TOLERANCE OF TWELVE COTTON CULTIVARS
TO THE COTTON BOLLWORM
(HELIOTHIS ZEA BODDIE)

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I dedicate this work to my wife, Sarah, whose sacrifices have made it a reality, and to Jon and Katie, who have added the spice.

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CHAPTER I

INTRODUCTION

The role of host-plant resistance is becoming increasingly important as the concept of integrated pest management develops from theory into practice. Plant breeders and entomologists working with many crops have made great strides in the identification, selection, and transfer of plant characteristics which lessen or prevent insect damage to the host plant.

Although interest in breeding for insect resistance in cotton has been expressed in the U. S. since the early 1900's when the boll weevil (*Anthonomus grandis* Boh.) threatened the American cotton industry, host-plant resistance has had its greatest impact in the last 15-20 years (Niles, 1975). Frego-bract, high-gossypol, nectariless, glabrous, high pubescence, okra- (and super-okra) leaved, red plant color, and early maturity have been used singly and in combination with one another to suppress most important cotton pests.

Resistance characteristics in cotton have been generally chosen in breeding programs because of their ability to suppress lepidopterous insects. The most important of these include the cotton bollworm, *Heliothis zea* Boddie; the tobacco budworm, *Heliothis virescens* Fabricius; and the pink bollworm, *Pectinophora gossypiella* Saunders. Although the pink bollworm is not common in Oklahoma, the *Heliothis* complex (i.e., the bollworm and budworm) represents the greatest danger to cotton production in Oklahoma today.

As costs spiral and government regulations continue to restrict insecticide usage, cotton producers and researchers will expand even further their search for alternate means of control. This is especially true with cotton because nearly half of all insecticides used on agricultural crops in the United States are applied to that crop (Eichers et al., 1970). Insect-resistant cultivars have proven to be effective in other crops and have shown great potential in cotton. Each heritable resistance mechanism of the cotton plant must be investigated to permit its intelligent use in developing future cottons.

This study, therefore, was designed to measure the relative levels of tolerance among twelve typical cotton cultivars to feeding damage caused by the bollworm. Additionally, efforts were made to establish artificial infestation rates necessary to provide economic damage to cotton in southwestern Oklahoma. Further efforts were made to develop an efficient bioassay technique to distinguish tolerance from antibiosis.

CHAPTER II

LITERATURE REVIEW

The bollworm complex was not considered a major cotton pest in Oklahoma until about 1950. Since then, it has rapidly become the most destructive cotton pest in Oklahoma as well as across the entire Cotton Belt (Roussel, 1976). In a study conducted in Mississippi, the tobacco budworm was shown to consume an average of 10 squares, 1.2 blooms, and 2.1 bolls per larva (Kincade et al., 1967). Its elevation from a secondary pest status was due, in part, to the chemical devastation of its parasites and predators and to its own ability to adapt to a succession of new pesticides. Not only has the bollworm exhibited resistance to DDT, but also to carbaryl, strobane, toxaphene, endrin, and methyl parathion (Adkisson and Nemec, 1965; Brazzel, 1963, 1964; Lowry et al., 1965; Graves et al., 1964; Adkisson, 1968; Wolfenbarger, 1970).

Since intensive host-plant resistance work with cotton was begun within the last decade, research has largely been aimed at the development and evaluation of antibiotic and antixenotic (non-preference) mechanisms of resistance. Antibiosis, the combined antibiotic factors, is defined by Painter (1951) as the adverse effect(s) of the plant on the biology of the insect. Antixenosis is a term coined by Kogan and Ortman (1978) to supercede Painter's term, non-preference. Antixenosis literally means something that keeps a guest away. Painter's original definition (1941) of non-preference was "the group of plant characters and insect responses that lead away from the use of a particular plant or variety, for oviposition, for food, or for shelter, or for combinations of the three."

In cotton, antibiosis most often refers to the presence of certain pigments within the plant tissues. These pigments are usually associated with the glands present in the seed and above ground portions of the plant. Several pigments have been identified, but the major one is gossypol (8,8'-dicarboxyaldehyde-1,1',6,6',7,7'-hexahydroxy-5,5'-diisopropyl-3,3'-dimethyl-2,2'-binapthalene).

The toxicity of this phenolic yellow pigment when fed to chickens, mice, rats, rabbits, and other nonruminant animals has been well documented (Bailey, 1948; Eagle et al., 1948). Not only is gossypol toxic to nonruminant mammals, but it is also toxic to many insects, including the bollworm complex. Moreover, the removal of those glands makes cotton more susceptible to many insects (Bottger et al., 1964; Maxwell et al., 1965; Murray et al., 1965; Lukefahr et al., 1966).

Because of the value of normally glanded cotton cultivars in cotton pest management, much work has been directed toward the development and testing of even higher gossypol cotton cultivars. This concept is not new. Quaintance and Brues (1905) and Cook (1906) discussed the possibility of using the contents of pigment glands to breed lines resistant to cotton insects. Most cotton cultivars have a gossypol content of about 0.5% to 0.8%. A minimum gossypol content of 1.2% is required to significantly inhibit growth and development of bollworm larvae in the laboratory. A high-gossypol line was developed from crosses of commercial cottons with several wild strains by Lukefahr and Houghtaling (1969). In replicated cage testing, their high-gossypol lines provided a 60% reduction in larval populations after the second generation. Experiments designed to determine the optimum gossypol percentage in different sized cotton buds showed that the size of the bud had no effect on gossypol percentage in G. arboreum L., and only small differences were measured in G. hirsutum and G. barbadense (Shaver and Parrott, 1970). Wilson and Lee (1971) studied the relationship of gland number and bollworm damage to cotton seedlings. Their findings indicate that the seedlings with the most glands are attacked the least.

Various researchers have incorporated gossypol into artificial diets and reported their results. Only 30% of bollworm larvae survived to the pupal stage when fed on artificial diet containing 0.2% gossypol (Lukefahr and Martin, 1966). Shaver and Parrott (1970) demonstrated that the growth of older larvae of the bollworm and tobacco budworm was less affected than that of younger larvae by diets containing gossypol. Gossypol incorporated into an artificial diet was shown to be toxic to both bollworm and tobacco budworm larvae (Shaver and Lukefahr, 1969). Oliver et al. (1971) studied bollworm larvae fed on lyophilized squares of glanded and glandless cotton. Their smaller size on glanded cotton was a result of decreased food consumption plus a reduction in efficiency of food conversion. Although decreasing the potential of cottonseed for human consumption, the usage of high-gossypol cottons is becoming an increasingly important tool in host-plant resistance.

While gossypol is the predominant toxic pigment in cotton, other compounds have been isolated from cotton which are also toxic to the Heliothis complex. Pratt and Wender (1959) reported that quercitin and rutin, two flavonoid pigments in cotton, were also toxic to larvae of the bollworm and tobacco budworm. Chan et al. (1978) found that tannin extracted from an experimental stock (Texas 254) retarded Heliothis larval growth when added to artificial diet. In addition, four individual heliocides have been isolated from the sesquiterpenoid, hemigossypolone (Stipanovich et al., 1978). These have been termed, in order of discovery: heliocide 2, heliocide 3, heliocide 1, and heliocide 4. Gossyverdurin is another pigment isolated from cottonseed pigment glands (Lyman et al., 1963).

The antixenotic mechanisms of cotton manifest themselves in the nectariless and glabrous characters. The nectaries are glandlike organs found at the base of the flower and on the primary midribs of the abaxial leaf surface. The nectaries secrete a sweetish fluid which serves as a food source for many pests, such as the boll weevil and the bollworm complex. Nectariless cottons have no extrafloral nectaries, rendering those cottons less attractive to insects. Meyer and Meyer (1961) first described the inheritance of the nectariless trait in upland cotton after they had succeeded in transferring it from _Gossypium_ _tomentosum_ Nutt. to _G._ _hirsutum_ L. Since that time, much interest has been shown in the development of nectariless cottons. Lukefahr and Martin (1964) and Lukefahr et al. (1965) reported bollworm oviposition was reduced from 39% to 64% on nectariless cotton cultivars. A similar reduction of egg numbers on nectariless cottons in cage tests at Brownsville, Texas, was demonstrated by Davis et al. (1973).

Since nectariless cottons decrease amounts of food available to adult bollworms, fecundity and longevity of the adults have also been shown to be reduced. A 50% reduction in fecundity was attained in a replicated field-cage experiment where the movement of the adults could be controlled (Lukefahr and Rhyne, 1960). A 40% reduction in egg deposition and some reduction in longevity was achieved in nectariless cottons when opposed to a standard cultivar (Lukefahr et al., 1965). This factor is impossible to measure in small plots where the mobility of the moths is unrestricted, but it is believed that if the nectariless character were widely adapted into cultivars, its impact would be substantial.

Another antixenotic feature of cotton cultivars which aids in resistance to bollworm attack is the glabrous condition (or absence of foliar hairs or trichomes) on plant terminals or growing points. Ultrasmooth glabrous lines may have no more than 50 trichomes/square inch. A glabrous plant seems to be less preferred for oviposition than a pubescent or hirsute plant (Lukefahr et al., 1968). Glabrous leaves appear to provide an unsatisfactory surface for oviposition which results in fewer eggs deposited and, ultimately, in fewer larvae and fewer damaged fruit (Lukefahr and Rhyne, 1960; Lukefahr et al., 1971). Lukefahr (1965) reported that oviposition was effectively reduced by 60% on glabrous plants. In developing a technique for determining oviposition preferences of the bollworm and tobacco budworm among cultivars and experimental stocks of cotton, Stadelbacher and Scales (1973) also found hirsute cultivars to be preferred oviposition sites.

Although hirsute cultivars are preferred oviposition sites, pubescent (very hairy) cultivars may add an antibiotic factor of resistance. Movement of pink bollworm larvae was impeded, and they became disoriented on pubescent leaves, thus increasing the possibility of exhaustion and exposure to predators (Smith et al., 1975).

Most promising in the development of Heliothis-resistant cotton cultivars is the integration of various resistance features into a single cultivar. Lukefahr et al. (1965) found that oviposition by adult bollworms was reduced by 80% on cotton plants possessing both nectariless and glabrous characters. Further tests of four lines with a combination of high-gossypol and glabrous characteristics suppressed populations 60-88% (Lukefahr et al., 1975).

Largely because of the difficulty in assessing its value within a dynamic environment, little research has focused on the role of tolerance in cotton. Tolerance is defined by Painter (1951) as "a basis of resistance in which the plant shows an ability to grow and reproduce itself or to repair injury to a marked degree in spite of supporting a population approximately equal to that damaging a susceptible host." In other words, there is a ratio in relation to injury and, other things being equal, the larger, more vigorous plants can carry a heavier infestation without serious injury than the smaller ones (Felt and Bromley, 1931). To the producer, this means growing a cultivar which will tolerate a relatively high infestation of pests and still produce an acceptable yield.

While antibiosis and antixenosis are generally considered strictly insect-plant relationships, tolerance is also widely influenced by the environment. The role of the environment becomes more important when insects with chewing mouthparts so destroy a plant that tolerance is manifested solely by replacement or regrowth (Painter, 1951). Additionally, when tolerance is present in a cultivar with other resistance features, it may be obscured or masked under normal environmental conditions.

Early research by Parnell (1927) and Cameron (1928) showed that some cotton lines exhibited tolerance to leafhoppers (Empoasca spp). Cotton tolerance to the tarnished plant bug, Lygus lineolaris, (Palisot de Beauvois), has been documented by Meredith and Laster (1975). Schuster and Douglas (1976) reported that the incorporation of the okra-leaf characteristics into normal cotton lines causes a nearly twofold production of squares. Although only a normal number of bolls are set by these plants, the larger number of early squares results in a dilution of plant bug injury. The literature is, however, devoid of research which evaluates tolerance to attack by the *Heliothis* complex.

CHAPTER III

MATERIALS AND METHODS

This experiment was conducted during the 1979 and 1980 growing seasons at the Southwestern Agronomy Research Station near Tipton, Oklahoma, under irrigation. Twelve cotton cultivars with no known morphological *Heliothis*-resistant traits were selected. The cultivars were chosen from among four regional classes of cottons and were considered to be typical representatives of that class. 'GSA 71', 'Westburn M', 'Tamcot SP21', and 'Lockett 77' were considered representative of Plains cottons. 'Acala SJ-5' and 'Acala 1517-77' were chosen from among the Acala cottons of California and New Mexico. The Delta types chosen were 'Stoneville 213', 'Deltapine 16', 'DES 56', and 'Delcot 277'. 'Delcot 311' replaced 'Delcot 277' in the 1980 test. 'Hybee 200A' and 'Coker 5110' were chosen to represent the Southeast cottons. 'McNair 235' was substituted for 'Hybee 200A' in the 1980 test.

A split-plot design consisting of four 6 m. (1979) or 9.2 m. (1980) rows of each cultivar replicated four times was used. Main plots were represented by the 12 cotton cultivars. Plots were planted by hand-dropping seed at a rate of approximately 33.6 Kg./Ha. At the seedling stage, a 3 m. section of each row was selected for uniformity and hand-thinned to about 6.6 plants/m.

The second and fourth rows of each plot served as buffer rows. To create subplots a random choice was made between the first and third rows in each plot. One was artificially infested with lab-reared *H. zea* larvae (infested). The other received chemical treatments to prevent naturally occurring *Heliothis* infestations (uninfested). All chemical applications were made with a 3.8 liter hand sprayer. Additionally, during the 1979 season two applications of methyl parathion at the rate of 0.22 Kg. A.I./Ha. were applied to all plots to eliminate predators and predispose the cotton to artificial infestation. These applications were made on July 11 and July 18, 1979. The same treatment was made once on July 11 during the 1980 season.

Using camel hair brushes, first instar *H. zea* larvae were placed on plant terminals in infested rows twice during the 1979 season. The first artificial infestation was made July 24 at the rate of 6.6 larvae/row m. The second infestation was made August 21 at the rate of 16.4 larvae/row m. During the 1980 season, plants were artificially infested twice, on July 23 and July 30, at the rate of 13.2 larvae/row m. and 19.8 larvae/row m., respectively.

In 1979, three insecticide treatments with Pydrin® at the rate of 0.089 Kg. A.I./Ha. were made to the infested rows after the first artificial infestation date. During the 1980 season, the uninfested subplots were treated twice with Pydrin®.

Squares, blooms, and bolls were counted in the infested and uninfested rows of each plot on a weekly basis throughout the growing season. Seven such fruit counts were made in 1979, and 11 were made in 1980. Lint yield data were collected by pulling and weighing all mature bolls in the infested and uninfested rows of each plot. A single pulling was made on November 29, 1979. Two pullings were made in 1980 on October 2 and November 29.

Lint samples from each plot were sent to the Cotton Quality Research Laboratory for analyses. Fiber length was measured on the digital fibrograph as 2.5% span length and 50% span length. Fiber length uniformity indices were obtained by dividing 50% span length by 2.5% span length. Fiber strength was measured on the stelometer at the 0 cm. and 0.32 cm. settings (in grams-force/tex).

Although these cultivars were selected on the basis that none possessed known resistance characters, an effort was made to remove antibiosis effect through feeding studies. Previous bioassay research for antibiotic constituents was considered in constructing a bioassay system. Jenkins et al. (1964) described a diet preparation technique to analyze components of antibiosis to the boll weevil. This diet combined lyophilized squares, sterile water, agar, and antimicrobial agents. Lukefahr et al. (1966) used essentially the same technique to bioassay cotton lines for antibiosis to second-instar bollworms. Shaver and Lukefahr (1971) noted that the nutrition provided larvae by squares depends upon the number of anthers within those squares. Because anther numbers vary greatly among cotton lines, a different bioassay system was developed. This system used ether and acetone extracts of lyophilized square powders coated onto alphacel and incorporated into the casein-wheat germ diet described by Berger (1963). Two- to three-day-old larvae were used in this test. A similar antibiotic phytochemical bioassay technique was developed and described by Chan et al. (1978). Our intent was to simplify, yet duplicate, the essential elements of previous bioassay attempts.

Squares were removed from plants in the border rows of each plot. These squares were placed on dry ice in the field and transported to the laboratory. They were then frozen and later lyophilized. The lyophilized squares were ground into a fine powder and incorporated into the modified pinto bean diet described by Burton (1969). Preliminary testing showed that at least a partial survival of larvae occurred when an equivalent amount of square powder was substituted for the pinto beans used in this diet. This test was arranged in a randomized, complete block experimental design using 15 larvae/treatment and 27 treatments. Two levels of square powder/cultivar were compared with two levels of gossypol acetate and a control. The test was performed twice.

First-instar larvae were placed in 30 ml. plastic cups containing the combined lyophilized square powder and pinto bean diet, and the larvae were then reared in a growth chamber. The number of larvae pupating in each treatment and the corresponding pupal weights were recorded.

Analyses of variance for blooms, squares, bolls, lint yield, fiber quality, and pupal weights were made in the Oklahoma State University Computer Center. The Statistical Analysis System Program was used in the data analyses.[1] Because of the sizable amount of variation in fruit count data and the fact that the fruiting distribution appeared to follow a negative binomial, log values of those data were analyzed. Differences were considered significant at the 0.05 probability level. Means were separated using Duncan's New Multiple Range Test.

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[1] The system was designed and implemented by Anthony J. Barr and James H. Goodnight, Department of Statistics, North Carolina State University, Raleigh, North Carolina.

CHAPTER IV

RESULTS AND DISCUSSION

Infestation rates used in the 1979 test were made on a subjective basis largely to determine how many lab-reared *H. zea* larvae were required to ensure adequate damage levels in this geographic area. The rates used (six larvae/row meter in the first infestation and 16 larvae/row meter in the second) proved inadequate for the existing environmental conditions. Therefore, an economic injury level was not reached and significant differences between infested and uninfested rows did not occur for any character measured. For this reason, the data obtained during 1979 could not be used to evaluate levels of tolerance among cultivars.

