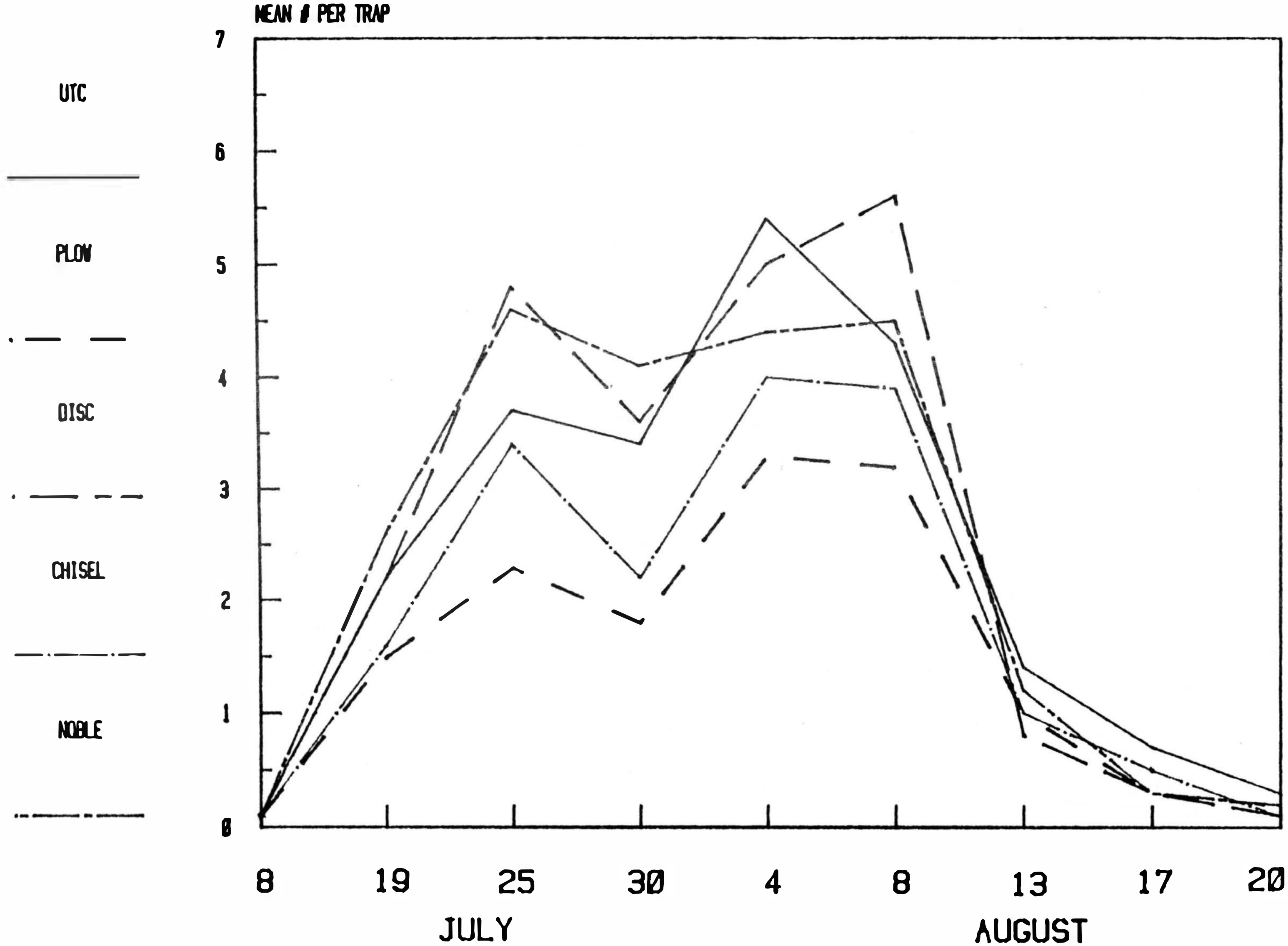

Figure 3. Time of adult seed weevil emergence as influenced by tillage treatments, Redfield 1980-81.

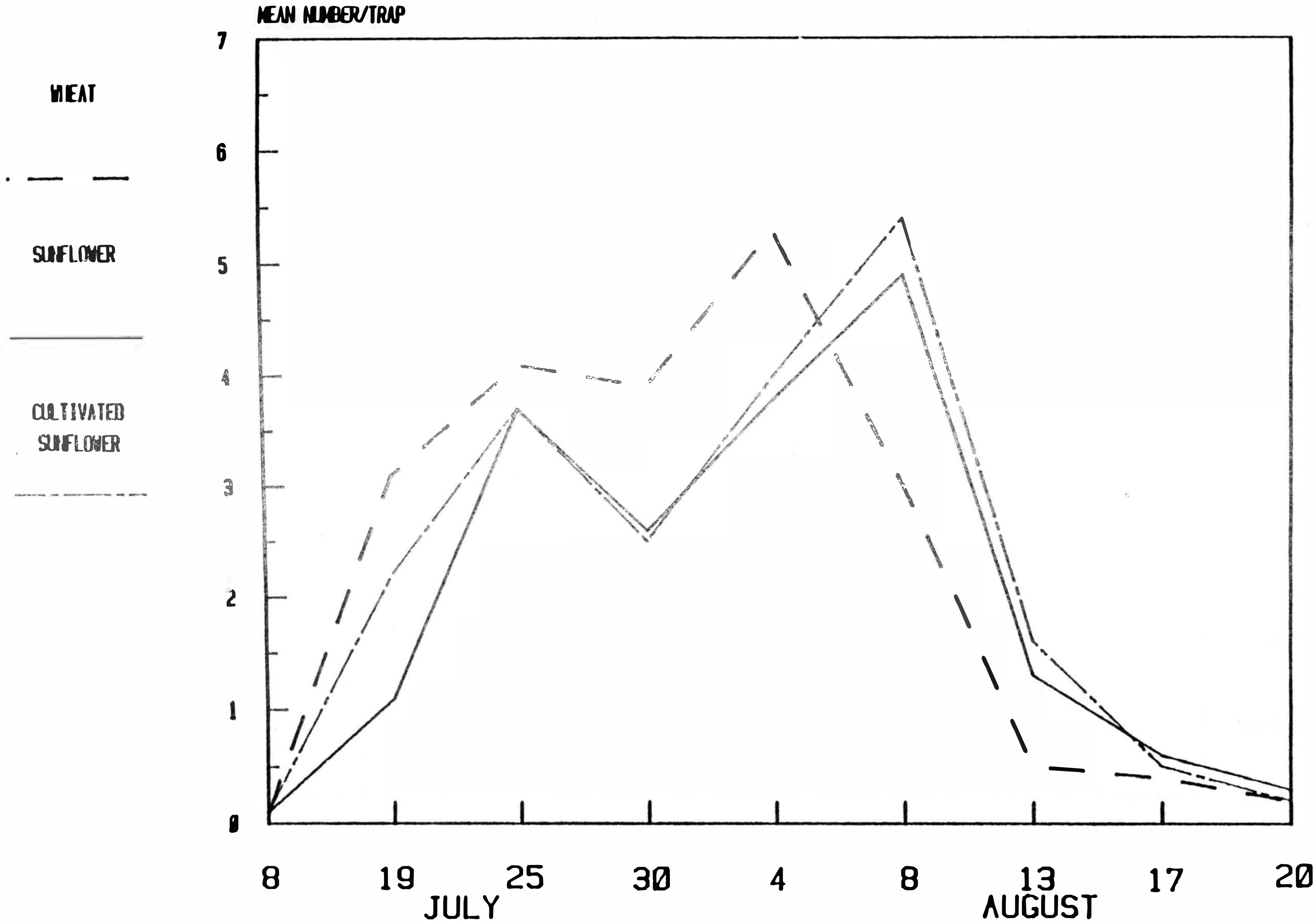

Figure 4. Time of adult seed weevil emergence as influenced by crop, Redfield 1980-81.