The numbers of larvae used in the 1980 test were increased (13.1 larvae/row meter for the first infestation and 19.7 larvae/row meter during the second). Also, rather than attempting to match artificial infestation dates with natural *Heliothis* population peaks, infestations were made one week apart late in July during the onset of rapid squaring. As an additional safequard, larvae were placed in terminals at dawn to take advantage of cooler, more humid conditions.

Significant reductions in square, bloom, and boll numbers were achieved in all cultivars during the 1980 season. Figures 1 through 12 show the comparisons between numbers of squares between infested versus uninfested rows for each tested cultivar. Artificial infestation extended the squaring period for all cultivars. There appeared to be differences, however, among cultivars in the intensity of secondary squaring subsequent to bollworm damage. 'Coker 5110', 'DES 56', Lockett 77', 'McNair 235', and 'Tamcot SP21' showed the highest levels of late season squaring. The infested rows of 'GSA 71', 'Stoneville 213', and 'Westburn M' had virtually ceased production of squares during the same period.

Even though there were distinct differences in bloom numbers between infested versus uninfested rows during the season, differences in boll numbers probably represent a more useful comparison. Figures 13 through 24 illustrate boll numbers in infested versus uninfested rows for each cultivar throughout the season. Significant differences between the infested versus uninfested rows are apparent in each cultivar except 'GSA 71' (Figure 19) and 'Westburn M' (Figure 24). Bollworm infestation reduced the number of bolls in each variety, and the initial reductions among cultivars were not significantly different. Thus, each cultivar appeared to suffer comparable damage. However, the abilities of the cultivars to rebound and compensate for this damage were not equivalent. Six cultivars (i.e., 'Lockett 77', 'Westburn M', 'Tamcot SP21', 'GSA 71', 'Acala 1517-77', and 'Deltapine 16') recovered to the extent that significant differences in bolls between infested and uninfested rows did not exist on the last sampling date (September 25). The fact that 'GSA 71' and 'Westburn M' appear within this group may be misleading. In both cultivars, the number of bolls in the infested rows outnumbered those in the uninfested rows prior to infestation, significantly so with 'Westburn M'. This situation ensured a dilution effect on the extent of damage and likely enhanced recovery.

When differences in square numbers were compared among geographical classes of cottons (Figures 25 through 28) few differences could be detected. Following infestation, significant differences were evident between infested and uninfested rows in each class; and the squaring curves are very similar in each class.

Comparisons of boll numbers among classes are shown in Figures 29 through 32. Boll numbers were reduced significantly in infested rows of members of each class beginning in the sixth week of sampling. Only the Plains cultivars as a class recovered to such an extent that significant differences were no longer evident on the final sampling date.

When lint yield comparisons were made between the infested vs. uninfested rows of each cultivar, it was noted that in the first pulling significant differences occurred in only four cultivars (Figure 33). 'Acala SJ-5', 'Coker 5110', 'DES 56', and 'Stoneville 213' showed significant reductions in snapped cotton weight, seedcotton weight, and lint weight when the infested rows were compared to those not infested. These reductions were apparent in the second harvest only in 'Acala SJ-5' and 'Coker 5110'. Cumulative harvest totals indicate that yields of all four entries were significantly reduced by the damage received. While a statistical reduction in yield was not exhibited by the other cultivars, it is noteworthy that the lint yield of the infested rows averaged about 72 Kg./Ha. less than the rows not infested.

A comparison of yield by classes (Table II) shows that the Acala and Southeast cottons had significantly lower bur cotton and seedcotton yields than the Plains and Delta cottons. The Plains class produced significantly more lint than the Delta class, and the Delta class produced significantly more than either the Acala or Southeast classes. The uninfested rows of all classes yielded more bur cotton, seedcotton, and lint than did the infested rows.

Significant differences in fiber quality appeared between infested and uninfested rows. Two measurements of fiber length (i.e., 2.5% span length and 50% span length) showed significantly greater values in infested row samples than in those from uninfested rows. The mean 2.5% span length for infested rows was 2.75 cm. while the uninfested rows were 2.71 cm. Infested rows had a mean 50% span length of 1.32 cm. compared to uninfested rows' mean value of 1.30 cm.

Lint strength was measured, and its mean 0 cm. gauge stelometer reading for infested rows was 3557.2 g./cm^2. The mean value for uninfested rows was 3507.9 g./cm^2. Those cultivars in which the mean infested row 0 cm. gauge stelometer readings were significantly greater than the uninfested rows were 'Coker 5110', 'Lockett 77', 'McNair 235', and 'Tamcot SP21'. The mean uninfested row 0 cm. gauge stelometer readings for 'DES 56' were significantly greater than the mean value for the infested row. The 0.32 cm. gauge stelometer and uniformity index means were not significantly different between infested vs. uninfested rows. Micronaire, a measure of lint fineness, was not measured due to insufficient sample size.

To describe growth patterns as being due to "tolerance," it was judged that possible antibiotic influences exerted by the host plant on the larvae should first be taken into consideration. Although laboratory tests are available to ascertain relative levels of certain biochemical substances in cotton known to be toxic to <u>Heliothis</u> larvae, no single test can measure the levels of all those substances. Likewise, it is probable that all of the antibiotic chemicals of the cotton plants are not yet known, and adequate tests to evaluate their levels of concentration are unavailable. Therefore, a simple bioassay procedure was used to determine if toxic substances were present in the cotton squares of the cultivars tested. It was deemed more important at this stage of inquiry to determine if and in what concentration antibiotic substances were present than to know specifically what those substances might be.

Initial testing demonstrated that the ratio of square powder to diet is critical to the survival of the larvae. A level of square powder in excess of 6% in the diet appeared to cause the diet to dessicate even in the confines of a high-humidity environmental chamber. Therefore, two levels of square powder (i.e., 3 and 6%) were incorporated into the modified pinto bean diet. Those levels were compared against 0.6 and 1.2% gossypol and a check of standard diet. The test was replicated twice.

The results were highly variable and are shown in Tables III and IV. While significant differences in mean pupal weight occurred among groups of larvae tested by this procedure, a clear trend was not discernible. Larvae fed the standard wheat germ-pinto bean diet and those fed the same diet possessing a 0.6% gossypol content had the highest pupal weights in both replications. Other treatments varied widely between replications, and yielded no conclusive information.

CHAPTER V

SUMMARY AND CONCLUSIONS

Due to the inconclusive nature of the bioassay portion of this experiment, it is difficult to assess the true nature of tolerance among the cotton cultivars tested. Likewise, it would not be prudent to make long-range predictions based on the observations made over only a single season. However, much of the groundwork for a long-term test has been accomplished.

This test did establish general guidelines regarding the artificial infestation rates necessary to insure an economic damage level in this geographic area. Predictably, this rate will vary in different years and would probably be different if larger larvae were used. A total of 33 larvae/row meter placed on the terminals during two consecutive weeks worked well in this study.

Perhaps, the prime accomplishment of this research is the indication that there are differences in levels of rebound or late-season squaring after infestation both in boll numbers and lint yield among cotton cultivars. This ability to recover is most evident in the Plains class of cottons. Each variety suffered a reduction of yield in infested rows, but only 'Acala SJ-5', 'Coker 5110', 'DES 56', and 'Stoneville 213' were reduced significantly.

Interestingly, in this test, certain aspects of fiber quality were significantly enhanced in the infested rows. The quality standards 2.5% span length, 50% span length, and 0 cm. gauge stelometer were significantly greater in the infested rows. Perhaps, fewer bolls allowed a greater partitioning of photosynthate into those bolls that were left.

Perhaps, one of the more complex, established bioassay methods should have been used for this test. The scheme used herein has severe deficiencies and will require additional testing to determine its practicality. To accurately determine levels of tolerance, a dependable bioassay technique is essential.

Although much of the preliminary work necessary to evaluate tolerance has been achieved by this experiment, a great deal remains unfinished. Ideally, field observations of the tested cultivars should continue for several years. Likewise, the bioassay procedure should be modified and tested to determine its practicality. It will be virtually impossible to discern the true role tolerance plays in cotton without this additional information. The data gathered from this test suggest that the potential importance of tolerance in cotton should not be overlooked.

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APPENDIX A

TABLES

TABLE I

A COMPARISON OF LINT YIELD (KG/HA) BY CULTIVAR, 1980

CULTIVAR	INFESTED ROW	UNINFESTED ROW
Deltapine 16	327	398
Acala 1517-77	223	316
Delcot 311	282	392
GSA-71	312	358
Lockett 77	365	419
McNair 235	306	401
Tamcot SP21	338	422
Westburn M	378	433
Stoneville 213*	270	451
DES 56*	212	399
Coker 5110*	151	315
Acala SJ-5*	121	281

*Denotes those cultivars whose yield differed significantly at the 0.05 probability level between infested versus uninfested rows.

TABLE II

A COMPARISON OF LINT YIELD (KG/HA) BY CLASS, 1980

CLASS	SNAPPED COTTON WEIGHT	SEEDCOTTON WEIGHT	LINT WEIGHT
Acala	1158 a*	772 a	273 a
Southeast	1240 a	864 a	316 a
Delta	1636 b	1159 b	399 b
Plains	1819 b	1302 b	461 c

*Values followed by the same letter do not differ significantly at the 0.01 probability level by Duncan's New Multiple Range Test.

TABLE III

ANTIBIOSIS STUDY, FIRST TEST*

CULTIVAR	LEVEL	NUMBER OF PUPAE	PUPAL WEIGHT (GRAMS)
DES 56	II	1	0.1182 a**
GSA 71	II	2	0.1394 a
Deltapine 16	II	2	0.1712 a
Lockett 77	II	3	0.1899 ab
McNair 235	II	2	0.1972 abc
Stoneville 213	II	1	0.2033 abcd
Lockett 77	I	7	0.2306 abcd
Coker 5110	I	7	0.2311 abcd
DES 56	I	3	0.2352 abcd
Acala 1517-77	II	7	0.2389 abcd
McNair 235	I	7	0.2426 abcd
Stoneville 213	I	10	0.2439 abcd
GSA 71	I	1	0.2520 abcd
Delcot 311	I	9	0.2528 abcd
Acala 1517-77	I	6	0.2537 abcd
Tamcot SP21	I	4	0.2742 abcd
Deltapine 16	I	10	0.2830 bcd
Acala SJ-5	I	13	0.2876 cd
Westburn M	I	8	0.3574 de
Gossypol	I	6	0.4333 ef
Check		14	0.4618 f

*Does not include those treatments in which no larvae pupated.

**Values followed by the same letter do not differ significantly at the 0.05 probability level by Duncan's New Multiple Range Test.

TABLE IV

ANTIBIOSIS STUDY, SECOND TEST*

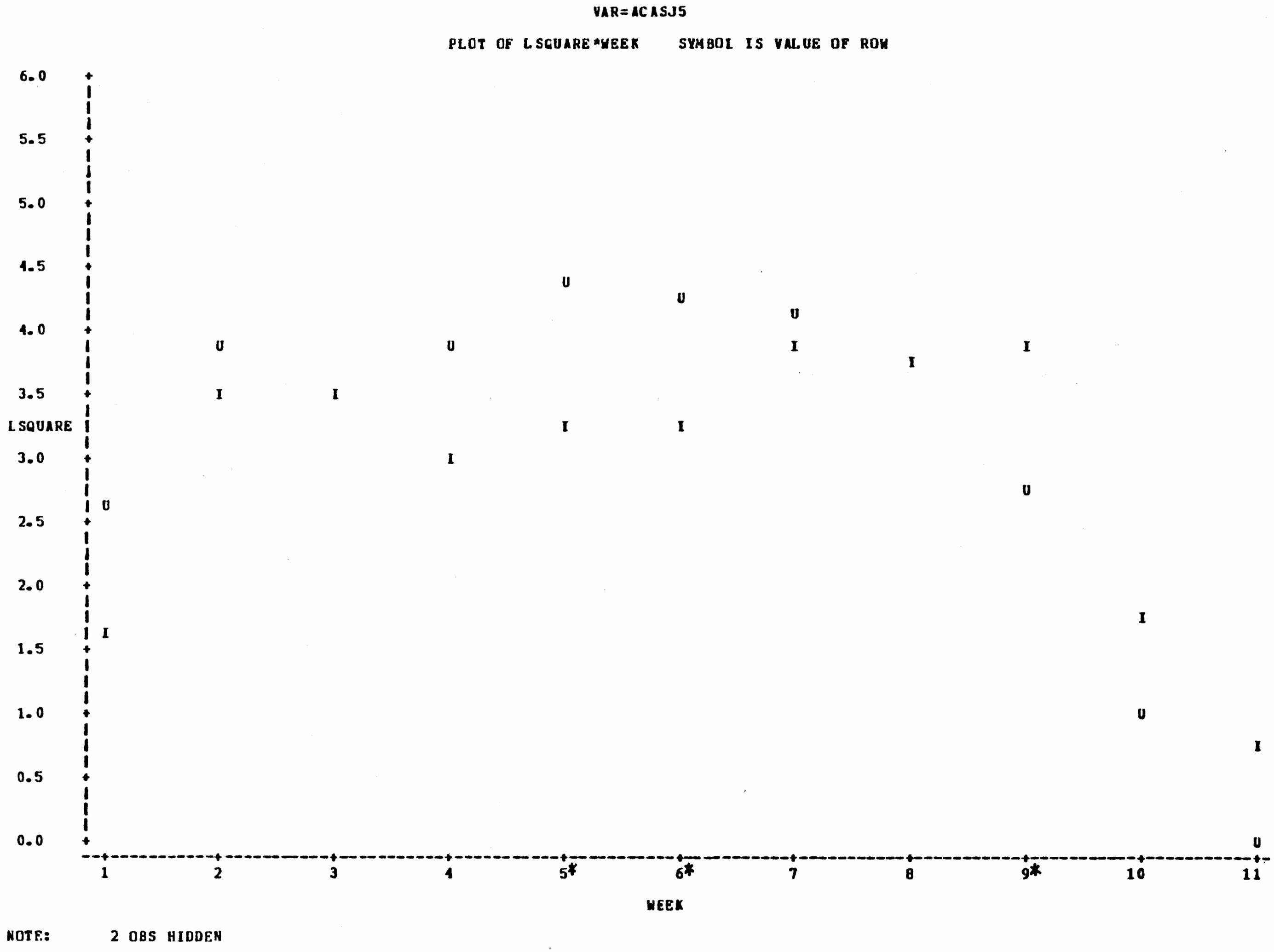
CULTIVAR	LEVEL	NUMBER OF PUPAE	PUPAL WEIGHT (GRAMS)
GSA 71	II	1	0.1598 a**
Tamcot SP21	II	3	0.1908 a
Lockett 77	II	1	0.2055 ab
Stoneville 213	II	3	0.2056 ab
Westburn M	II	1	0.2087 ab
Coker 5110	II	6	0.2090 ab
Acala SJ-5	II	3	0.2133 ab
GSA 71	I	10	0.2153 ab
DES 56	II	3	0.2195 ab
DES 56	I	7	0.2598 ab
Tamcot SP21	I	10	0.2610 ab
Stoneville 213	I	6	0.2610 ab
Acala 1517-77	II	6	0.2613 ab
Westburn M	I	7	0.2803 ab
Lockett 77	I	11	0.2803 ab
Delcot 311	I	5	0.2806 ab
Acala SJ-5	I	11	0.2818 ab
Deltapine 16	II	9	0.2966 b
Coker 5110	I	9	0.3124 bc
Acala 1517-77	I	9	0.3211 bc
Deltapine 16	I	11	0.3211 bc
Gossypol	II	8	0.3662 c
Check		12	0.5025 d
Gossypol	I	8	0.5055 d

*Does not include those treatments in which no larvae pupated.

**Values followed by the same letter do not differ significantly at the 0.05 probability level by Duncan's New Multiple Range Test.

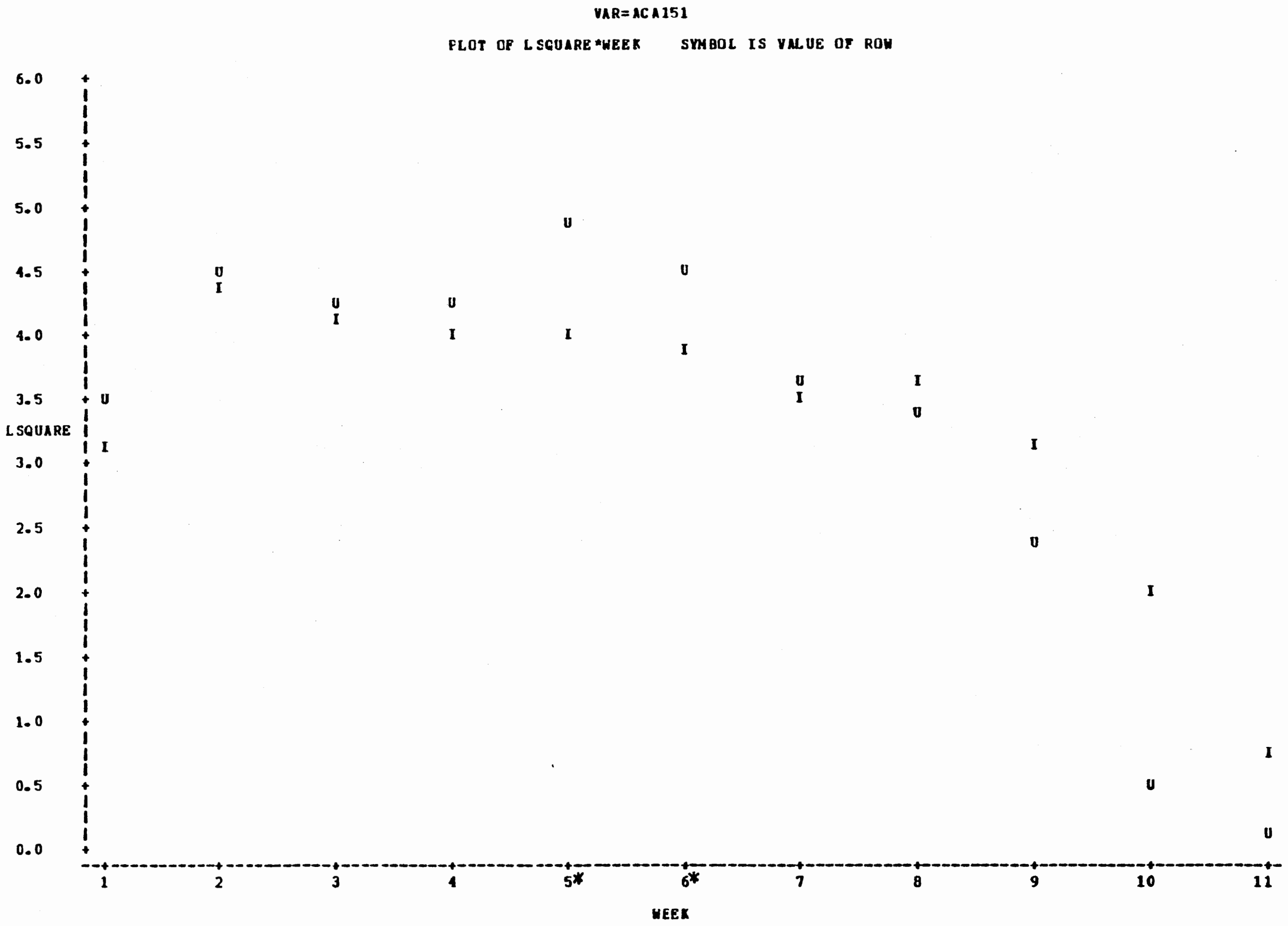
APPENDIX B

FIGURES



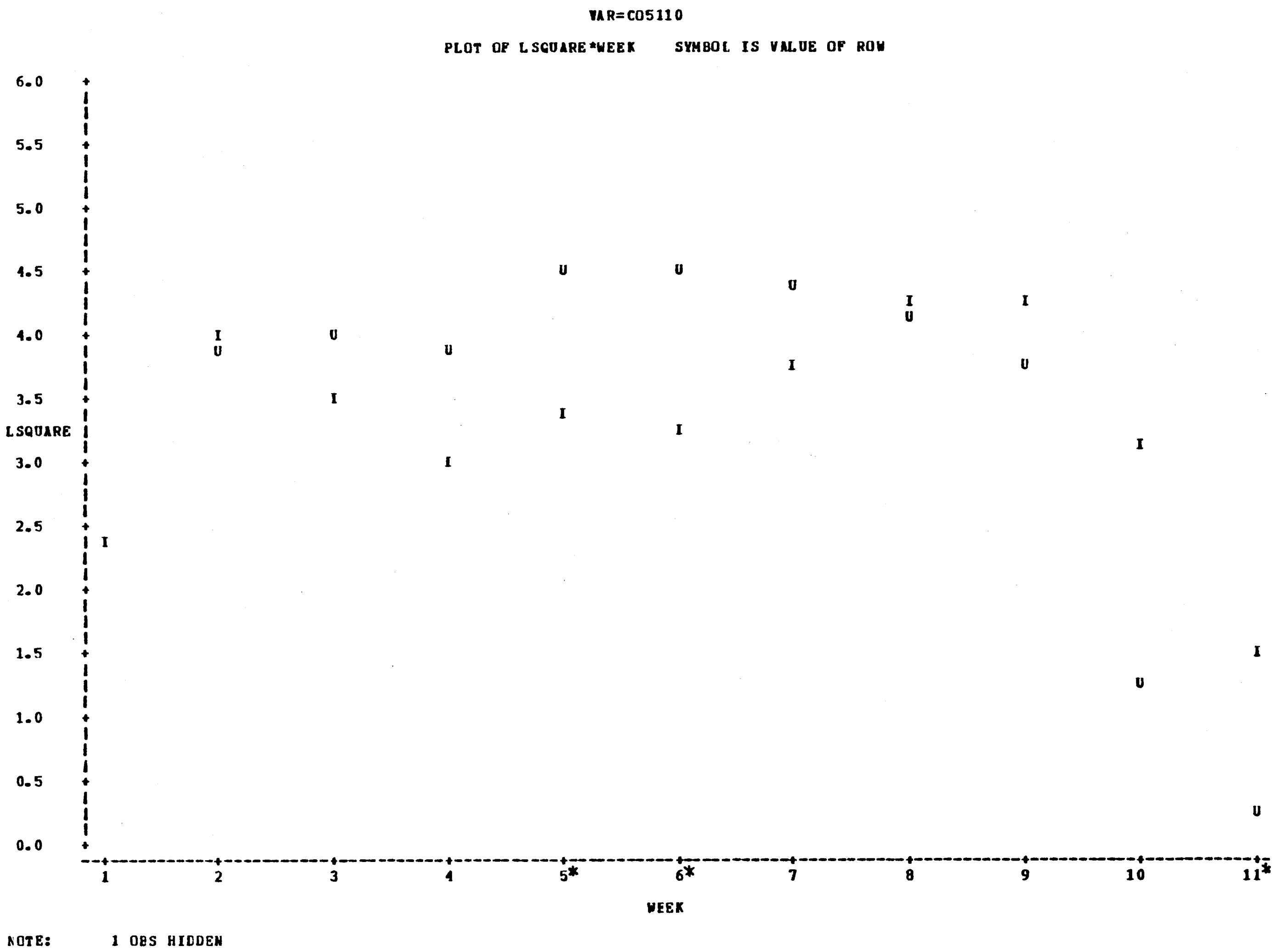
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 1. Log Value of Squares by Week in the Cultivar 'Acala SJ-5'



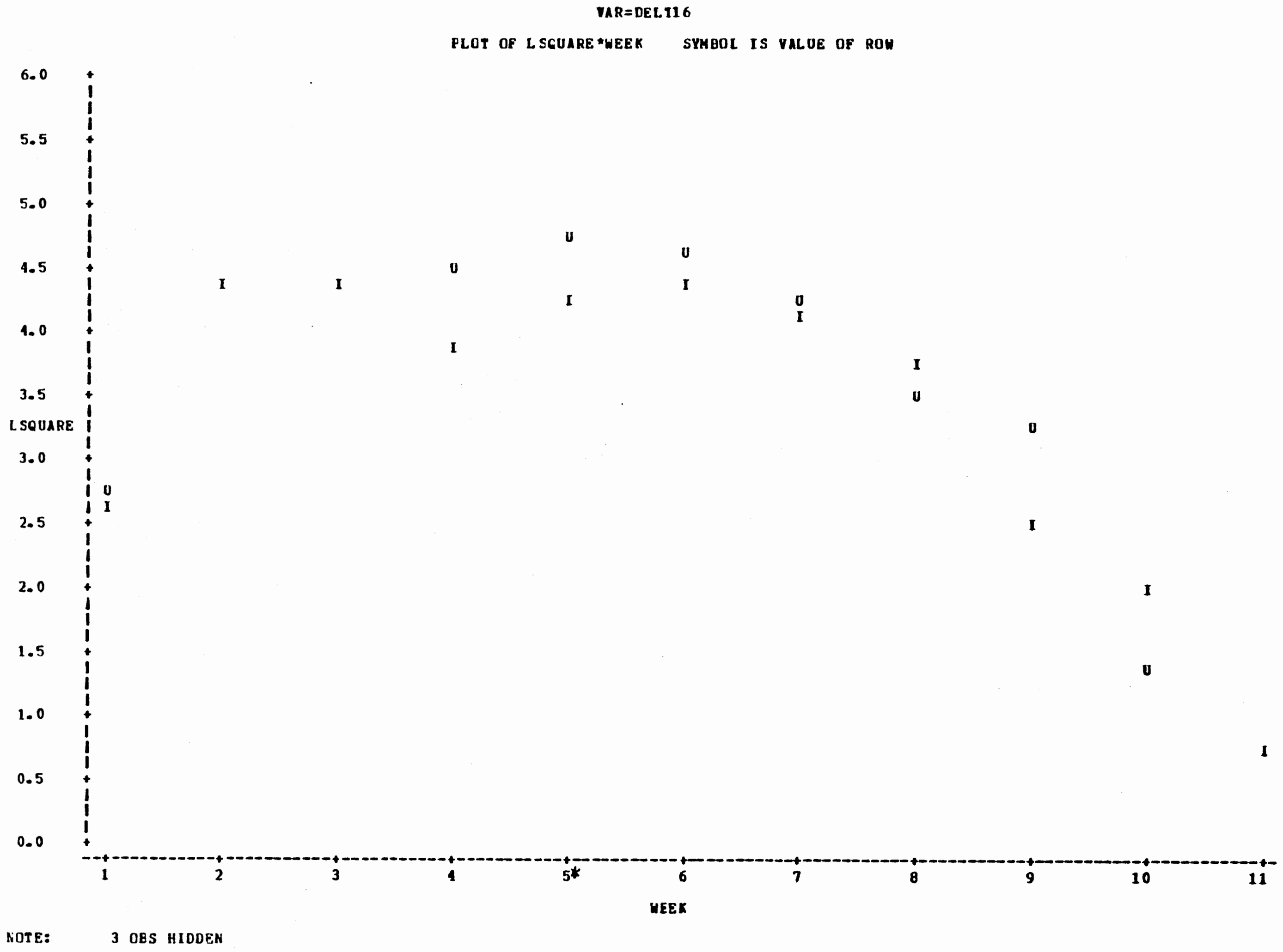
*Indicates dates when square numbers in the infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 2. Log Value of Squares by Week in the Cultivar 'Acala 1517-77'



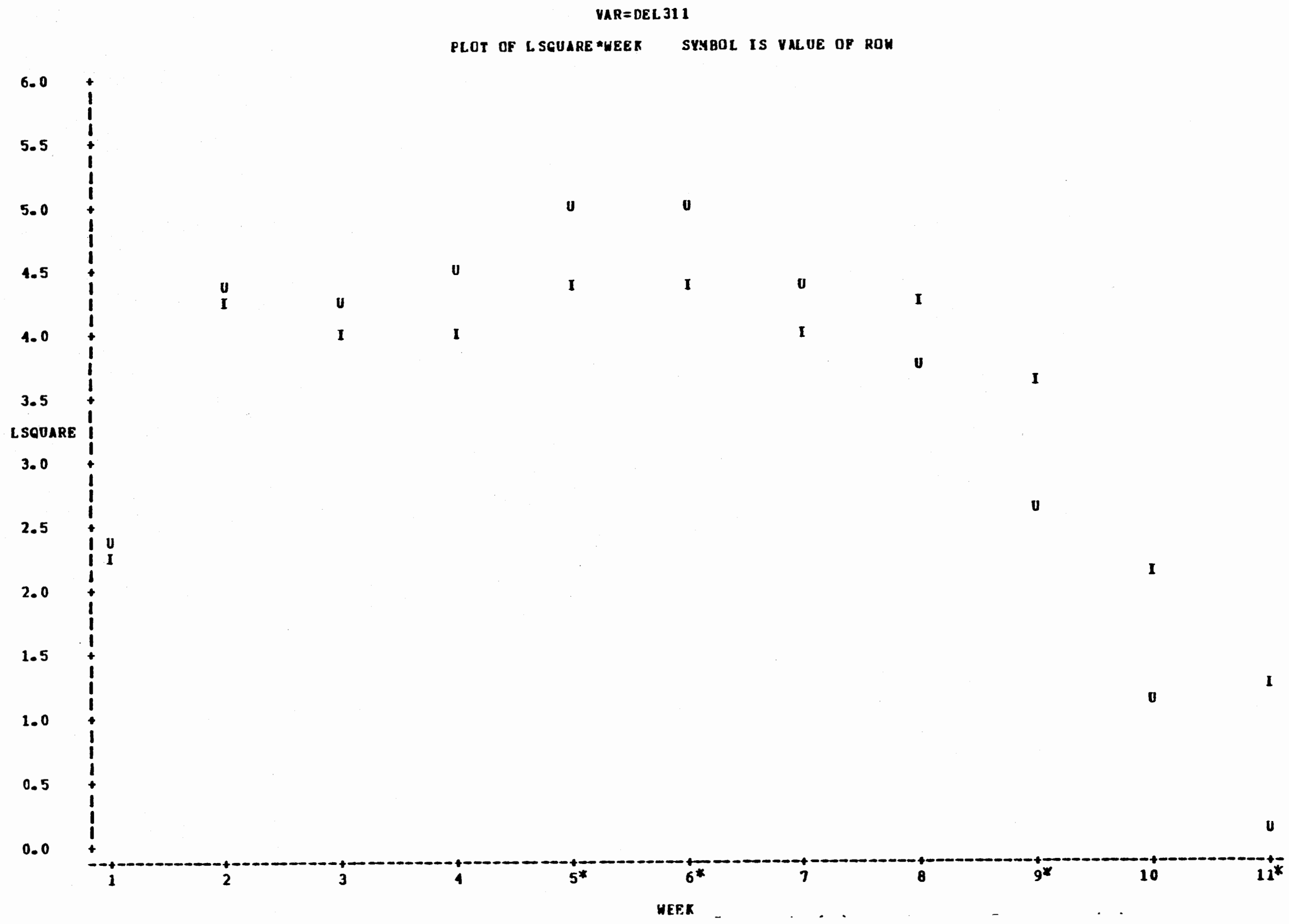
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 3. Log Value of Squares by Week in the Cultivar 'Coker 5110'



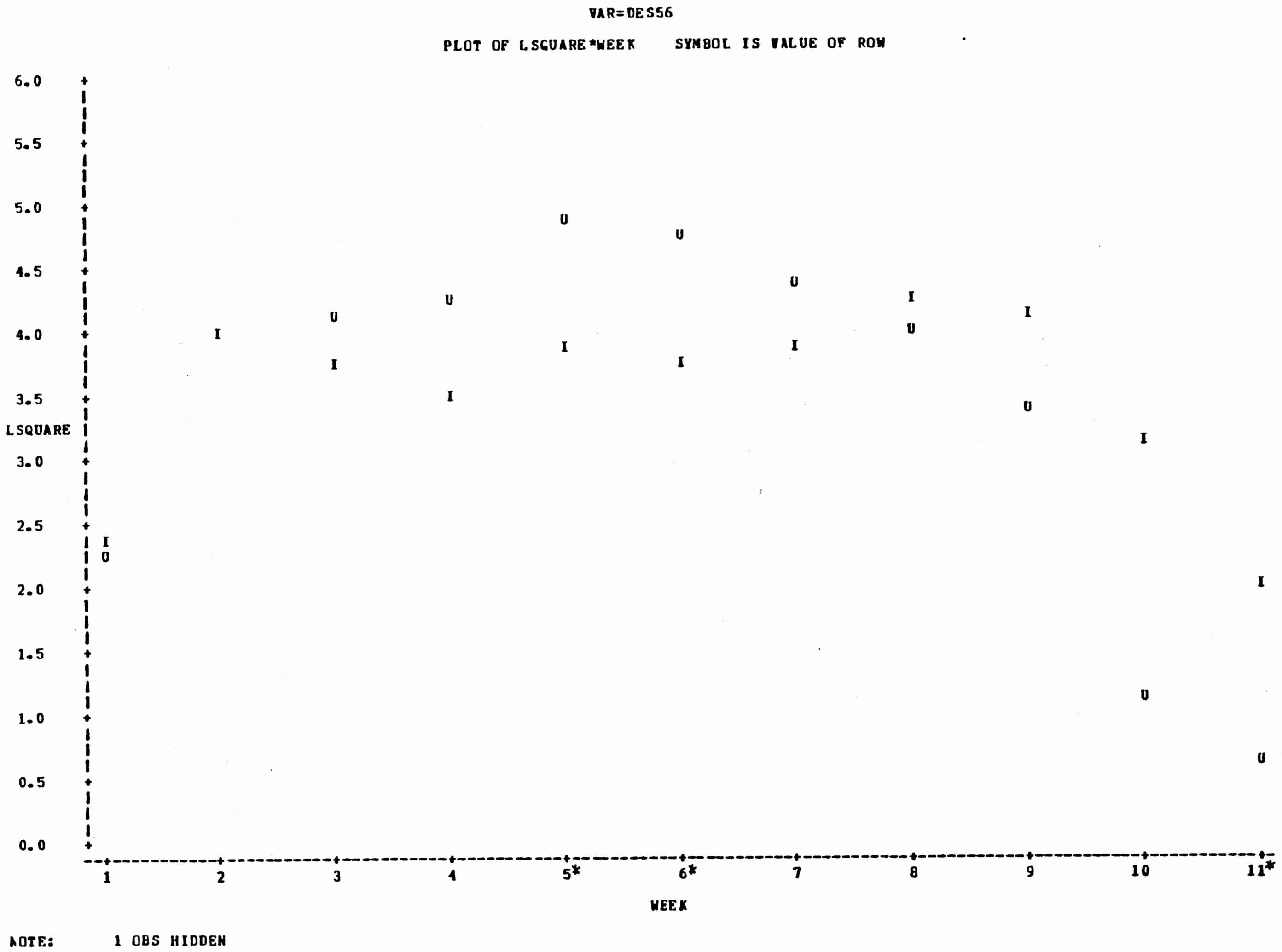
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 4. Log Value of Squares by Week in the Cultivar 'Deltapine 16'