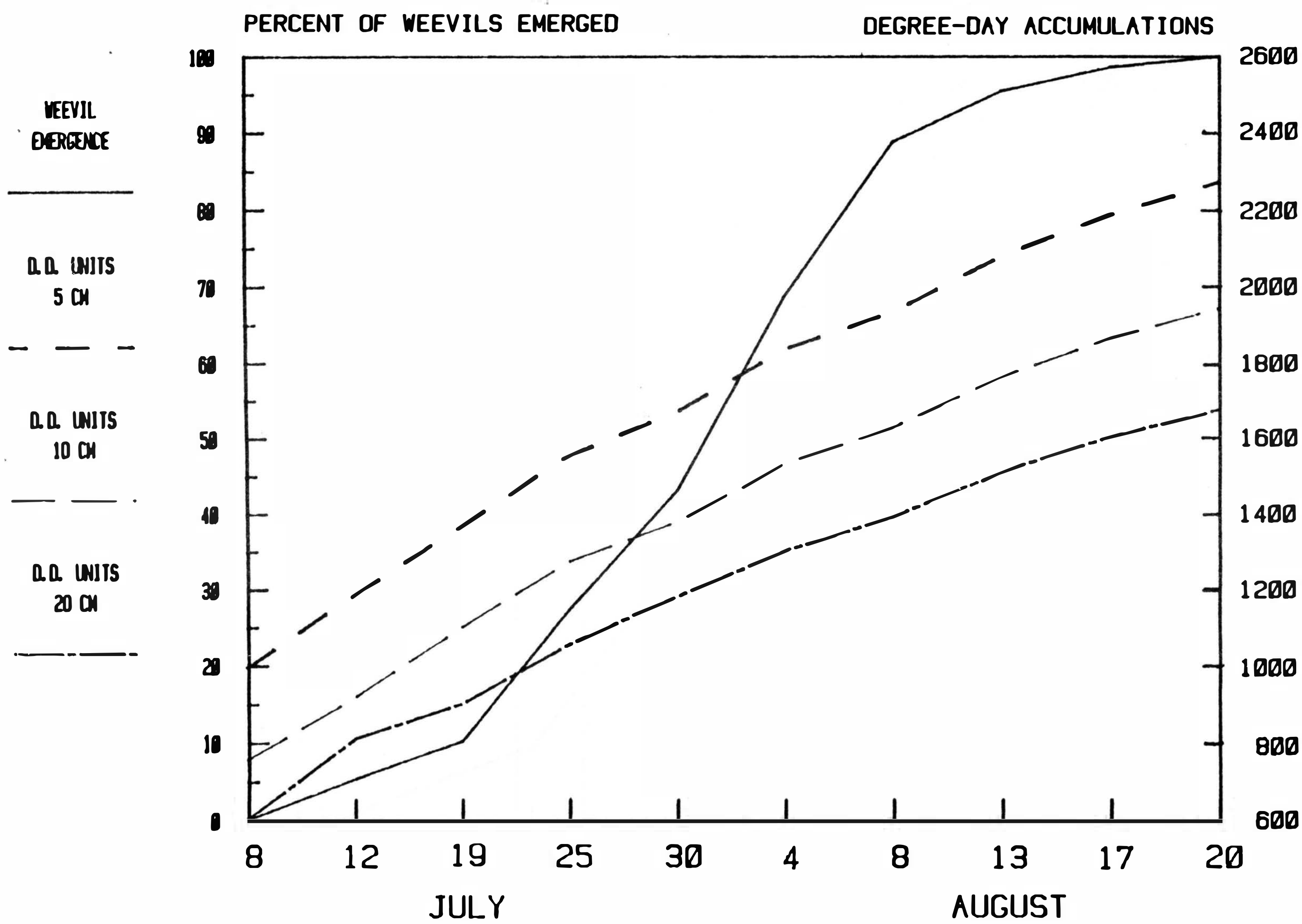

Figure 5. Influence of degree-day units accumulated at three depths, on adult seed weevil emergence, Redfield 1980-81.

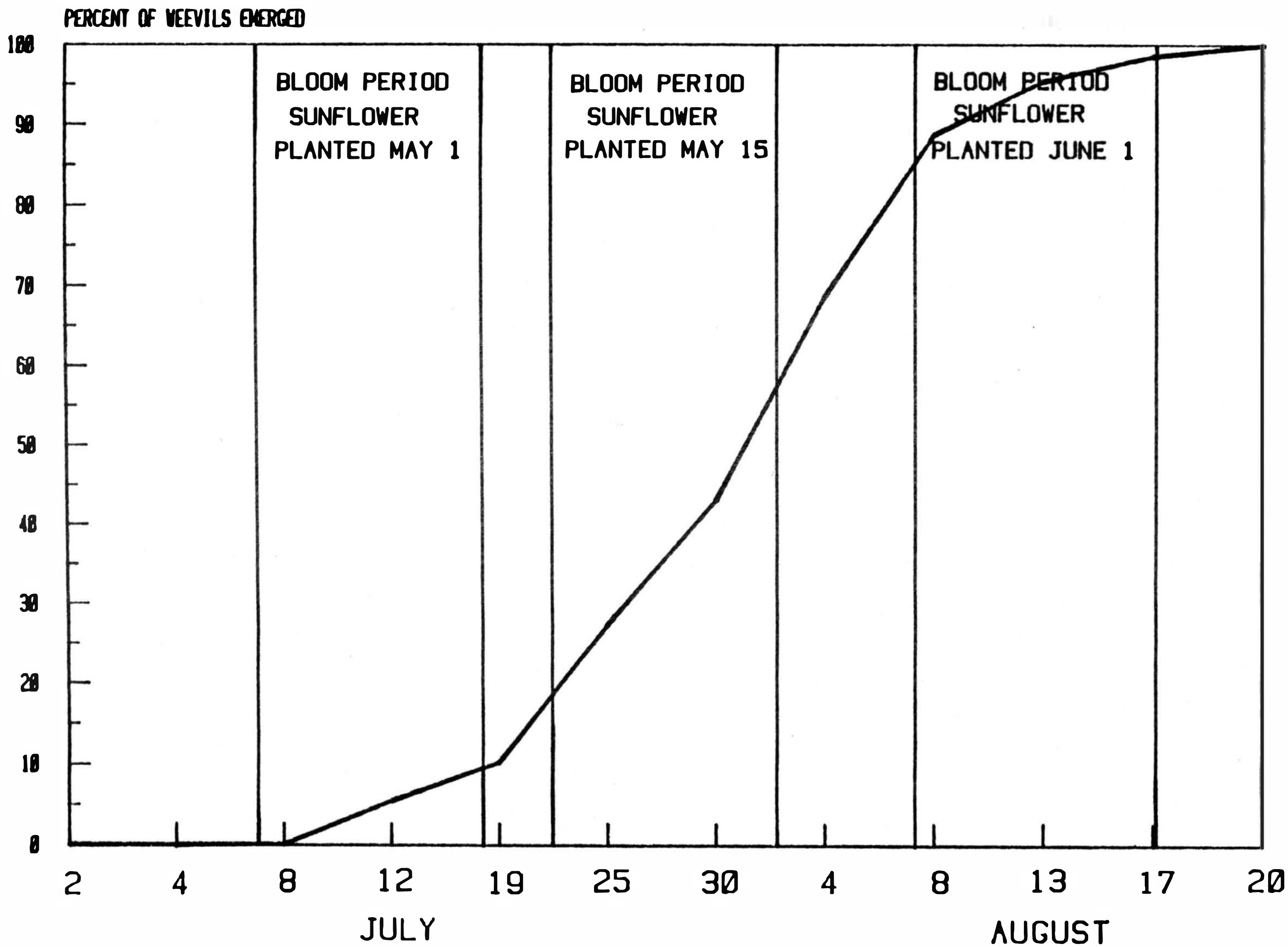

Figure 6. Percent of adult seed weevils emerged from the soil in comparison to bloom periods for sunflower planted at three dates, Redfield 1980-81.

METHODS AND MATERIALS

1981-82 Field Study

A. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil.

A 0.5 hectare plot was selected near White, South Dakota. The plot area was previously in sunflowers that had seed weevil infestations of 50 weevils per head, based on survey counts at 80 percent bloom. The plot selection was based on uniformity of the sunflower plant stand, and on seed weevil infestation levels. The seed weevil larvae tunneled from the seed and dropped to the soil in mid-September, and the field was harvested on October 22. Sunflower rows were flagged for future trap placement.

Fall tillage treatments were done on November 6, 1981. The tillage treatments included discing, chisel plowing, moldboard plowing, and an untilled control in a randomized complete block design with three replications. Treatments consisted of one pass with a 4.9 m tandem disc having 45.7 diameter blades that penetrated to a depth of 18 cm; one pass with a 3 m wide chisel plow with 10 shanks spaced 30.5 cm apart with penetration to a depth of 20 cm; and one pass with a 5 bottom moldboard plow with 35.6 cm high speed shares turning soil to a depth of 20 cm. Treatments were 18.3 m in length, and approximately 5 m wide perpendicular to previous sunflower rows.