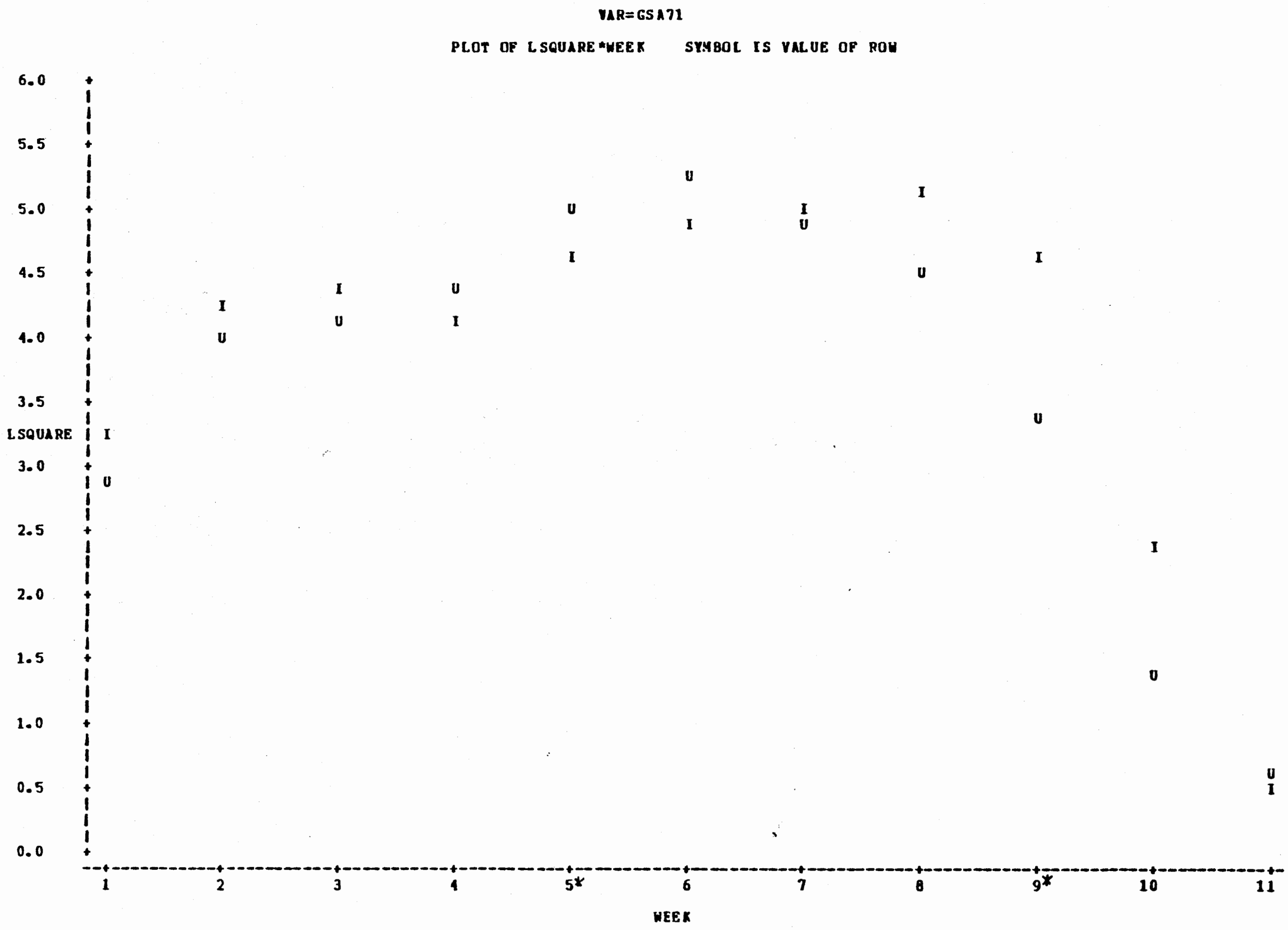
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 5. Log Value of Squares by Week in the Cultivar 'Delcot 311'



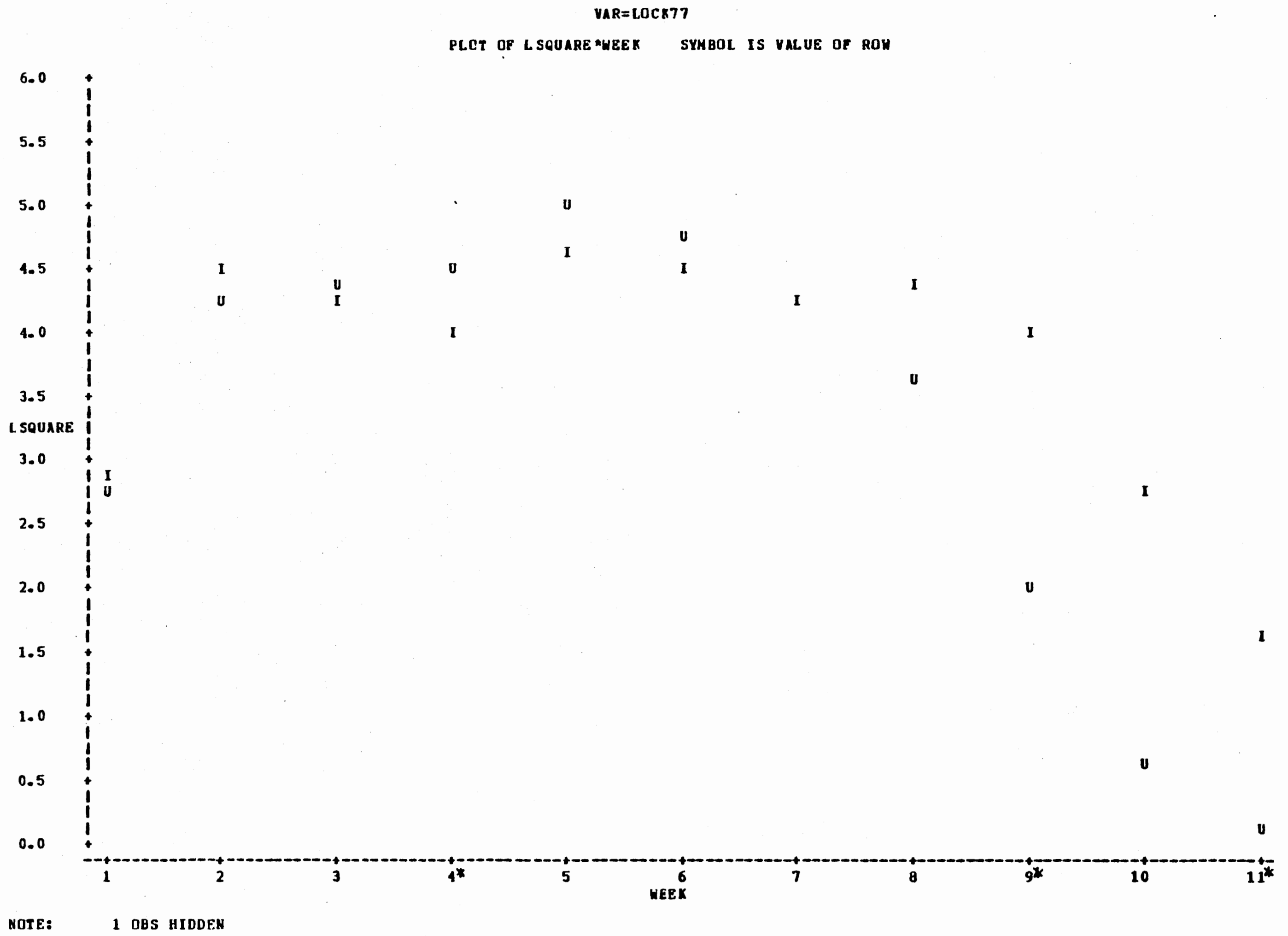
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 6. Log Value of Squares by Week in the Cultivar 'DES 56'



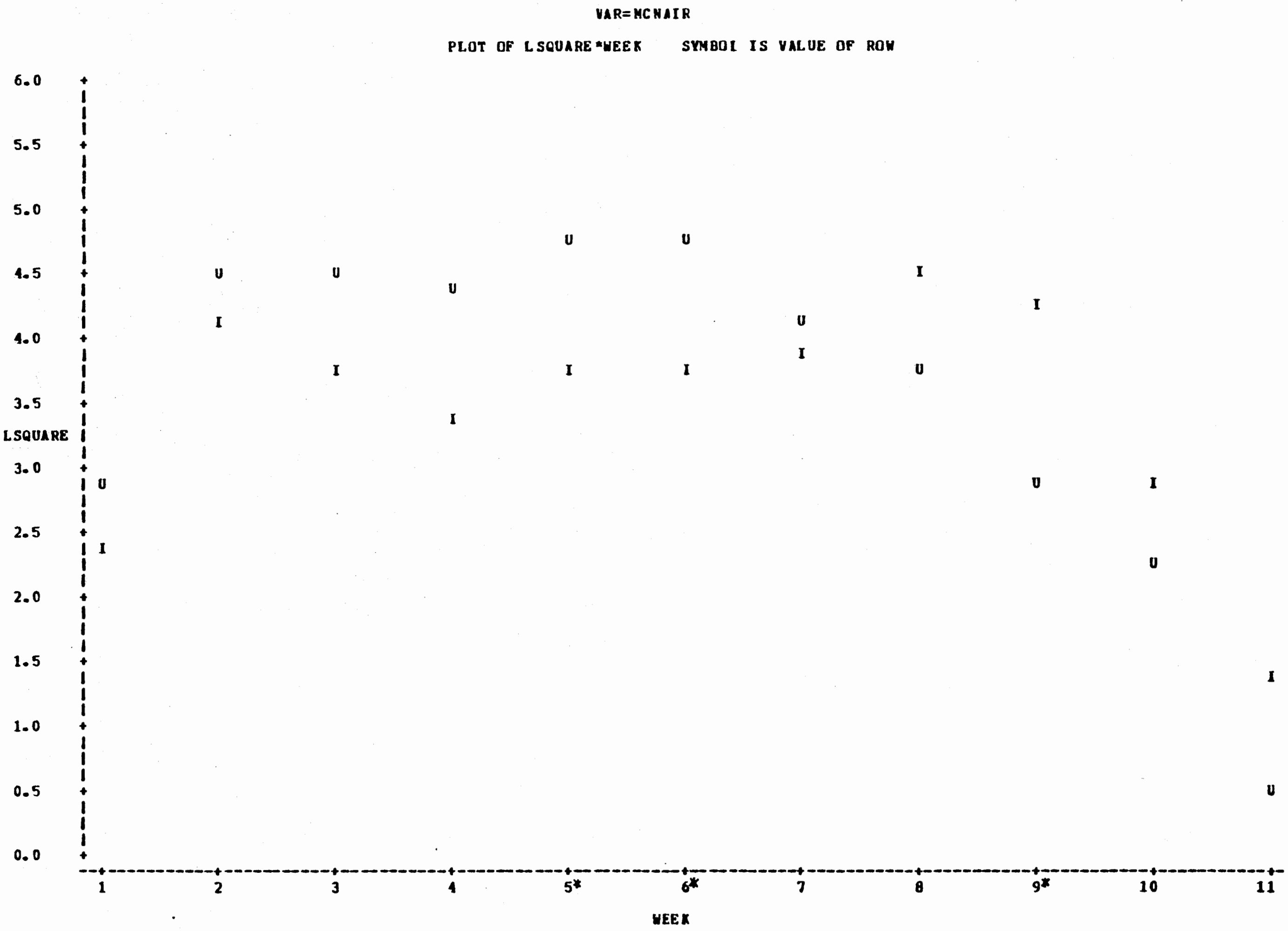
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level.

Figure 7. Log Value of Squares by Week in the Cultivar 'GSA 71'



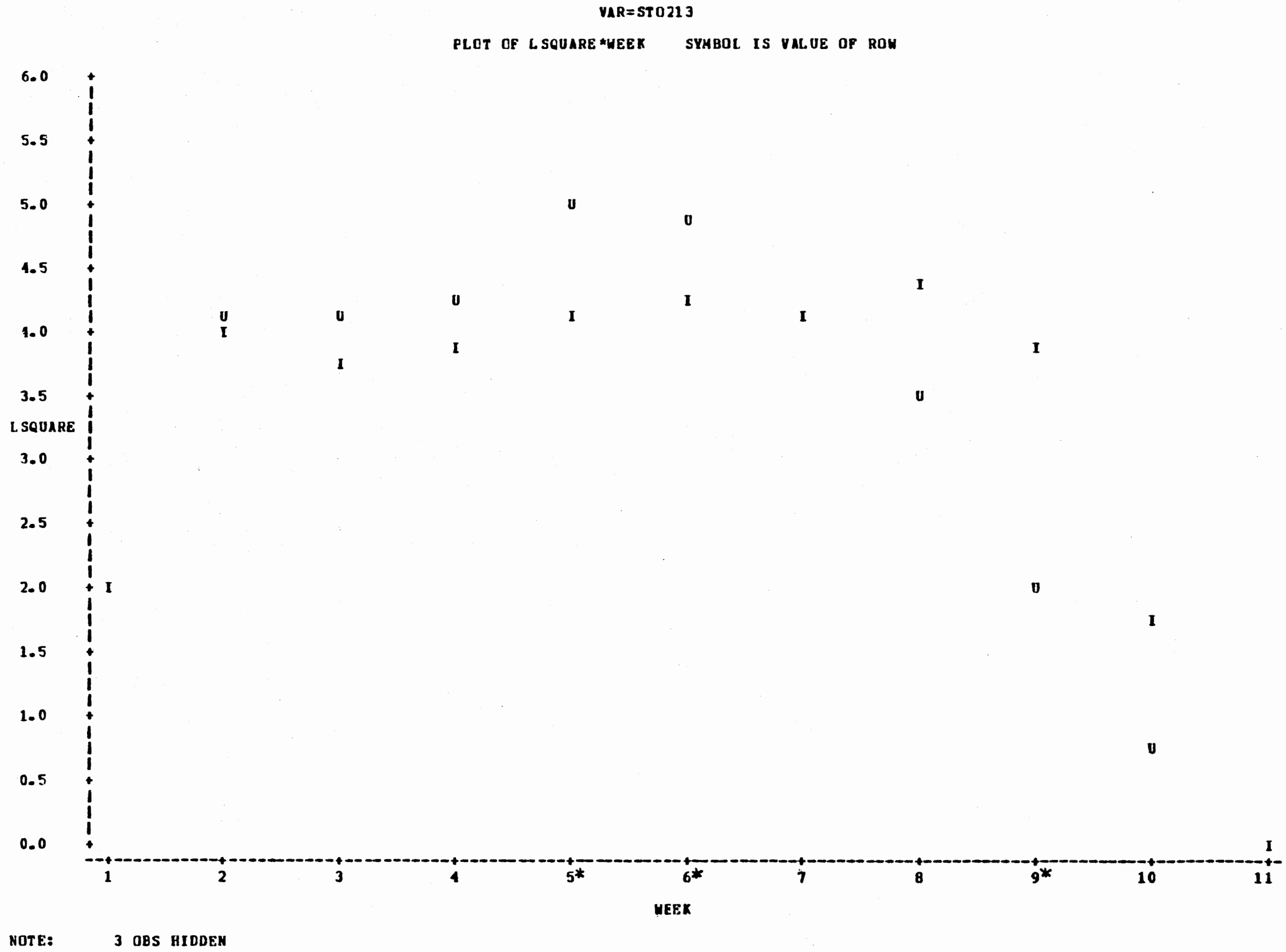
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 8. Log Value of Squares by Week in the Cultivar 'Lockett 77'



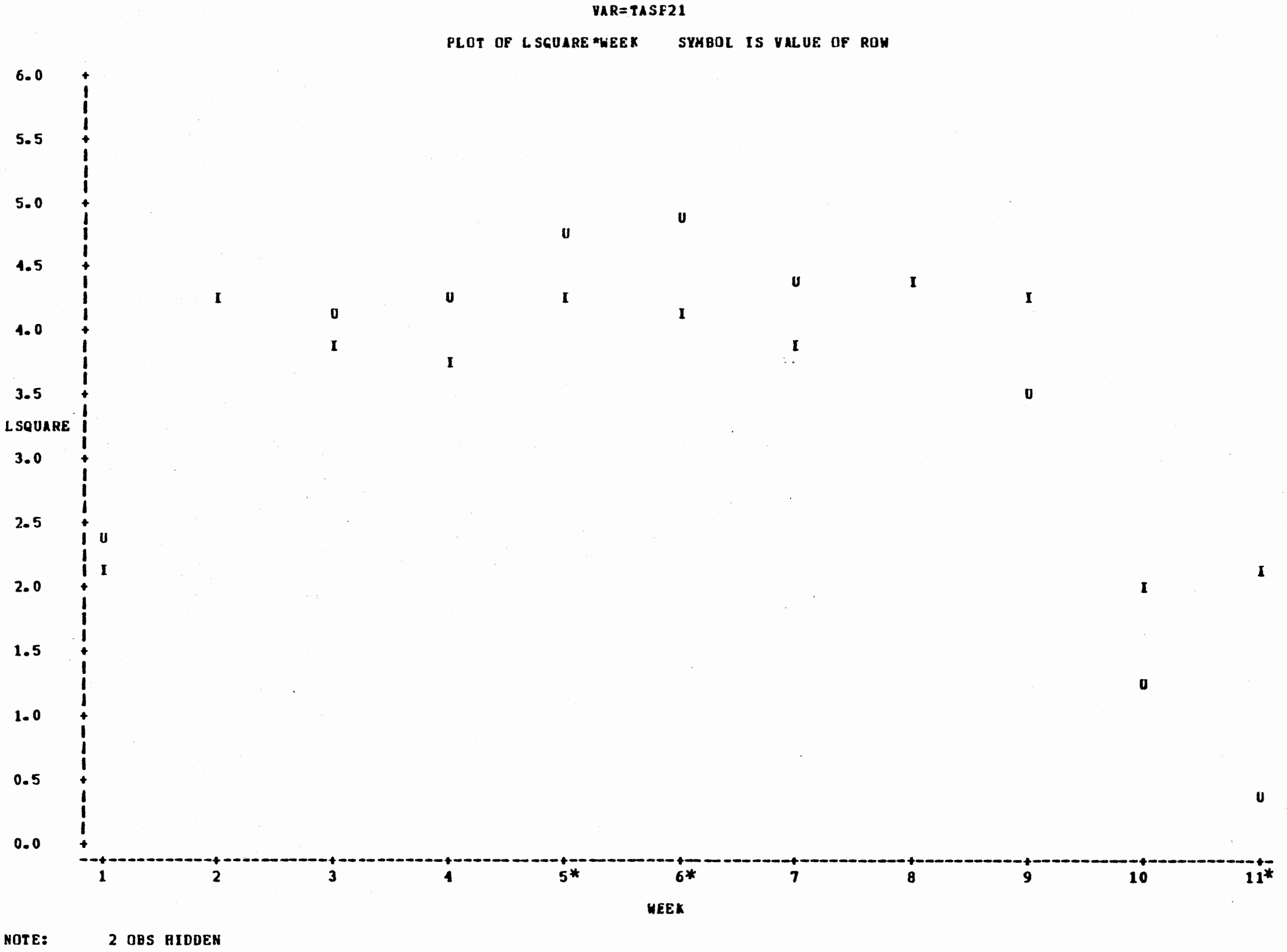
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 9. Log Value of Squares by Week in the Cultivar 'McNair 235'



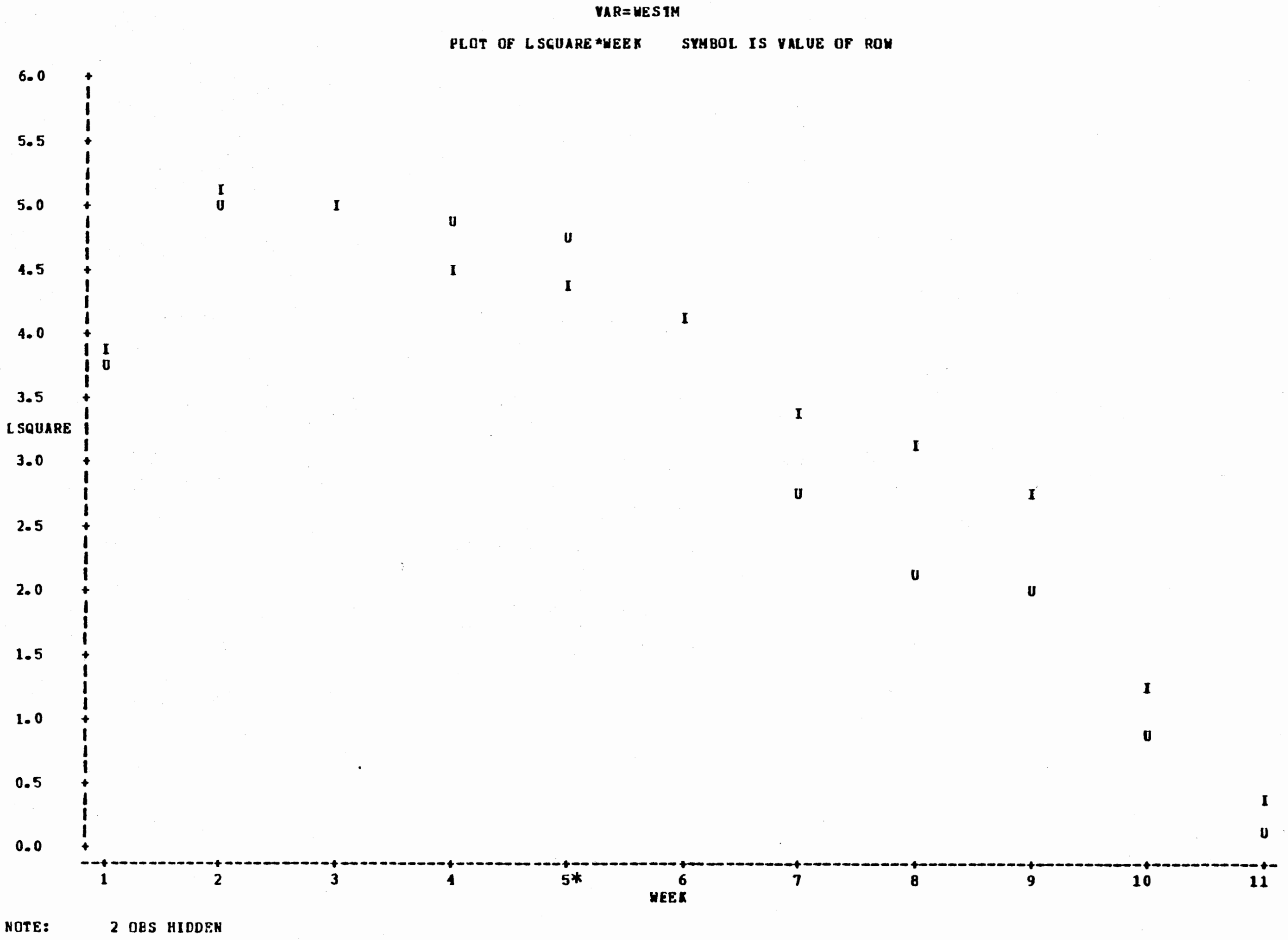
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 10. Log Value of Squares by Week in the Cultivar 'Stoneville 213'



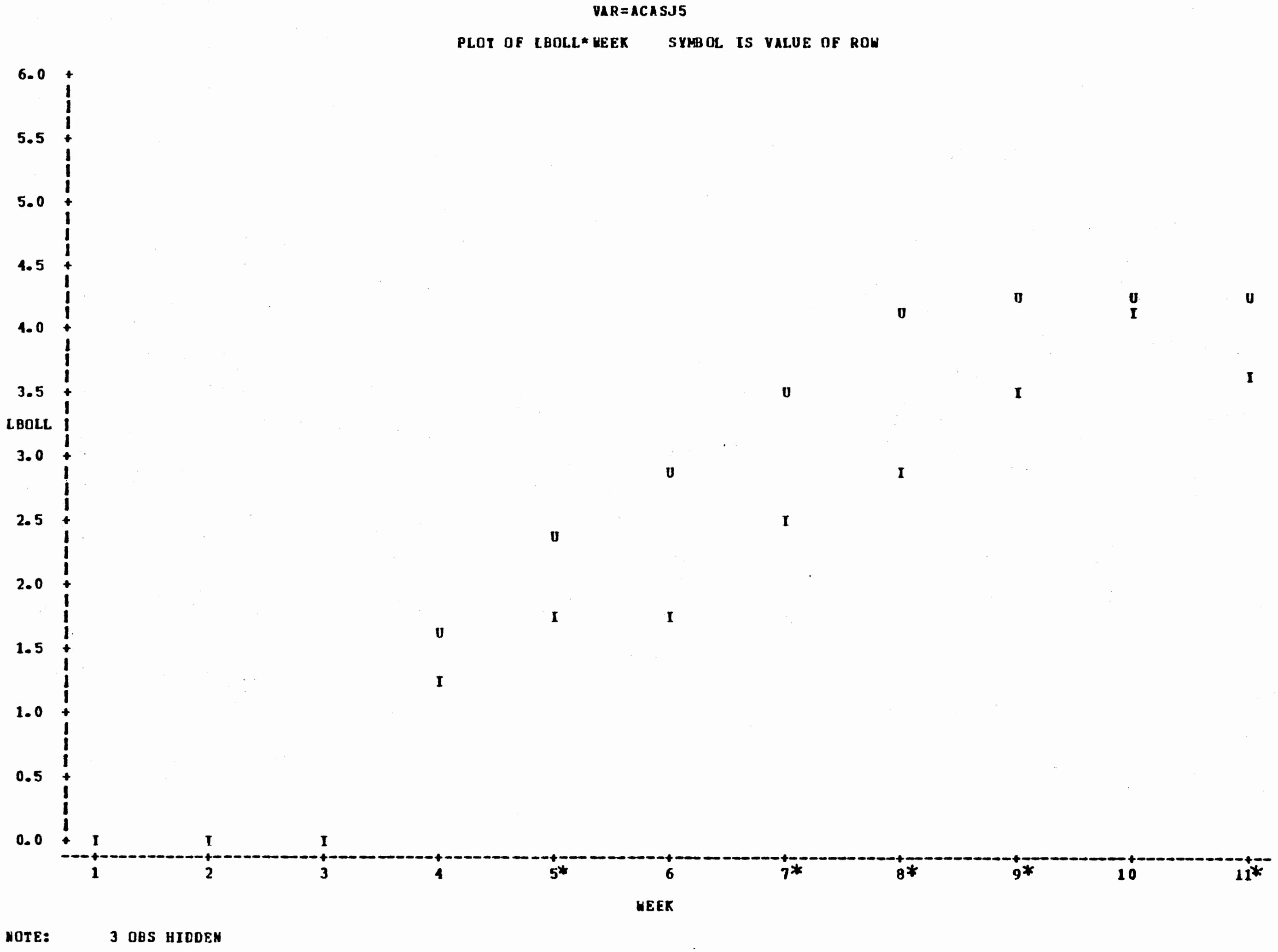
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 11. Log Value of Squares by Week in the Cultivar 'Tamcot SP21'



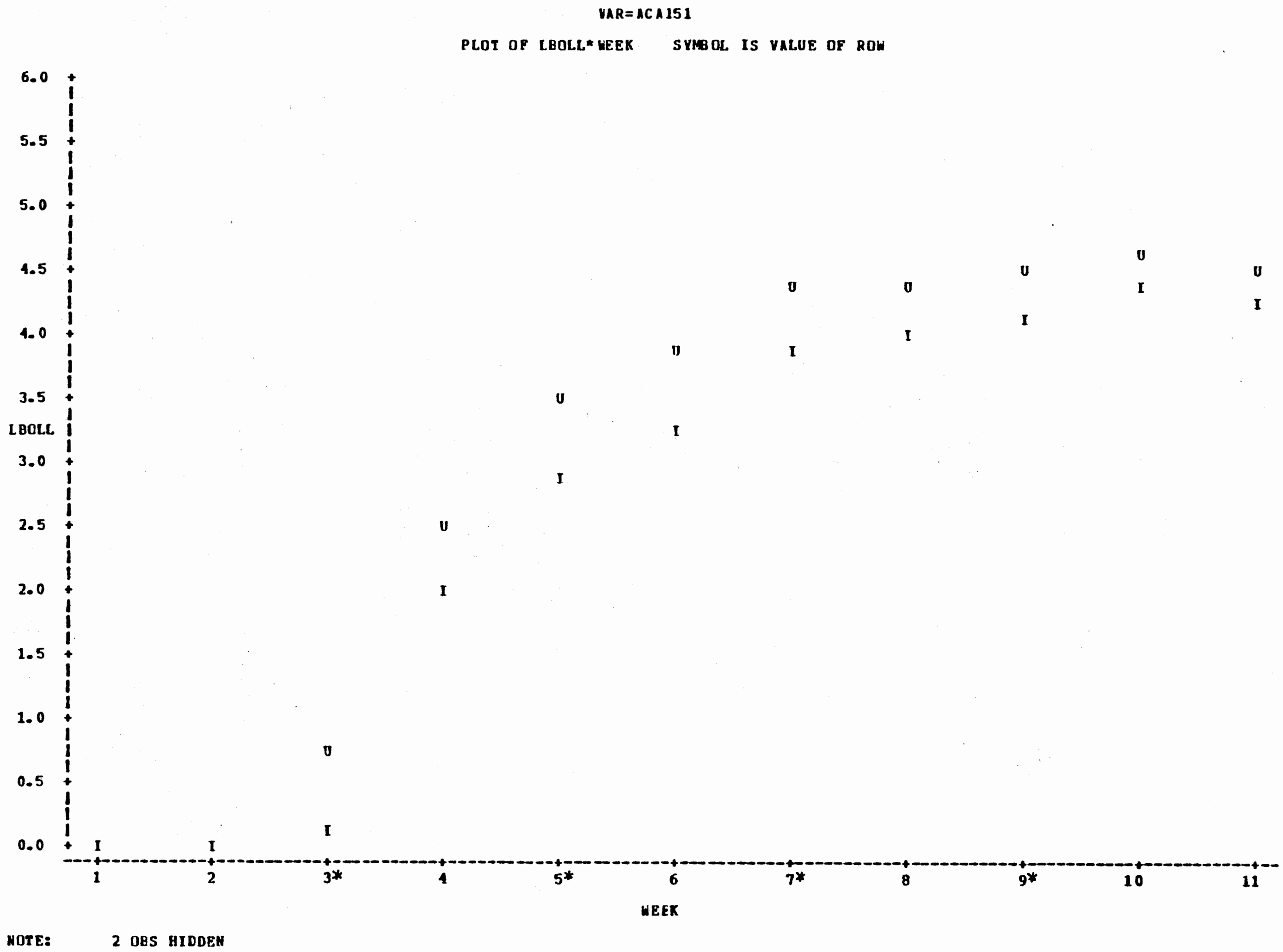
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 12. Log Value of Squares by Week in the Cultivar 'Westburn M'



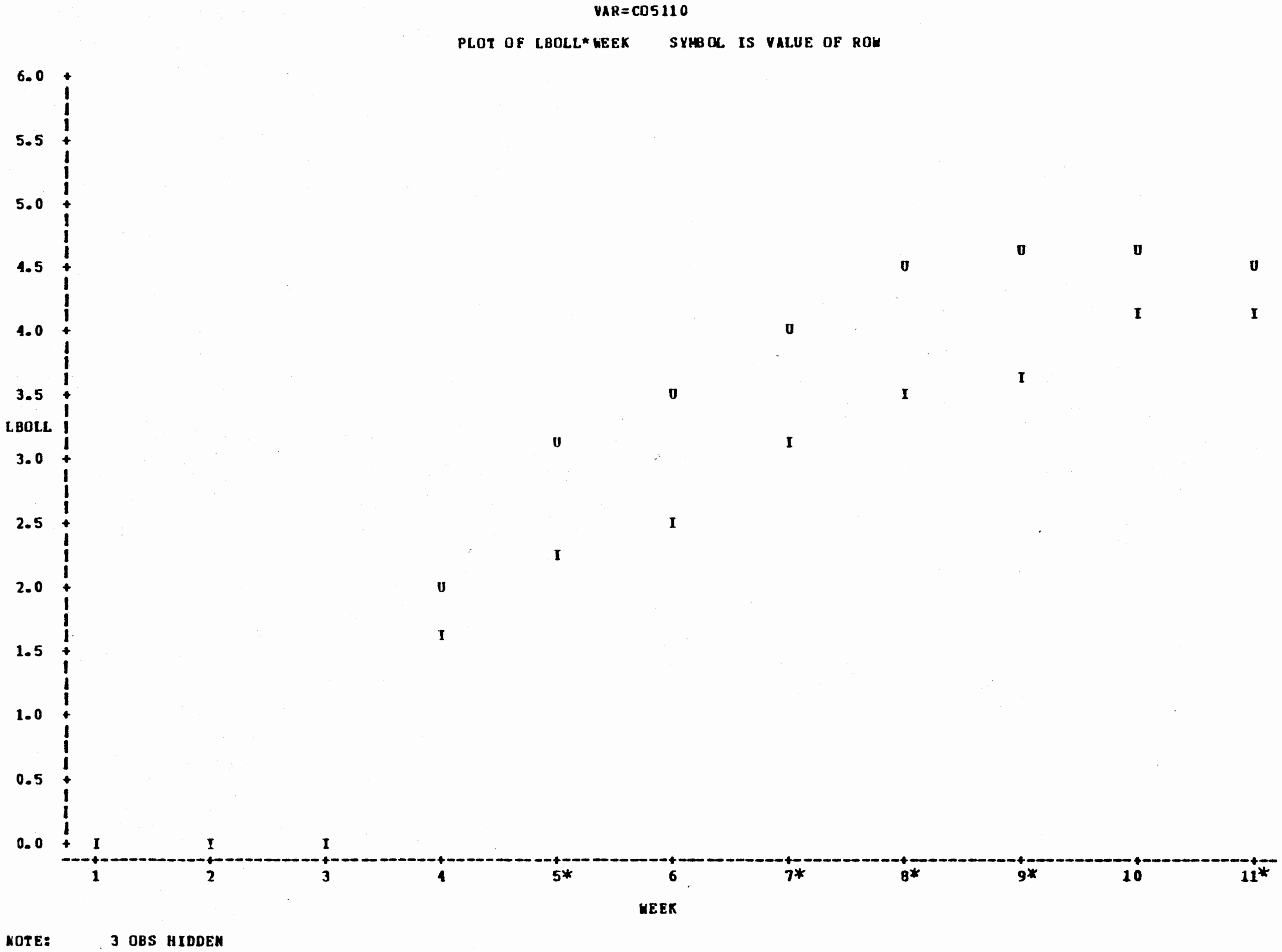
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 13. Log Value of Bolls by Week in the Cultivar 'Acala SJ-5'