Spring tillage treatments were conducted on April 26, 1982 in the same manner as fall treatments. Rain through much of the month of May delayed planting of crops in the plot until May 27. At that time a light discing to a depth of 10 cm was applied across treatments in preparation for wheat and corn planting. Wheat was seeded with a 2.4 m John Deere grain drill with 15.2 spacings at 2 bu per hectare to one-half of the plot. Corn was planted at 44,460 plants per hectare in 91.4 cm rows to the other half.

Eight emergence traps were placed in each subplot on June 21. Subplots were 9.14 x 5 m areas which contained one tillage treatment overlaid by one crop. Traps were placed in previously marked rows relating to the position of the drooping sunflower heads of the preceding sunflower crop as described by Oseto and Charlet (1981). Location of larvae was confirmed through soil sampling.

Traps were constructed from 18.9 liter polyethylene pails with 10 cm of the basal portion removed, leaving the traps 27.7 cm in height. Traps were 28.6 cm in diameter at the top and 27.7 cm in diameter at the bottom. Traps were forced into the soil approximately 10 cm and covered with a 10 x 10.5 cm mesh Lumite® Saran screen, secured to the trap with a rubber band. Each trap covered 602 sq. cm of soil surface.

Traps were checked twice weekly, and the number of weevils were recorded. Counts began at the appearance of the first weevils on July 12, and continued until emergence stopped August 23.

Adult weevil numbers were fitted to a logistic curve over dates of emergence. An analysis of variance was conducted on the total number of weevils trapped per plot, comparing effects of tillage and crops. A Waller-Duncan K-ratio T test was used to make comparisons of mean weevil emergence counts between tillage methods and between crops.

B. Effects of Tillage on Larval Distribution in the Soil

To ascertain the effect of different tillage operations on the depth of larvae in the soil, the following study was conducted: On April 27, 1982 soil cores were taken in the fall tillage treatments with soil temperatures at 4°C. On April 29 soil cores were taken in spring tillage treatments with soil temperatures at 6°C. A 11.2 cm diameter hydraulic soil probe mounted on a truck was used to remove soil cores. Cores were taken to a depth of 22.5 cm and divided into upper, middle, and lower 7.5 cm sections. Fifteen cores were taken per plot in both fall and spring tillage treatments. The number of larvae collected per section of the core was recorded and subsequently used to determine the depth to which tillage operations moved the larvae. Seed weevil larvae were extracted from the soil cores using the procedure described by Heilman, Gednalske, and Walgenbach (1983). The effect of tillage treatment on depth of larvae was analyzed with a Chi-Square analysis. Treatments were compared by calculating the percentage of larvae found in each of the three layers of the soil profile.

C. Timing of Seed Weevil Emergence Study

In this study the relationships were examined between tillage treatments, cropping patterns, soil temperature, sunflower anthesis, and time of weevil emergence. Comparisons were made between tillage treatments for their effect on time of seed weevil emergence and similar comparisons were made between the two crops.

Degree-day units were calculated on soil temperatures and compared to weevil emergence periods. Degree-day units were accumulated when the mean soil temperature for the day was greater than 50°F (10°C) and a unit was added for each degree over 50°F. Calculations were made for soil temperatures at 5, 10, and 20 cm depths. Degree-day comparisons to weevil emergence were made from data from the White tillage study described in section A, and for an emergence study at Redfield in 1982. Soil temperatures were taken under bare soil conditions at Redfield and at Brookings which were used for comparisons with the White data.

The study at Redfield in 1982 had insufficient weevil emergence to make comparisons for tillage or crop effects. The plot at Redfield was an irrigated sunflower field in 1981 which had an average of 5-7 weevils per head at 80 percent bloom. This plot was selected on the basis of uniformity of plant stand as drought problems in 1981 caused poor stands in the area.

On April 27, 1982 tillage treatments including discing, chiseling, moldboard plowing, and an untilled check were established in a completely random design replicated three times. A light discing was applied over one-half the tillage treatments, and was planted to wheat on April 29. The remaining half of the plot was planted to sunflowers on May 14.

Emergence traps of the same design as those in the White study were placed in the Redfield plot in a similar manner on June 28.

A time of weevil emergence curve was developed for the 647 weevils which were caught in the 192 traps. Weevil emergence patterns were compared to bloom periods for different planting dates at Redfield and Watertown.

D. Date of Planting Influence on Seed Weevil Infestations

This study was initiated on the basis of data from the 1981 time of weevil emergence study. A 1 hectare plot located near Watertown, and another near Redfield, SD were used as study sites. Both plots were in wheat in 1981 and two sunflower hybrids were planted on three dates with 2 week intervals. The hybrids Sigco 432 (an early maturing hybrid requiring 62 days from planting to bloom) and Sigco 894 (a full season hybrid requiring 68 days from planting to bloom) were planted in four row plots 100 ft. long, and replicated 6 times.

At the Watertown site tillage for seed bed preparation and incorporation of trifluralin at 1.74 liters per hectare was conducted on April 28, 1982. The first date of planting was planted at 49,400 plants per hectare on April 28 in 91.4 cm rows with a John Deere Flexplanter. The other dates of planting were accomplished on May 15 and June 1 with a similar protocol.

At Redfield preparation and planting was done in a similar manner with planting dates on May 1, May 15, and June 1.

In late August, 5 heads were randomly bagged in each replication for all planting dates at both locations to protect heads from bird damage. This was necessary at the Redfield location because birds destroyed the bulk of the plot. Bird damage was minimal at the Watertown location.

The Watertown plot was harvested on October 5 and yield data was taken at this location. Samples were taken from the combine harvested seed lots in each replication and planting date. Five head samples from each replication and planting date were taken prior to combining. Seed samples from the combine and the bagged head samples were analyzed for percent of seed infested by seed weevils. Four 100 seed subsamples were removed from each seed sample. These 100 seed subsamples were then hand inspected for seed weevil damage. A percentage of infested seed was then calculated for each subsample. The data was tested with analysis of variance and a Waller-Duncan K-ratio T test was used to compare treatment means.

At Redfield, because of the bird damage, only the bagged heads were used to assess weevil damage. These seeds were hand harvested on October 7. Seeds were removed from the heads with a hand sheller. The percent of infested seed was determined in the same manner as the seed from the Watertown location, and a similar analysis was conducted.

RESULTS AND DISCUSSION

1981-82 Field Study

A. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil.

Adult weevil emergence numbers during 1982 indicated that the type of tillage following sunflower production had an affect on the number of weevils emerging the following year. The fall moldboard plow treatments caused a significant reduction in the number of weevils emerging from the soil compared to untilled plots, reducing emergence by 56.1 percent. Chisel plow treatments also gave a significant reduction of 21.2 percent, whereas the disc treatment was not different from the untilled (Table 4).

Table 4. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil (Fall Treatments 1981-82).

Fall Treatments	Mean No. Weevils/Plot*	Percent Reduction Compared to Untilled
Untilled	462 a	-
Disc	484 a	0
Chisel	369 b	21.2
Moldboard Plow	203 c	56.1

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

The spring tillage treatments also indicate a similar trend with the moldboard plow reducing emergence by 29.1 percent compared to the untilled, however, there was not a significant reduction at the .05 level (Table 5). The spring chisel plow and the disc treatments reduced adult weevil emergence 38.8 and 22.4 percent respectively compared to the untilled. The chisel plow, discing, and untilled means were also not significantly different (Table 5).

Table 5. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil (Spring Treatments 1981-82).

Spring Treatments	Mean No. Weevils/Plot*	Percent Reduction Compared to Untilled
Untilled	299 a	-
Disc	232 a	22.4
Moldboard Plow	217 a	29.1
Chisel	186 a	38.8

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

The type of the crop following sunflower did not have a major effect on weevil emergence. Neither the wheat or the corn crop had a significant impact on the number of weevils emerging from the soil when compared to each other (Table 6).

Table 6. Tillage and Crop Rotation Influence on Adult Seed Weevil Emergence from the Soil (Crop Treatments 1981-82).

Treatments	Mean No. Weevils/Plot*
Wheat	284.5 a
Corn	326.2 a

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

B. Effects of Tillage on Larvae Distribution in the Soil.

The type of tillage used following sunflower had a significant effect [P ($x^2 \geq 398$) = .01] on the location of larvae in the soil in both spring and fall treatments in 1982.