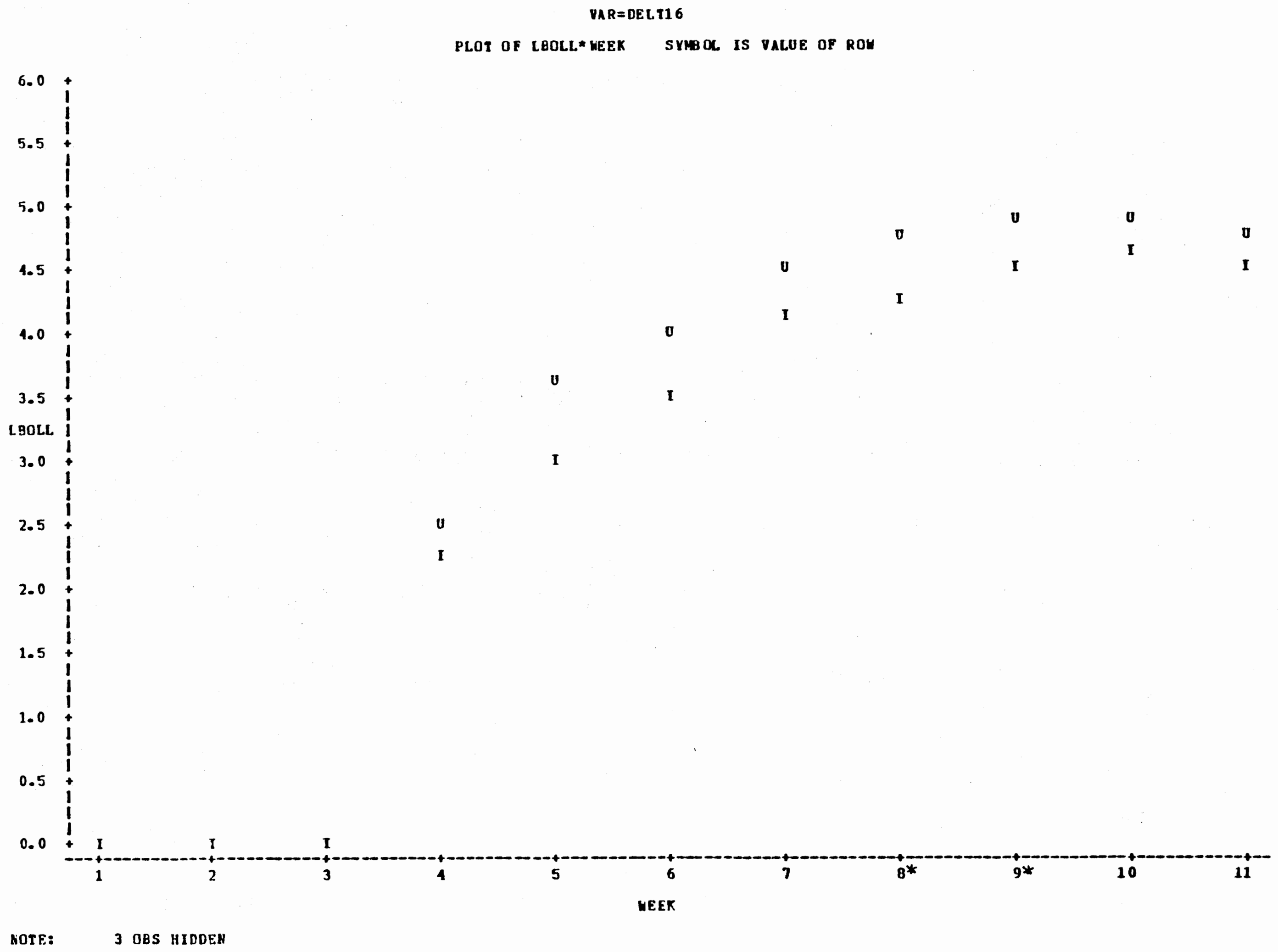
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 14. Log Value of Bolls by Week in the Cultivar 'Acala 1517-77'



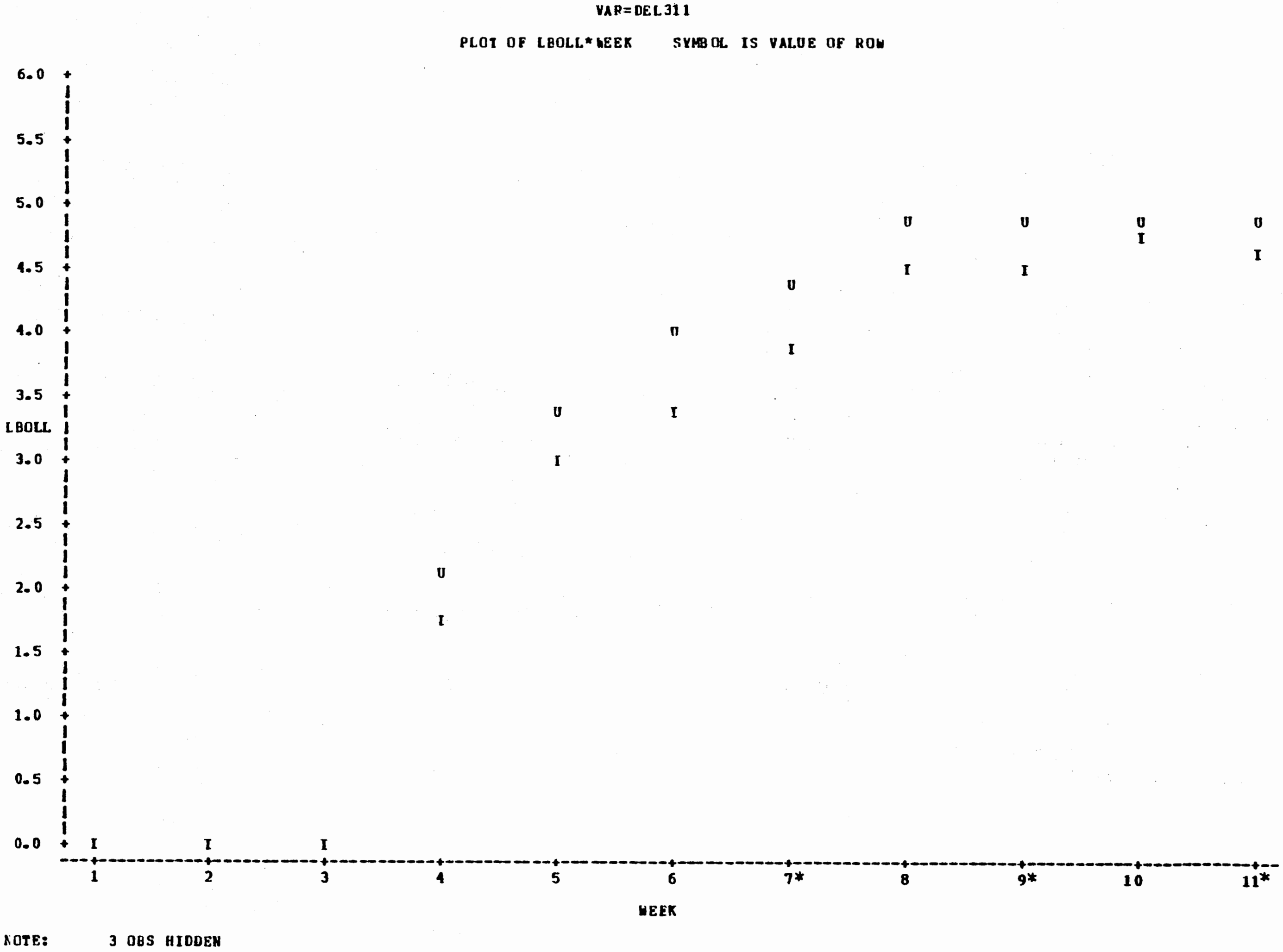
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 15. Log Value of Bolls by Week in the Cultivar 'Coker 5110'



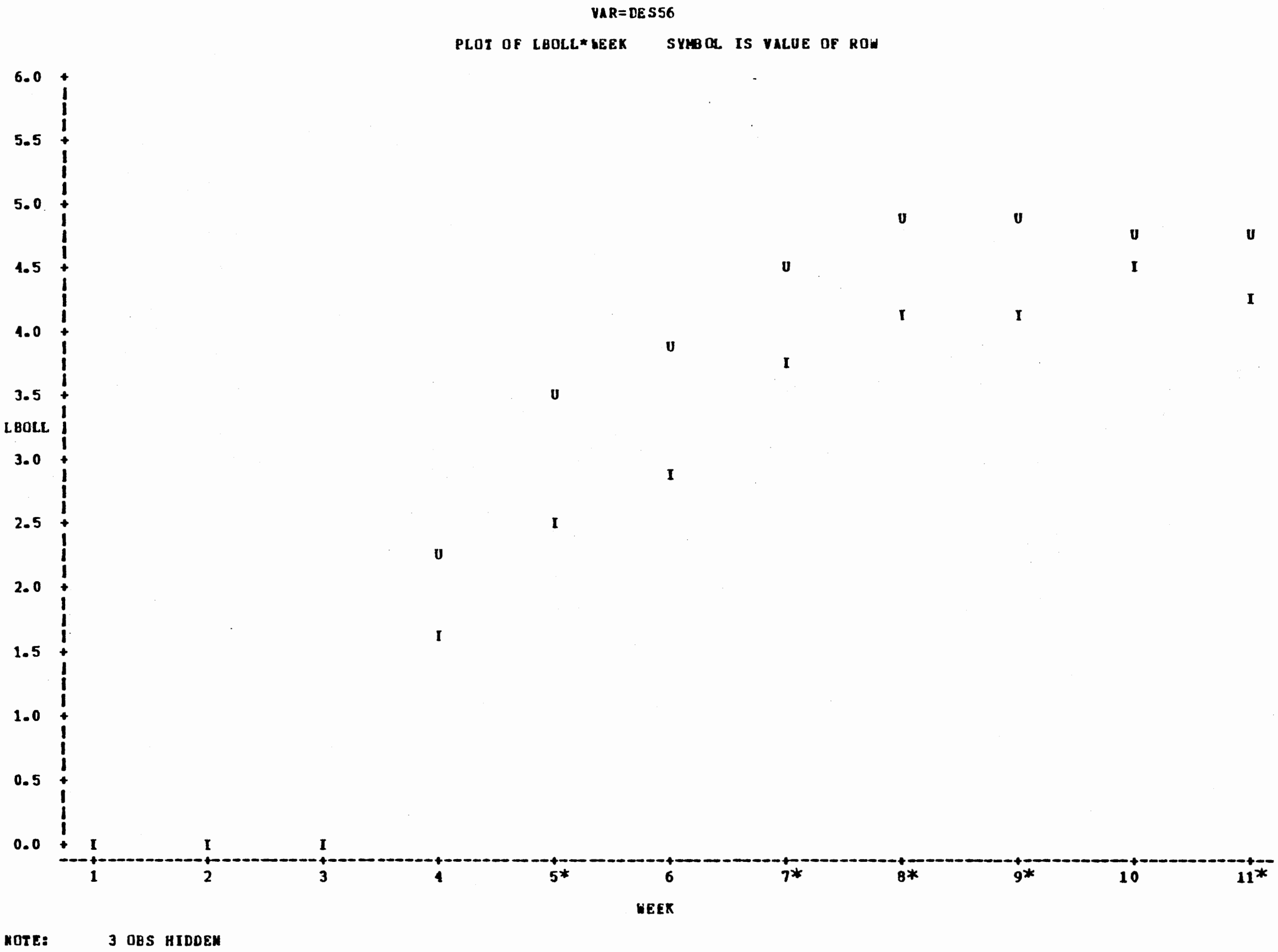
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 16. Log Value of Bolls by Week in the Cultivar 'Deltapine 16'



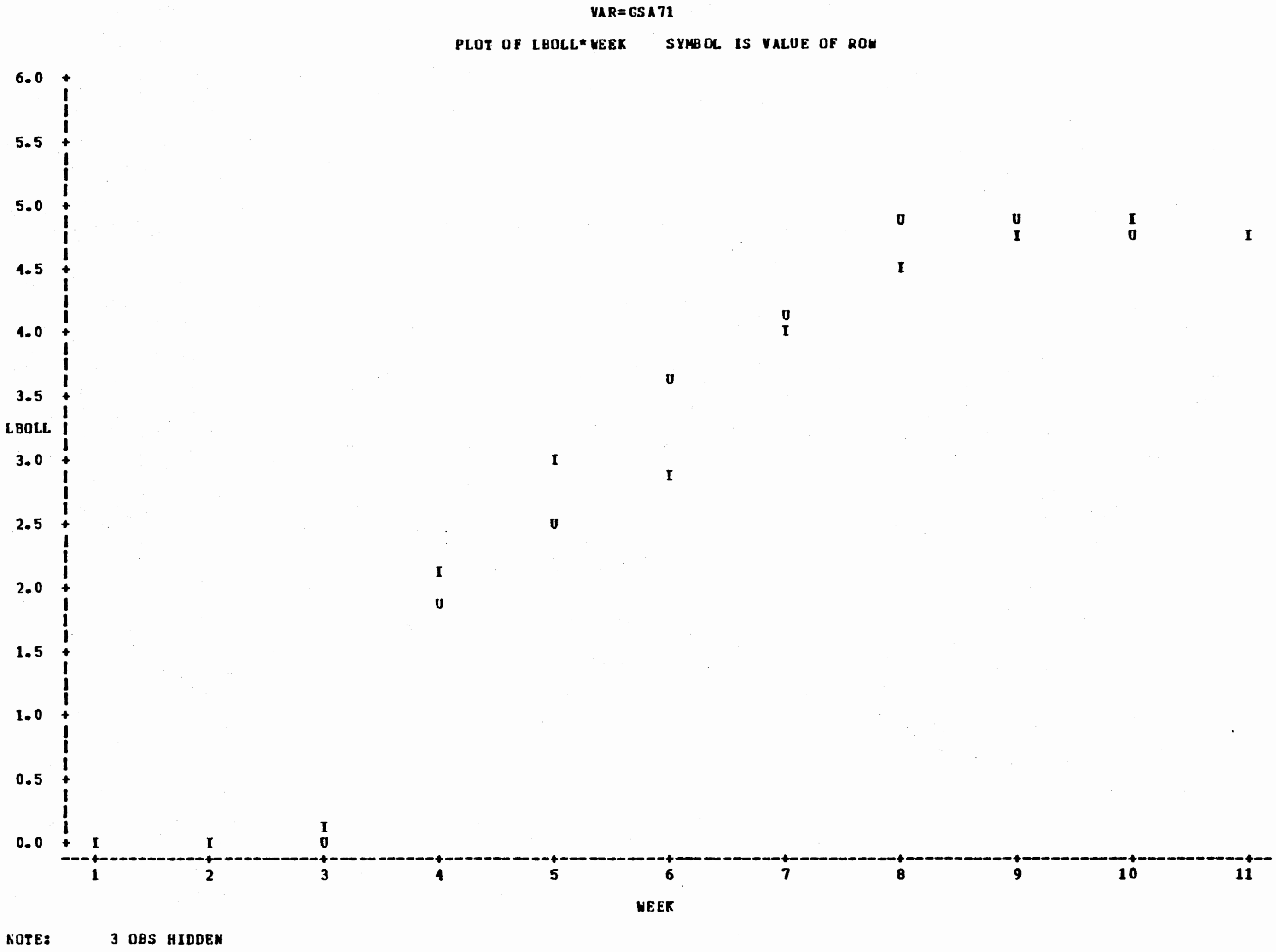
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 17. Log Value of Bolls by Week in the Cultivar 'Delcot 311'



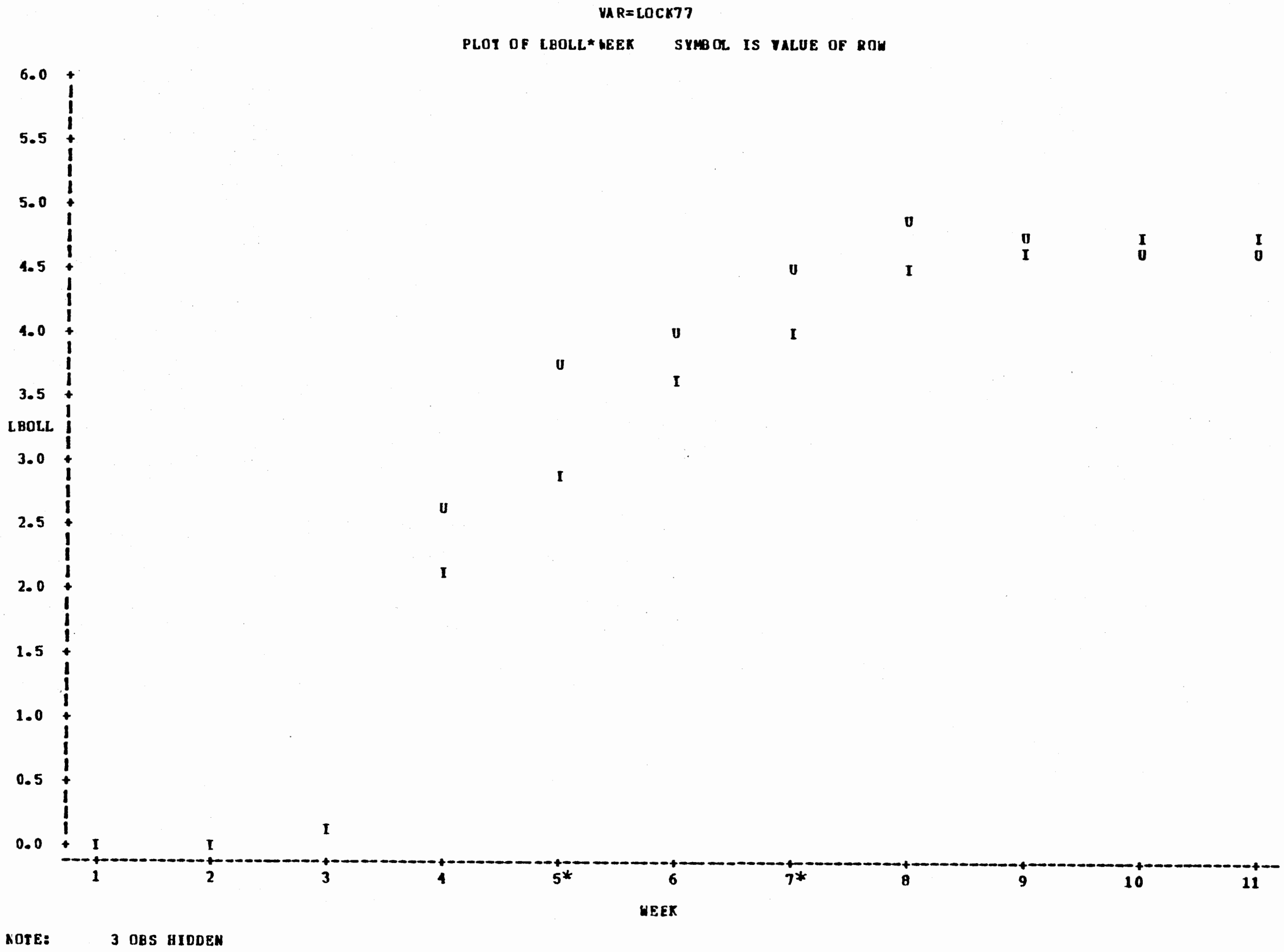
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 18. Log Value of Bolls by Week in the Cultivar 'DES 56'