In the untilled treatments 90 percent of the seed weevil larvae collected were at the 0-7.5 cm depth in both fall and spring tilled plots. The location of the larvae was nearly identical in the fall and spring tilled plots indicating no detectable vertical movement of the larvae as was the behavior pattern reported by Oseto and Braness (1979a).

The moldboard plow treatment placed over 50 percent of the larvae deeper than 7.5 cm into the soil profile (Figures 7 and 8). Less than 20 percent of the larvae were found deeper than 15.1 cm. This is in contrast to the 1980-81 results. The difference is probably due to variation in plow shares. The plow used in 1980-81 had a rollover share while the plow used in 1981-82 was a high speed share which did not turn the soil over as well. This change in depth did not change the number of emerged adults.

The chisel plow moved over 20 percent of the larvae deeper than 7.6 cm into the soil (Figures 7 and 8). The discing treatment showed virtually no vertical movement of the larvae. Both chiseling and discing treatments gave very similar results to the 1980-81 study as far as larval placement in the soil.

C. Timing of Seed Weevil Emergence Study.

Weevil emergence at White in 1982 indicated that the type of tillage did not have a significant effect on the time of adult emergence

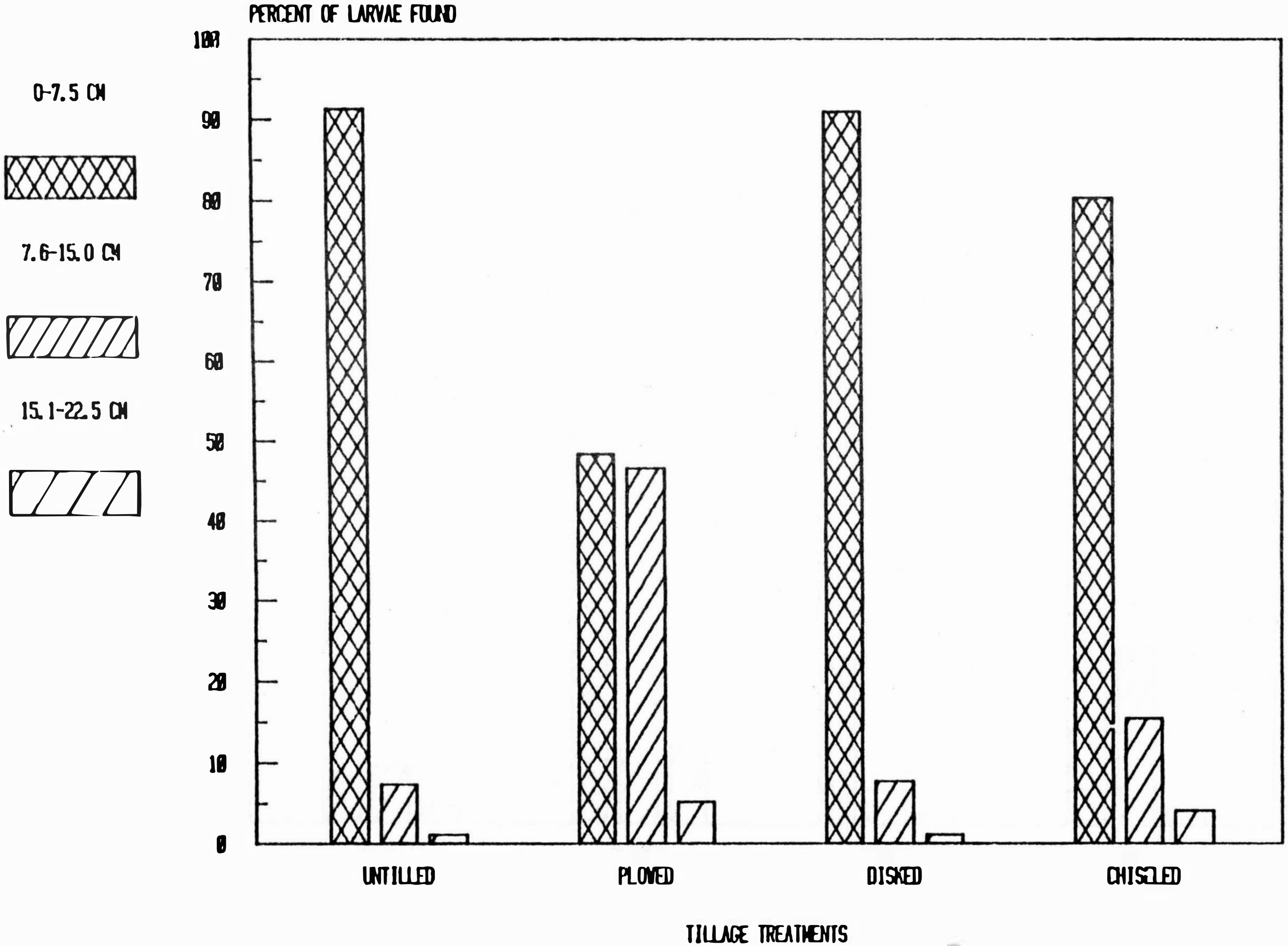

Figure 7. Influence of fall applied tillage treatments on the percent of larvae found at three levels of the soil profile, White 1981-82.

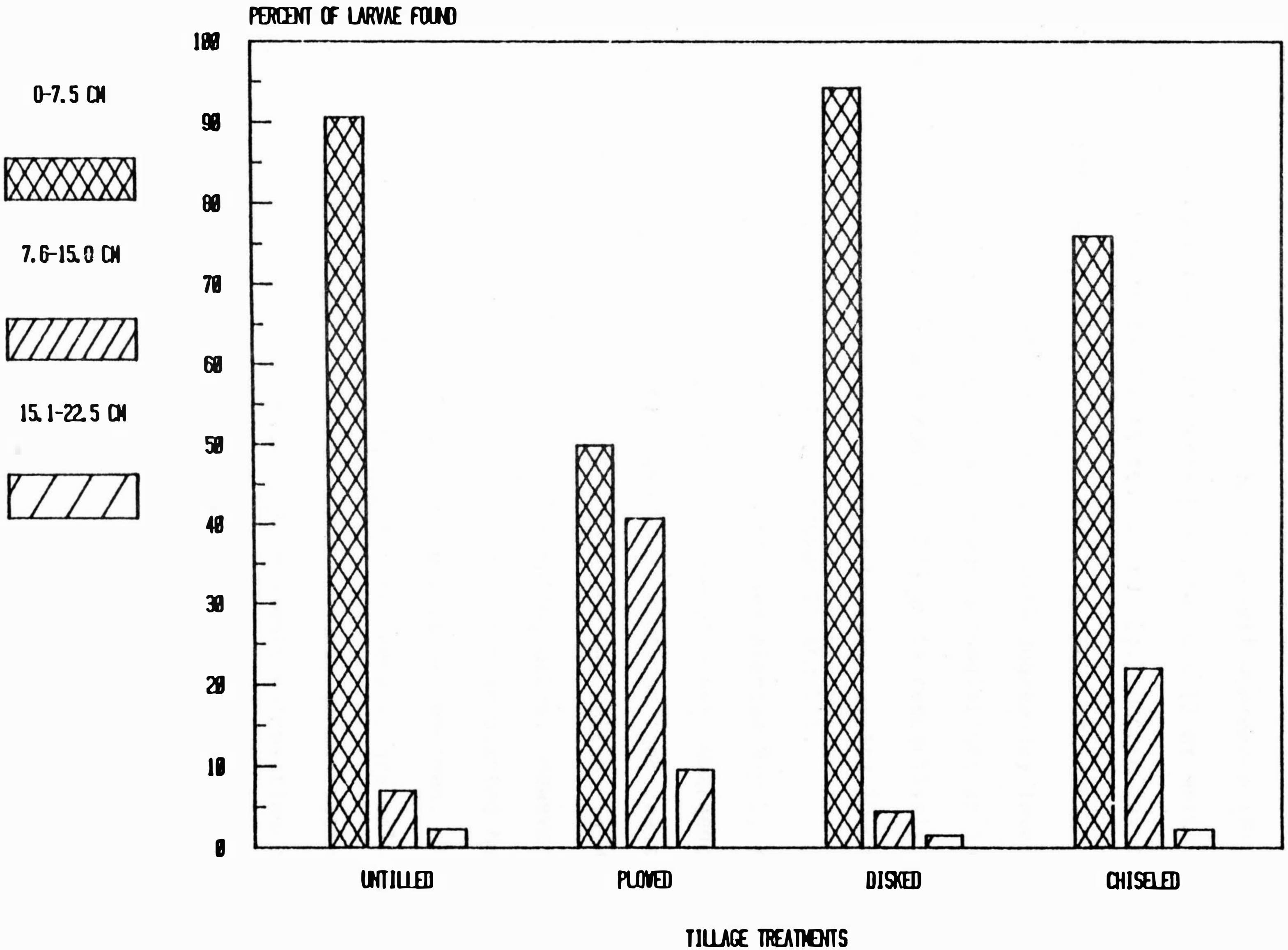

Figure 8. Influence of spring applied tillage treatments on the percent of larvae found at three levels of the soil profile, White 1981-82.