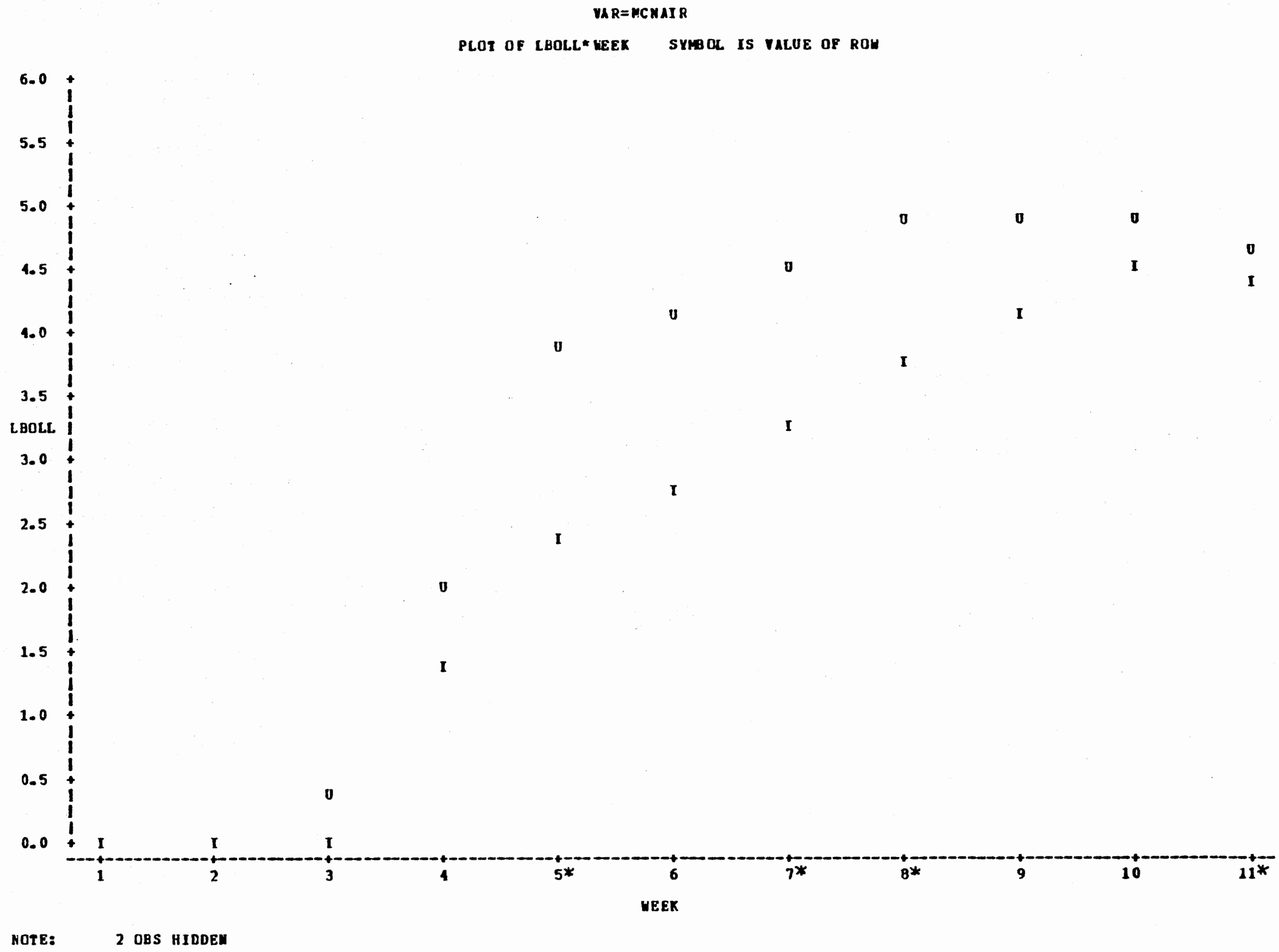
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 19. Log Value of Bolls by Week in the Cultivar 'GSA 71'



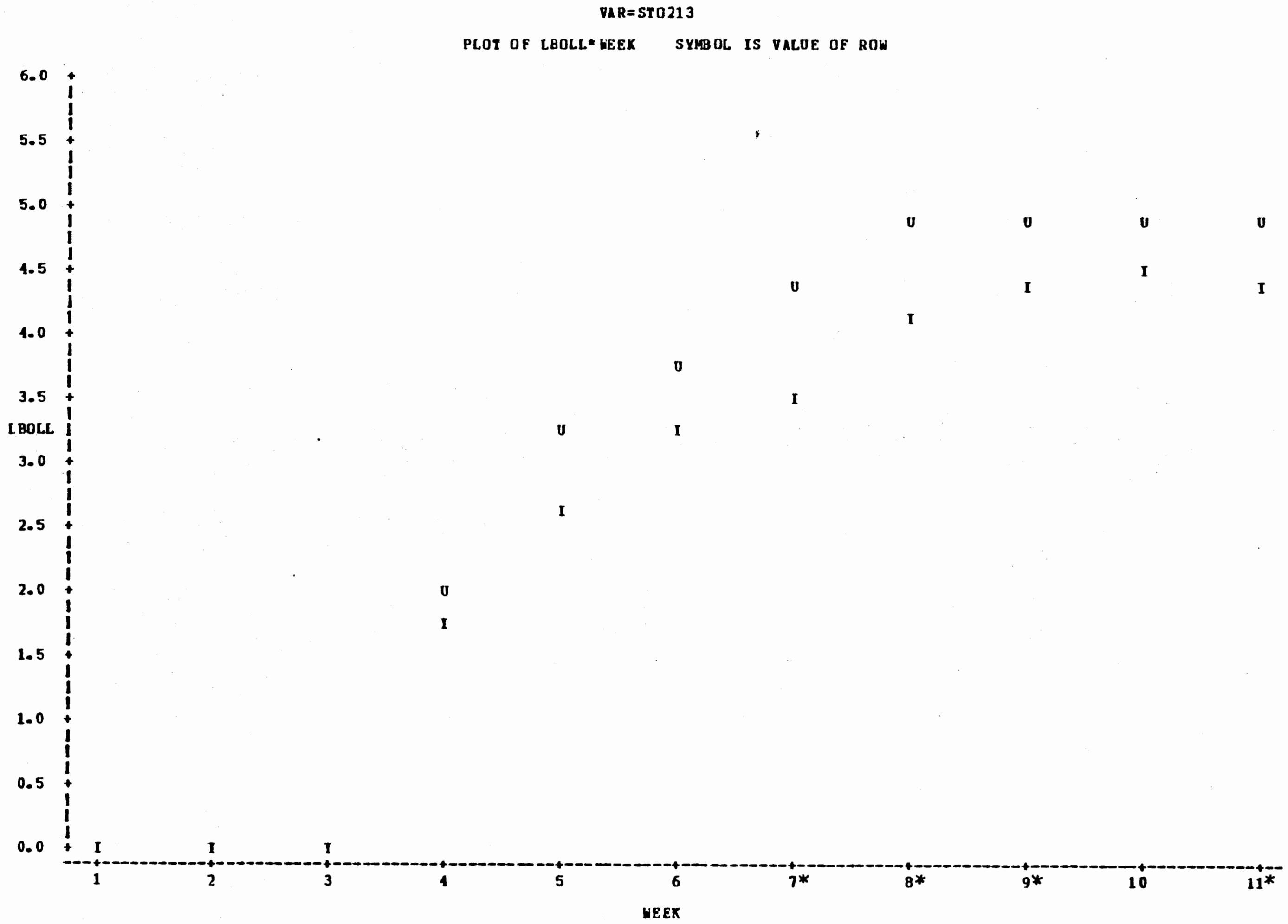
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 20. Log Value of Bolls by Week in the Cultivar 'Lockett 77'



*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

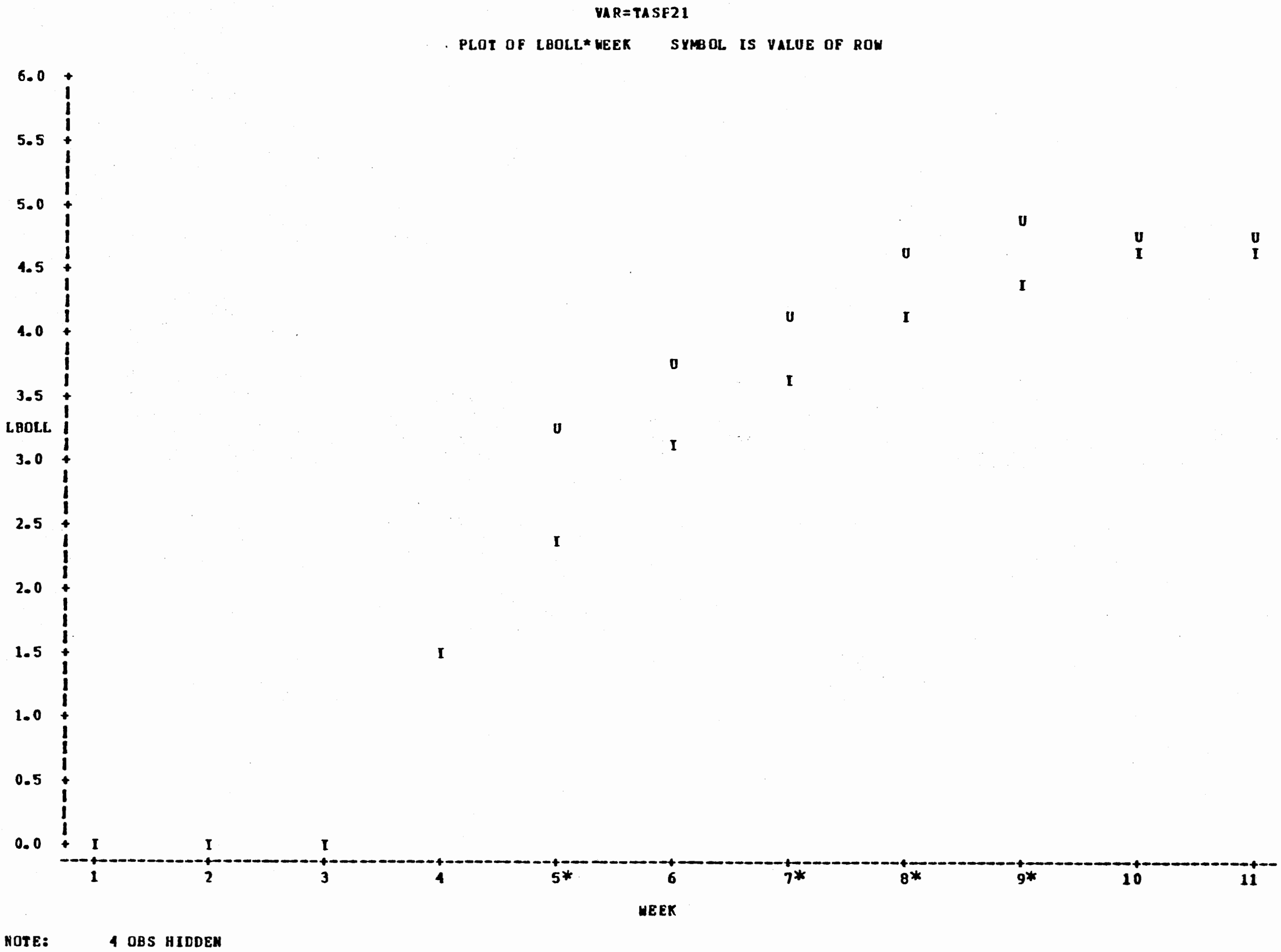
Figure 21. Log Value of Bolls by Week in the Cultivar 'McNair 235'



NOTE: 3 OBS HIDDEN

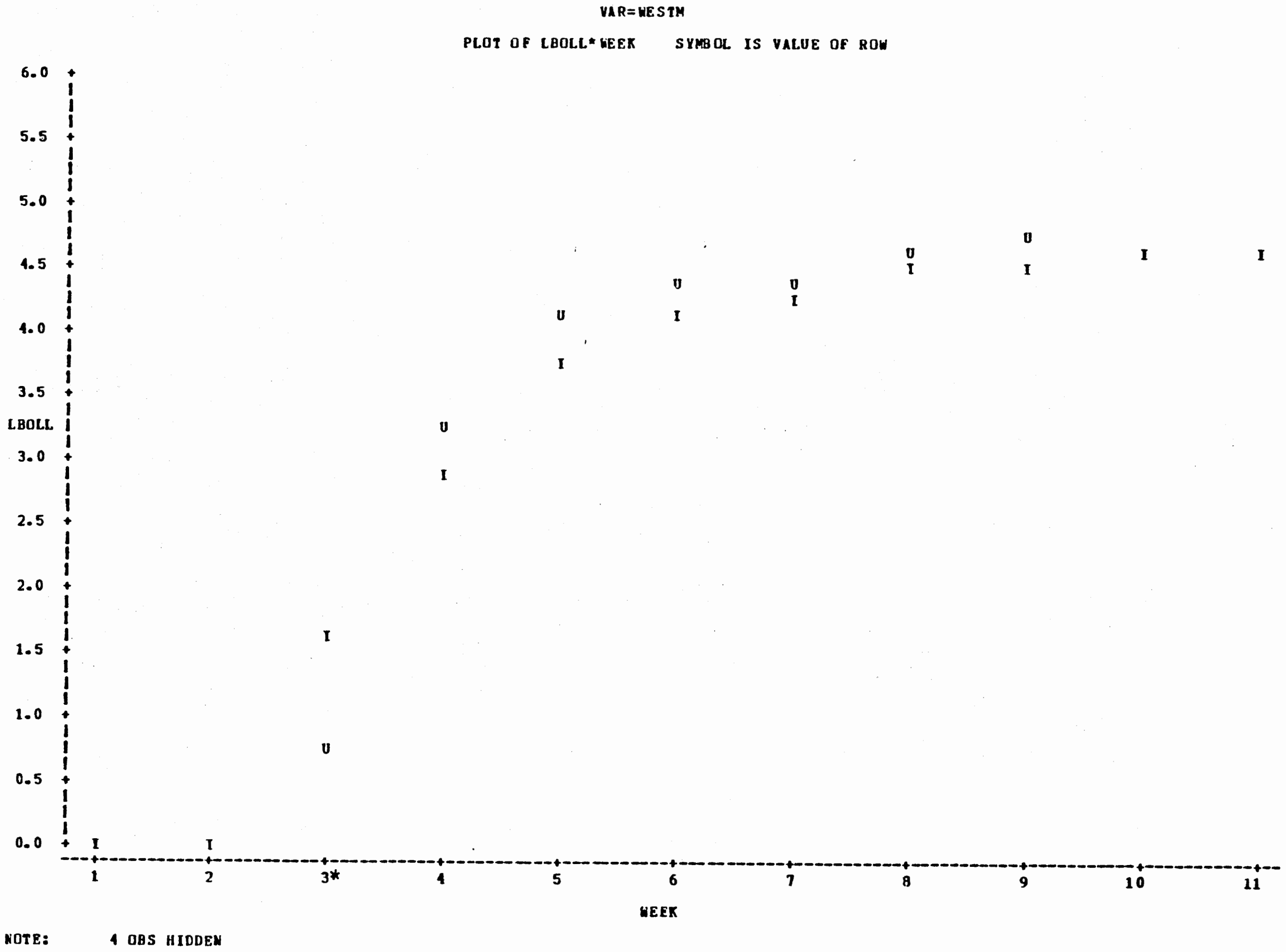
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 22. Log Value of Bolls by Week in the Cultivar 'Stoneville 213'