(Figure 9). Also the type of crop following a sunflower crop did not have a significant effect on the time of weevil emergence (Figure 10).

Adult seed weevil emergence began on July 12 at White and on July 10 at Redfield in 1982 (Figures 11 and 12). Degree-day totals at initial emergence at White were 662 units at the 5 cm level. Maximum weevil emergence occurred about August 2 with degree-day levels at 1066 at the 5 cm depth. At Redfield degree-day accumulations at initial and maximum weevil emergence were 805 and 1279 units respectively. Degree-day totals were approximately 150-200 units lower at the 20 cm depth on each study date at both locations (Figures 11 and 12).

The actual bloom period for sunflower planted May 1, May 15, and June 1 at Redfield, SD was compared to time of weevil emergence at White and Redfield in 1982 (Figures 13 and 14). Bloom periods are slightly later than those predicted in 1981. Cold and wet weather in May delayed sunflower growth for May 1 and May 15 planting dates. However, even with poor early season growing conditions sunflower planted May 1 bloomed before a substantial number of weevils had emerged. This is an important factor to sunflower producers since weevils are only attracted to heads actively shedding pollen (Oseto personal communication). The hardened achene following anthesis also prevents oviposition by Weevils (Oseto and Braness 1979a).

D. Date of Planting Influence on Seed Weevil Infestations.

Data from 1982 indicates that date of planting and hybrid maturity has a significant effect on the percent of seed infested by sunflower seed weevils (Tables 7 and 8).

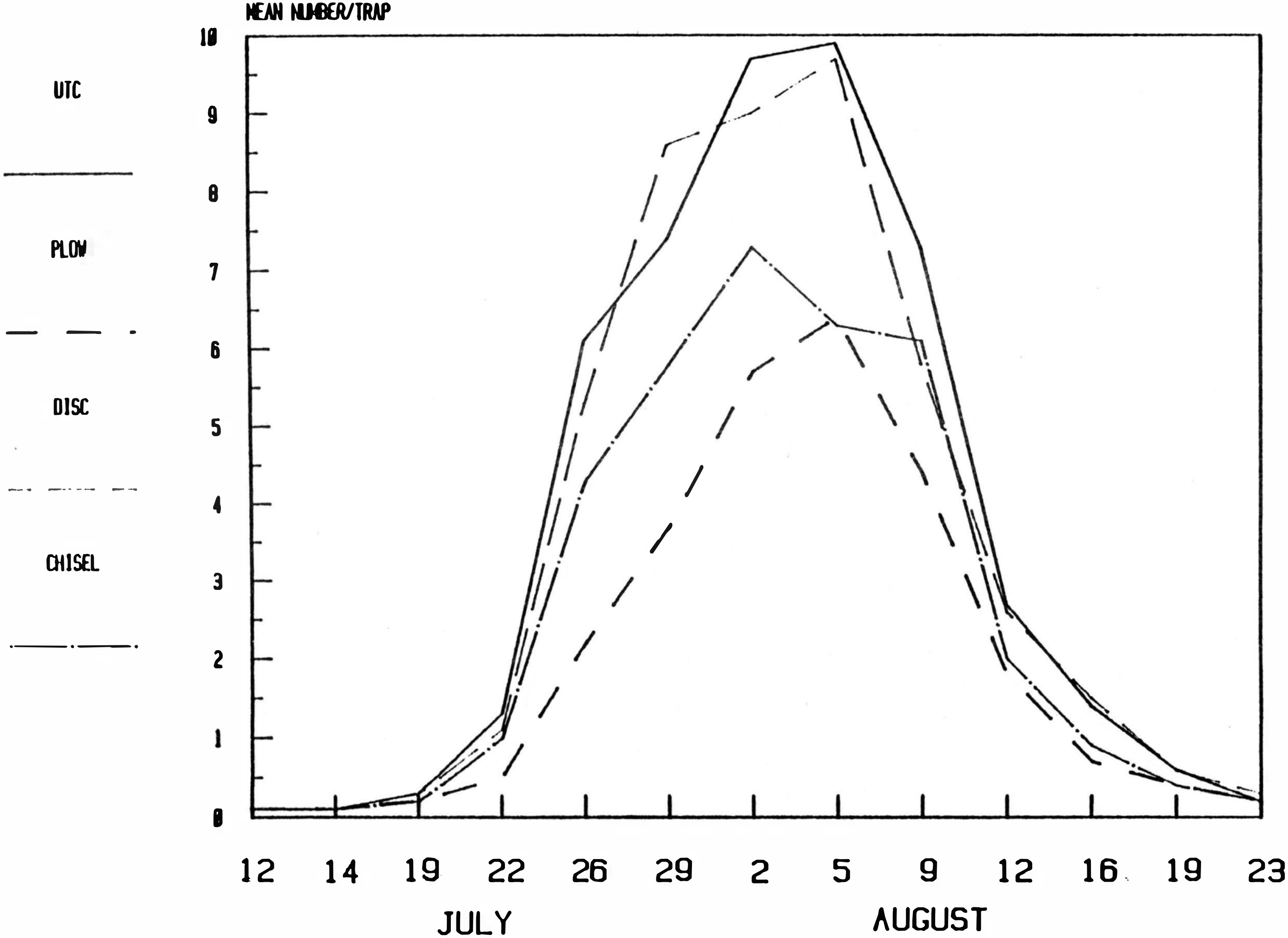

Figure 9. Time of adult weevil emergence as influenced by tillage treatments, White 1981-82.

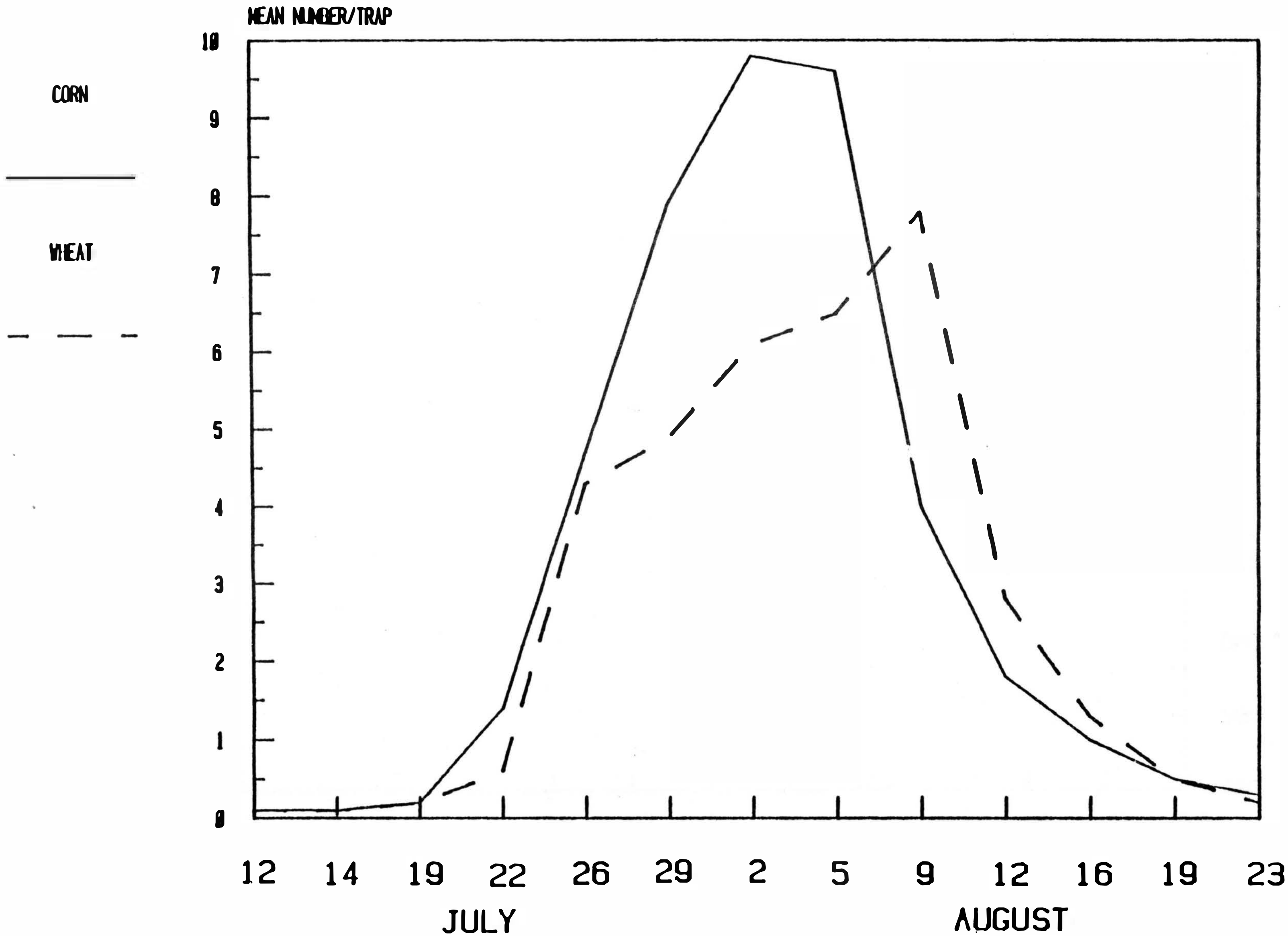

Figure 10. Time of adult weevil emergence as influenced by crop, White 1981-82.

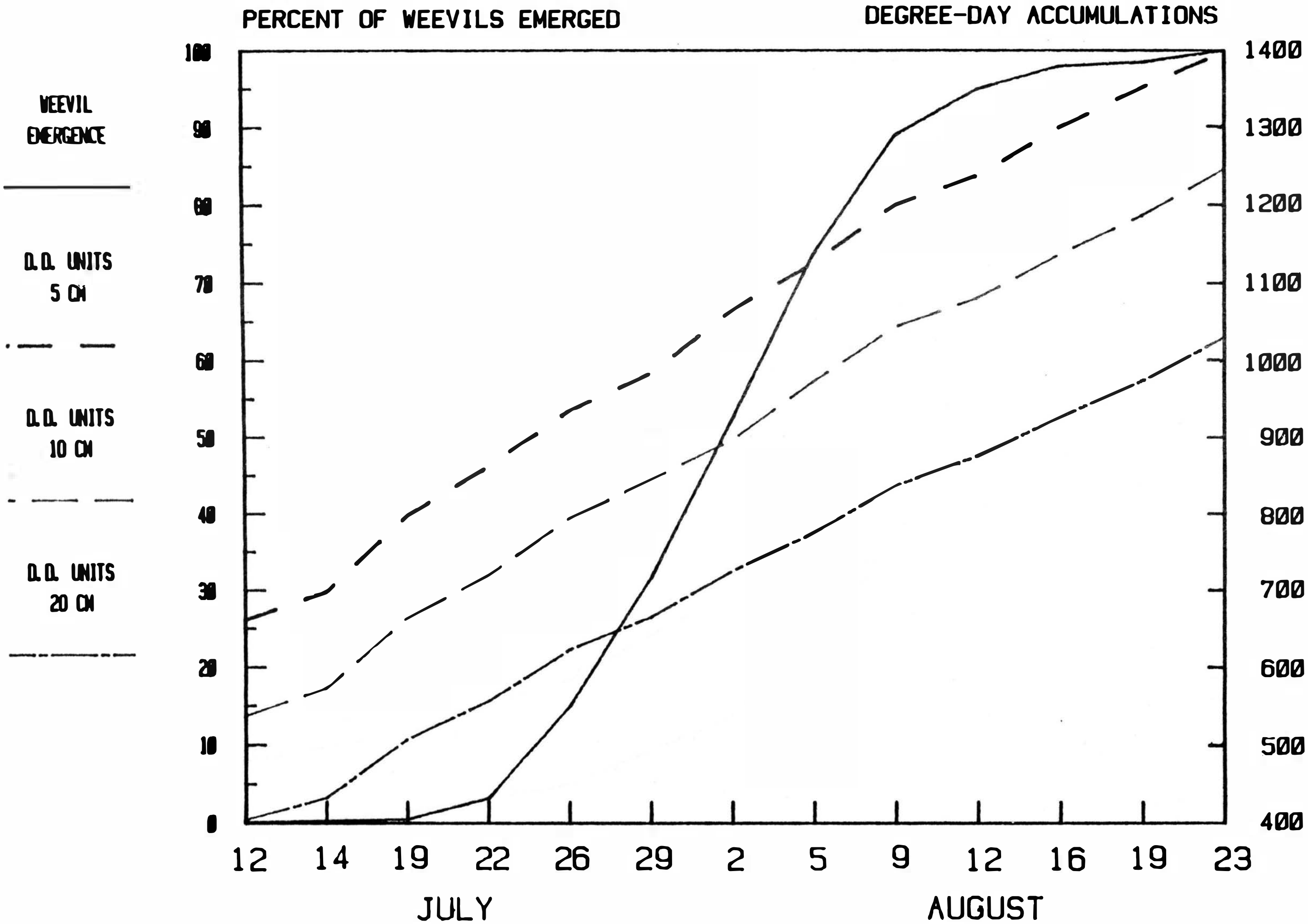

Figure 11. Influence of degree-day units accumulated at three depths, on adult seed weevil emergence, White 1981-82.

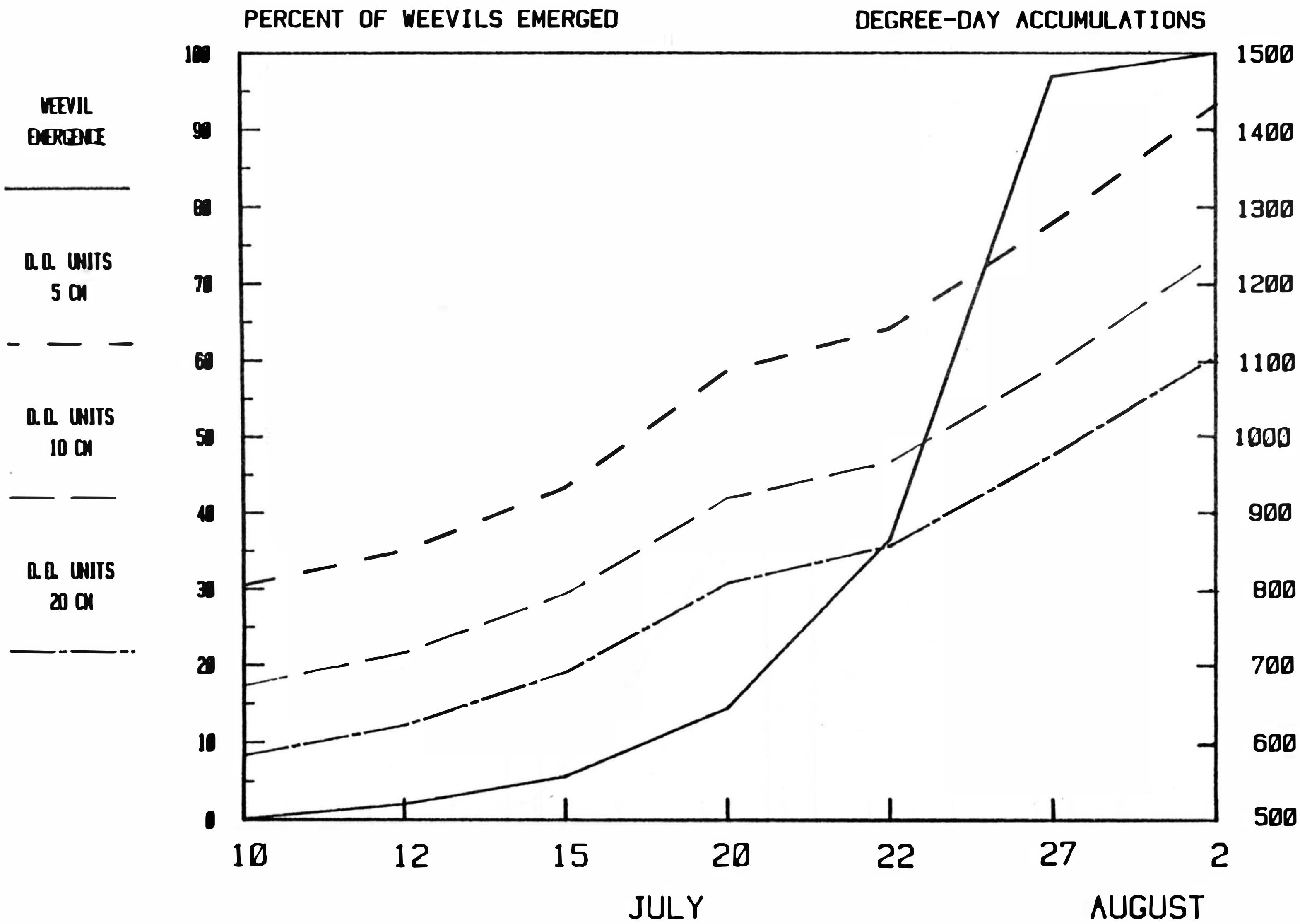

Figure 12. Influence of degree-day units accumulated at three depths, on adult seed emergence, Redfield 1981-82.

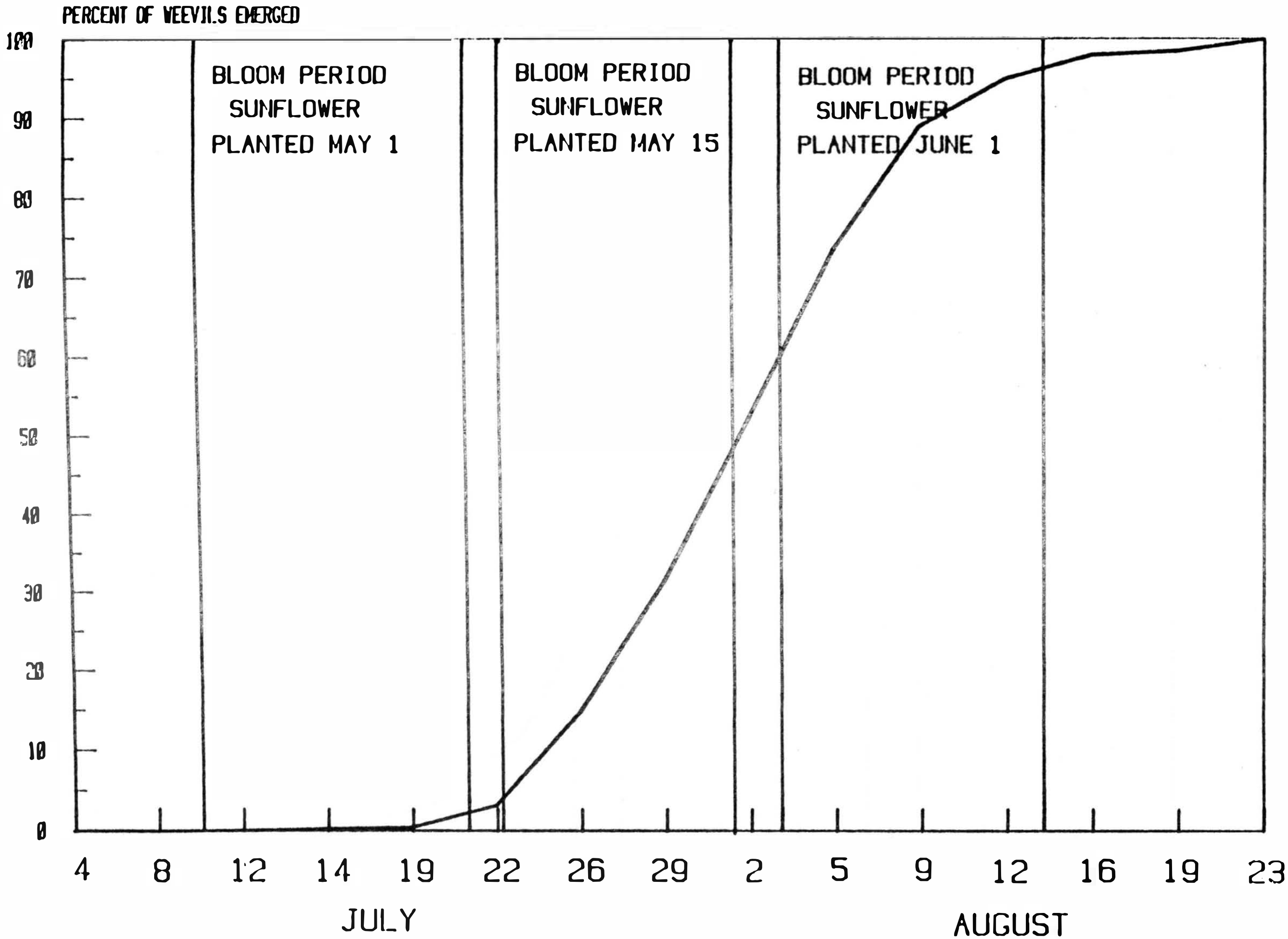

Figure 13. Percent of adult seed weevils emerged from the soil in comparison to bloom periods for sunflower planted at three dates, White 1981-82.

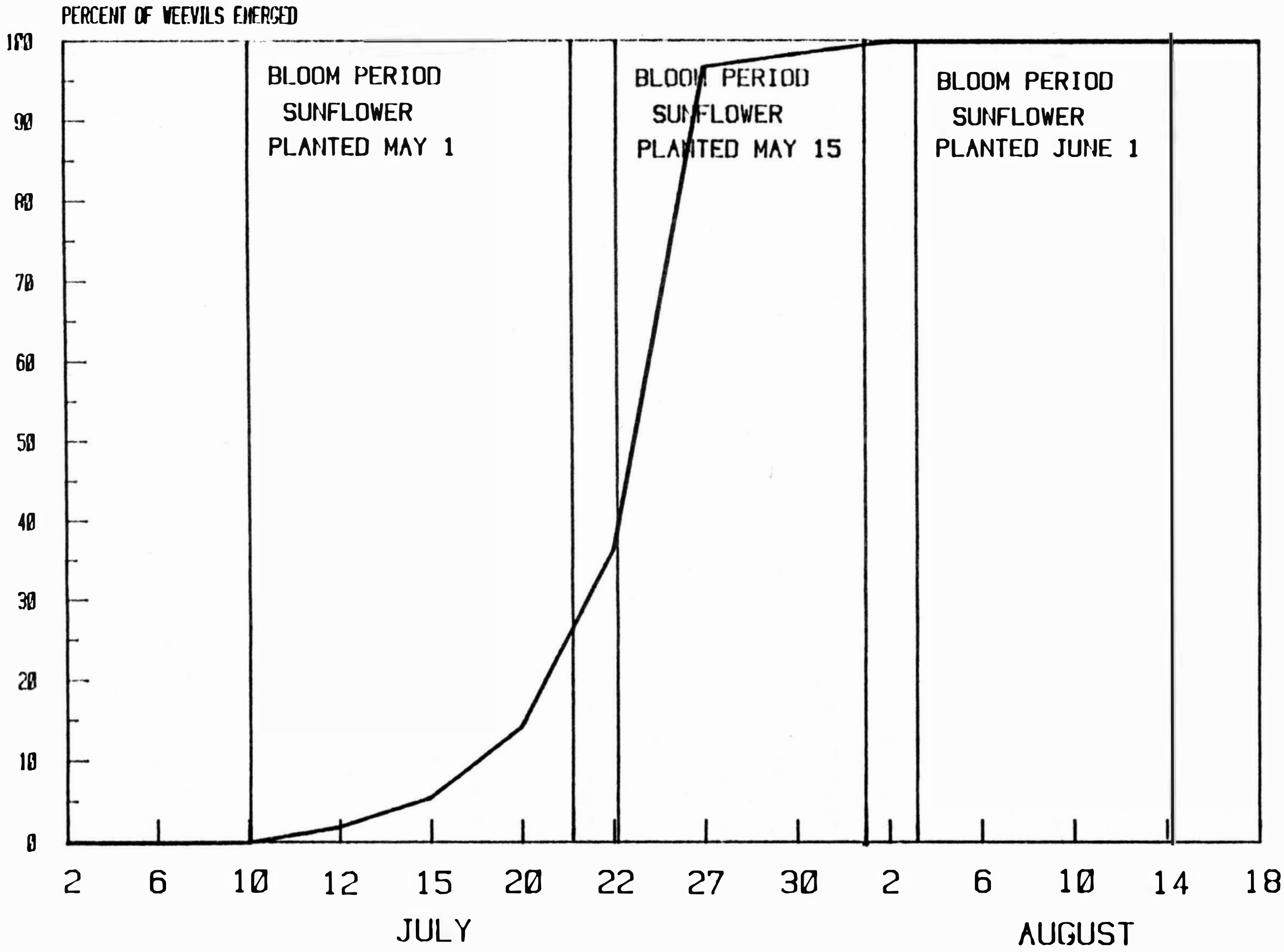

Figure 14. Percent of adult seed weevil emerged from the soil in comparison to bloom periods for sunflower planted on three dates, Redfield 1981-82.

At Watertown seed from the combine harvested grain tank samples ranged from 37.4 percent infested for the full season hybrid (Sigco 894) planted June 1 to 0.7 percent of the seed infested in the early maturing hybrid (Sigco 432) planted April 28 (Table 7). The results from the hand harvested heads showed very similar trends to the combine samples, however, percent of infested seed was higher (Table 7).

The difference in percent infested seed between the combine harvested samples and hand harvested are probably caused by a portion of the infested seed being passed through the combine because of lighter weight associated with weevil damage. While these seeds are blown out of the combine with the chaff, they remained in the hand harvested samples.

Table 7. Date of Planting Influence on Seed Weevil Infestations (Watertown 1982).

Treatments		Mean Percent of Seed Infested*	
Hybrid	Date Planted	Combine Samples	Head Samples
Sigco 432	April 28	.7 e	3.4 d
	May 15	13.8 c	19.8 c
	June 1	18.0 b	28.6 b
Sigco 894	April 28	5.0 d	7.5 d
	May 15	16.9 bc	21.3 bc
	June 1	37.4 a	38.9 a

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

Yield data showed no real advantage nor disadvantage for early planting. Variety and weather conditions for the May 15 planting seemed to have the greatest impact on yield (Table 8).

Table 8. Date of Planting Influence on Seed Weevil Infestations on Yield (Watertown 1982).

Treatments Hybrid	Date Planted	Mean kg/block*	Kg/ha
Sigco 432	April 28	7.8 a	1393.8
	May 15	6.2 c	1103.7
	June 1	6.6 bc	1173.7
Sigco 894	April 28	6.7 abc	1204.9
	May 15	6.3	1131.5
	June 1	7.7 abc	1382.7

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

Results from the data of planting at Redfield were similar to those at Watertown. Percent of infested seed ranged from 1.3 for sunflower planted May 1 to 56.1 for those planted June 1 (Table 9). The first two planting dates showed that the early maturing hybrid (Sigco 432) had significantly fewer seeds infested than the late maturing hybrid (Sigco 894).

Table 9. Date of Planting Influence on Seed Weevil Infestations (Redfield 1982).

Treatments Hybrid	Date Planted	Mean Percent of Seed Infested*
Sigco 432	May 1	1.3 d
	May 15	14.1 c
	June 1	56.1 a
Sigco 894	May 1	8.9 c
	May 15	48.5 b
	June 1	52.2 a

*Means with the same letter are not significantly different at the .05 level by Waller-Duncan K-Ratio T test.

This data indicates that date of planting can be a viable means of reducing seed weevil infestations.

CONCLUSIONS

The use of tillage implements to reduce insect populations is a common management practice for many crop insect pests. Data from this two year study indicates that the moldboard plow used in the fall or spring, or the chisel plow used in the spring are management tools capable of reducing seed weevil populations.

Reductions in sunflower seed weevil emergence due to moldboard plowing may be explained by the large portions of weevil larvae being buried to depths below 7.6 cm. This would make adult emergence difficult.

Spring chisel plowing did not move larvae significantly deeper into the soil, but gave similar reductions in adult weevil emergence. In this case I speculate that changes in soil moisture or porosity are responsible for the increased mortality. The causes of mortality resulting from these two tillage treatments are areas which deserve greater research.

The time of seed weevil emergence can be important to sunflower producers. Adult weevil emergence the past 2 years began in the second week of July and 50 percent of the weevil population had not emerged until the end of July. If this trend continues, it seems clear that early planted sunflowers will bloom before the majority of the weevils have emerged. These early planted sunflowers would escape major seed weevil infestations.

Soil temperatures and degree-day accumulations have a relationship with emergence of many insect species. If a correlation can be reached between degree-day units and initial or maximum seed weevil emergence, it could be a useful tool in a pest monitoring program. This is an area in which several more years research are needed to make such a correlation.

The adjustment of planting date as a means of insect control is a common practice. One years' data showed a clear trend that planting date and hybrid maturity can have a dramatic influence on seed weevil infestation levels. However, before this should become a recommended practice, factors of yield potential and the impact of other pests must be determined.

APPENDIX

Analysis of Tillage Treatment Effects on Adult Weevil Emergence, 1981.

Source	dF	SS	F
Trt.	4	3525.60	10.33
Rep.	2	98.40	0.58
Trt. * Rep.	8	964.00	0.32
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	4	3525.60	7.31

Analysis of Crop Influence on Adult Weevil Emergence, 1981.

Source	dF	SS	F
Crop	2	389.62	2.28
Rep.	2	98.40	0.58
Crop * Rep.	4	164.64	0.48
Test of H = Crop, E = Crop * Rep.			
Source	dF	SS	F
Crop	2	389.62	4.73

Chi-Square Analysis for Tillage Treatment Effects on Larvae Depth, 1981.

Source	dF	Chi-Square
Trt.	4	70.29**
Rep.	2	1.80
Trt. * Rep.	8	16.98*
Time	1	1.36
Trt. * Time	4	4.43
Rep. * Time	1	3.19
Trt. * Rep. * Time	4	5.54

**Significant at .01 level.
*Significant at .05 level.

Analysis of Influence of Tillage Treatments on Time of Adult Weevil Emergence, 1981.

Source	dF	SS	F
Trt.	4	4.82	0.25
Rep.	2	0.42	0.04
Trt. * Rep.	8	22.01	0.58
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	4	4.82	0.44

Analysis of Influence of Crops on Time of Adult Weevil Emergence, 1981.

Source	dF	SS	F
Crop	2	18.29	1.91
Rep.	2	0.42	0.04
Crop * Rep.	4	14.29	0.75
Test of H = Crop, E = Crop * Rep.			
Source	dF	SS	F
Crop	2	18.29	2.56

Analysis of Tillage Treatment Effects on Adult Weevil Emergence, 1982.

Source	dF	SS	F
Trt.	3	209861.50	21.71
Rep.	2	212970.04	33.05
Trt. * Rep.	6	48944.66	2.53
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	3	209861.50	8.58

Analysis of Crop Influence on Adult Weevil Emergence, 1982.

Source	dF	SS	F
Crop	1	20916.75	6.49
Rep.	2	212970.04	33.05
Crop * Rep.	2	51304.88	2.53
Test of H = Crop, E = Crop * Rep.			
Source	dF	SS	F
Crop	1	20916.75	.82

Chi-Square Analysis for Tillage Treatment Effects on Larvae Depth, 1982.

Source	dF	Chi-Square
Trt.	3	398.40**
Rep.	2	.52
Trt. * Rep.	6	38.62**
Time	1	.30
Trt. * Time	3	2.46
Rep. * Time	2	10.51**
Trt. * Rep. * Time	6	17.45**

**Significant at .01 level.

Analysis of Influence of Tillage Treatments on Time of Adult Weevil Emergence, 1982.

Source	dF	SS	F
Trt.	3	0.06	0.24
Rep.	2	0.03	0.17
Trt. * Rep.	6	0.59	1.19
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	3	0.06	0.21

Analysis of Influence of Crops on Time of Adult Weevil Emergence, 1982.

Source	dF	SS	F
Crop	1	3.38	40.77
Rep.	2	0.03	0.17
Crop * Rep.	2	0.17	4.27
Test of H = Crop, E = Crop * Rep.			
Source	dF	SS	F
Crop	1	3.38	9.55

Analysis of Date of Planting Influence on Seed Weevil Infestations (Watertown, Combine Samples) 1982.

Source	dF	MS	F
Trt.	5	986.49	104.3
Error	25	9.45	

Analysis of Date of Planting Influence on Seed Weevil Infestations (Watertown, Head Samples) 1982.

Source	dF	MS	F
Trt.	5	1046.58	19.53
Error	25	53.60	

Analysis of Date of Planting Influence on Seed Weevil Infestations (Watertown, Seed Yield) 1982.

Source	dF	MS	F
Trt.	5	14.6	3.52
Error	25	4.15	

Analysis of Date of Planting Influence on Seed Weevil Infestations (Redfield Head Samples) 1982.

Source	dF	MS	F
Trt.	5	2786.34	71.81
Error	25	52.73	

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