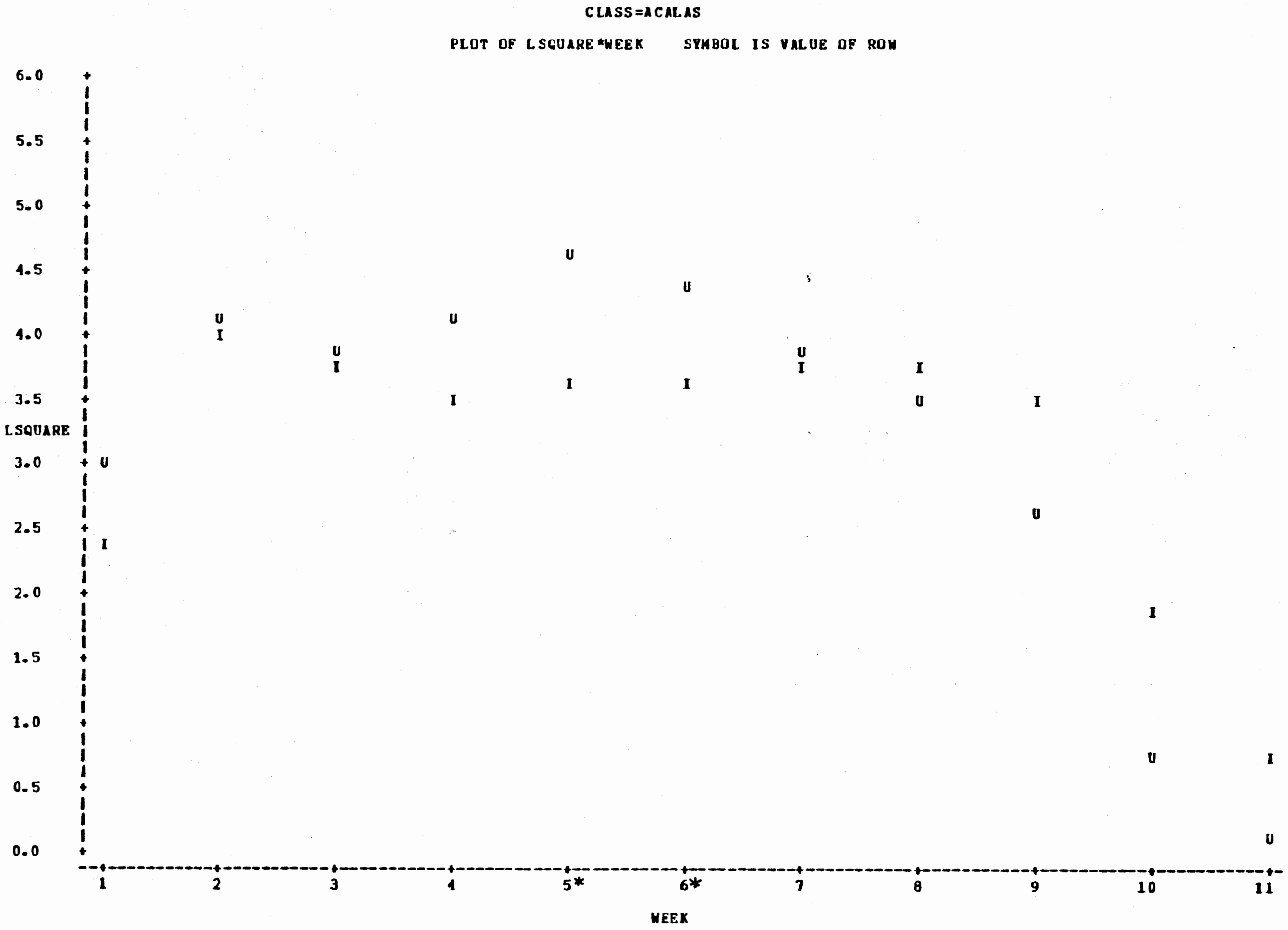
*Indicates dates when boll numbers in the infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 23. Log Value of Bolls by Week in the Cultivar 'Tamcot SP21'



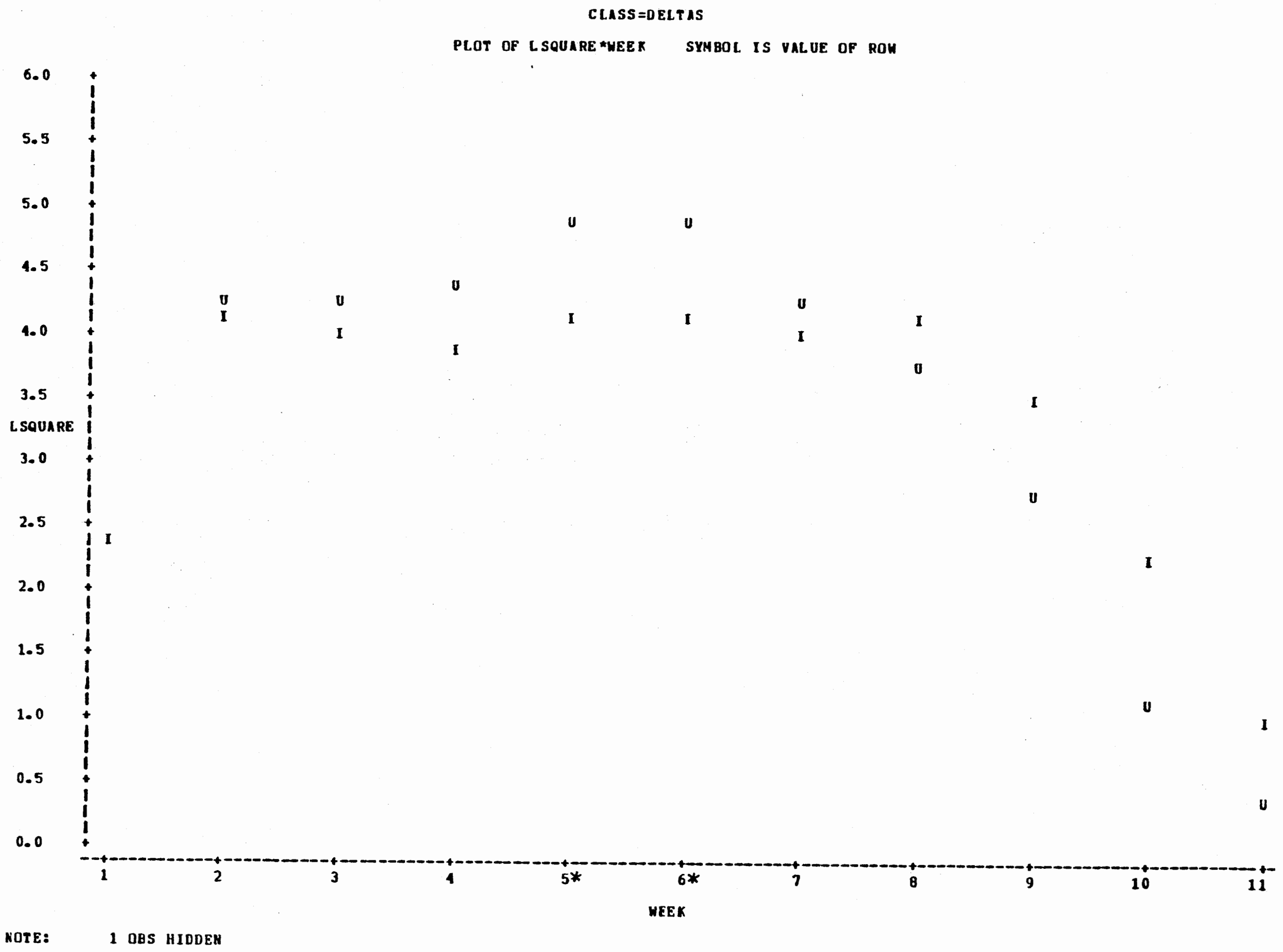
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 24. Log Value of Bolls by Week in the Cultivar 'Westburn M'



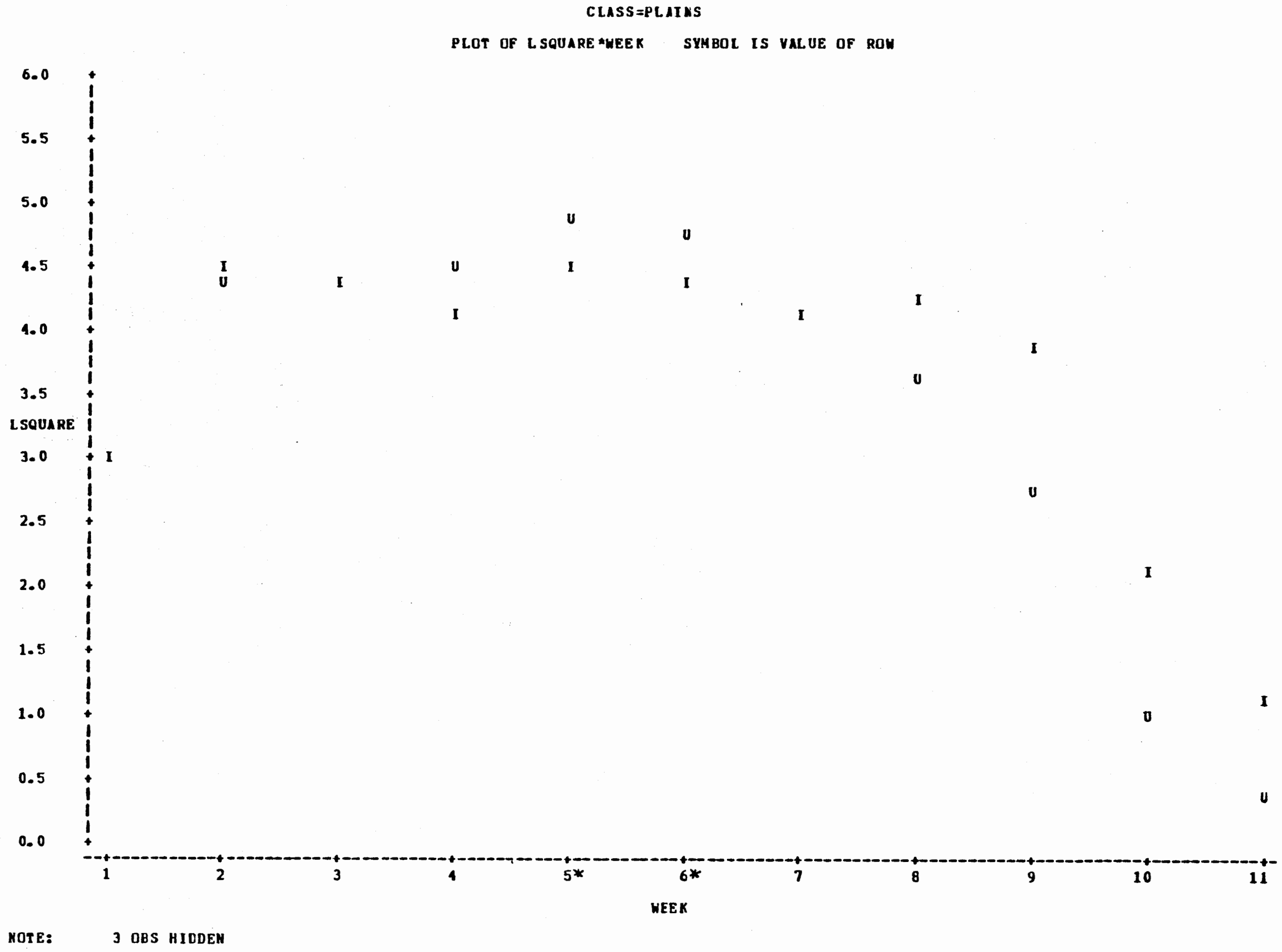
*Indicates dates when square numbers in infested (I) and uninfested (U) rows ficantly different at the 0.05 probability level

Figure 25. Log Value of Squares by Week in the Class "Acala"



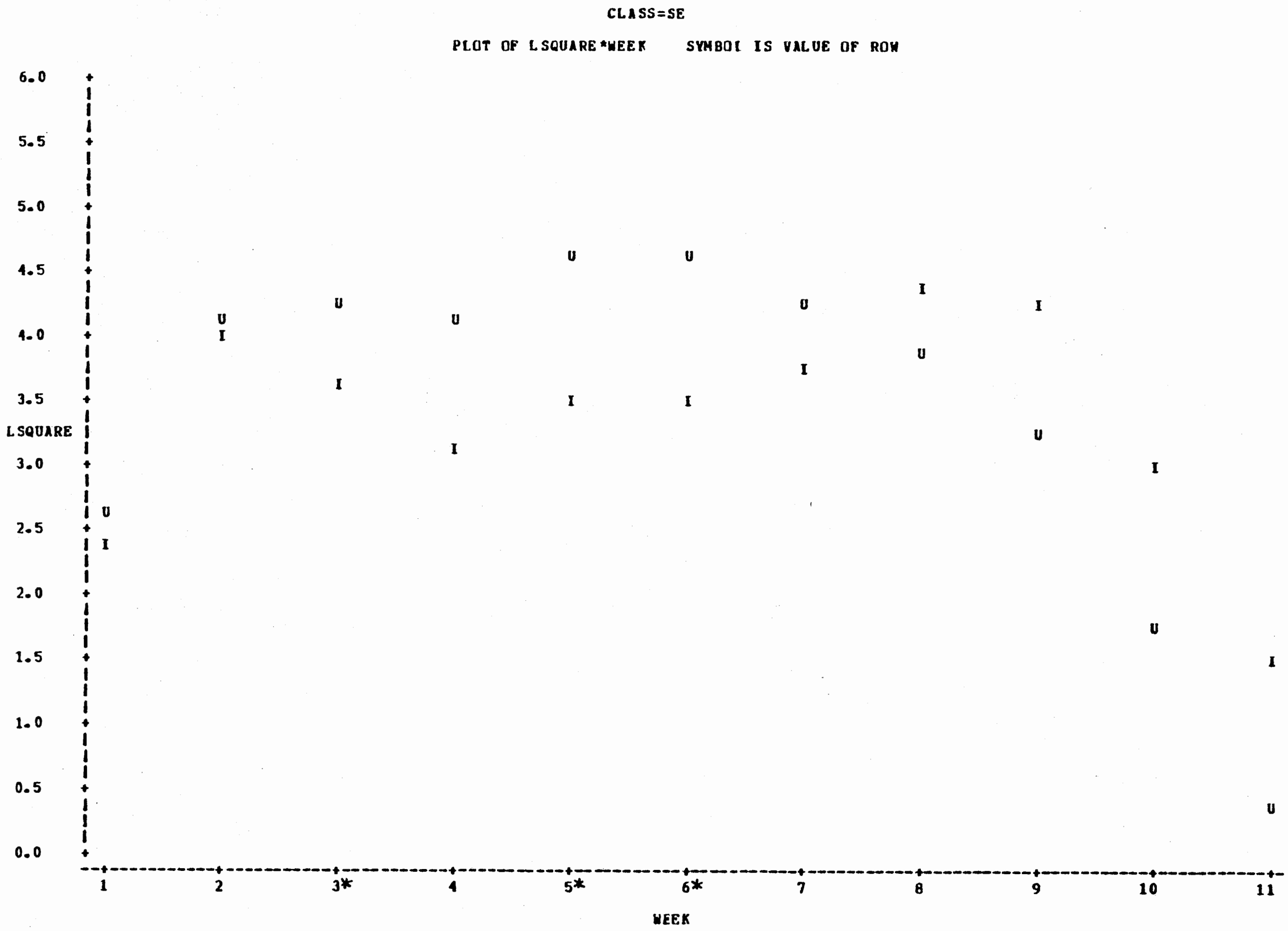
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 26. Log Value of Squares by Week in the Class "Delta"



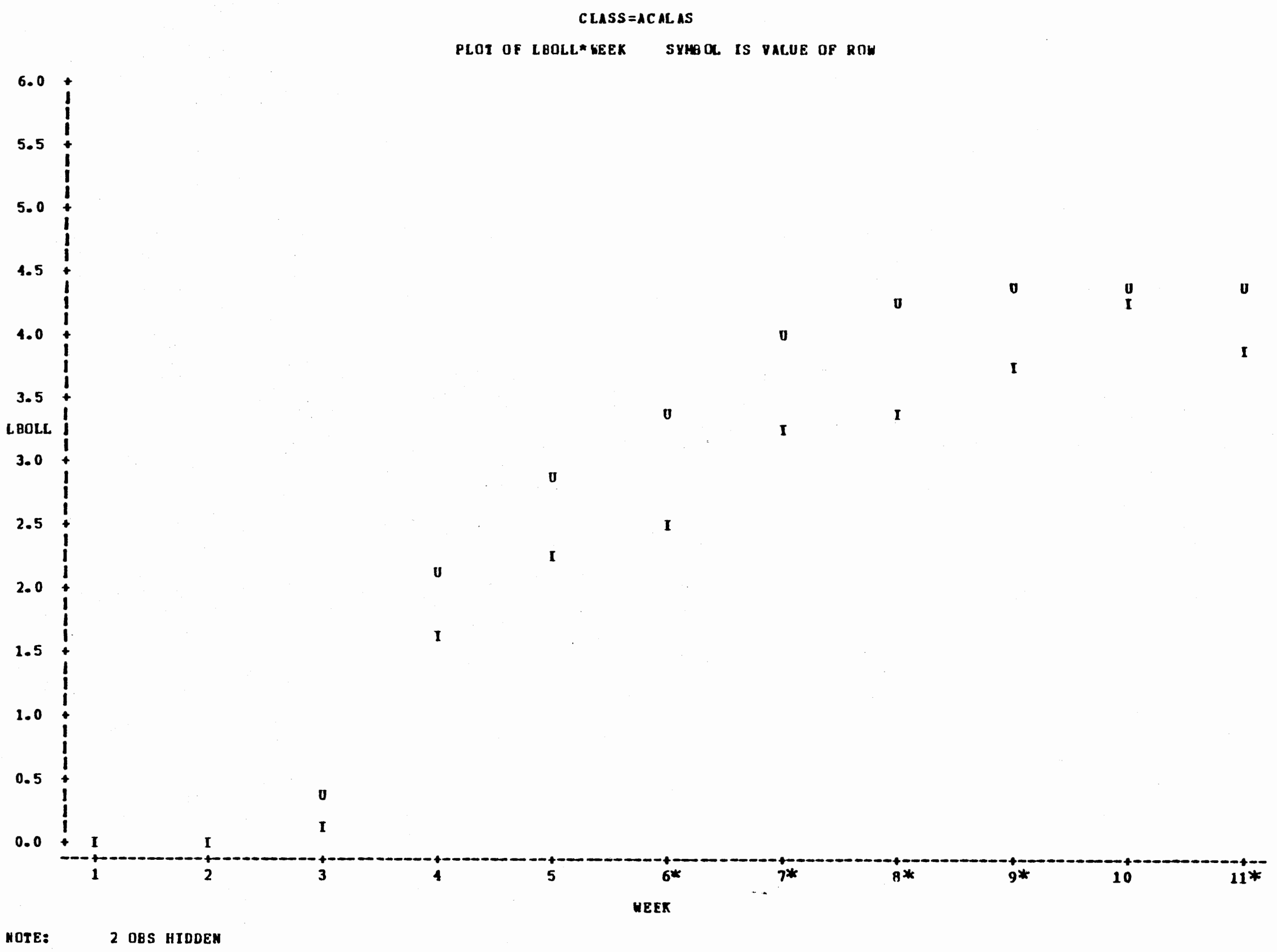
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 27. Log Value of Squares by Week in the Class "Plains"



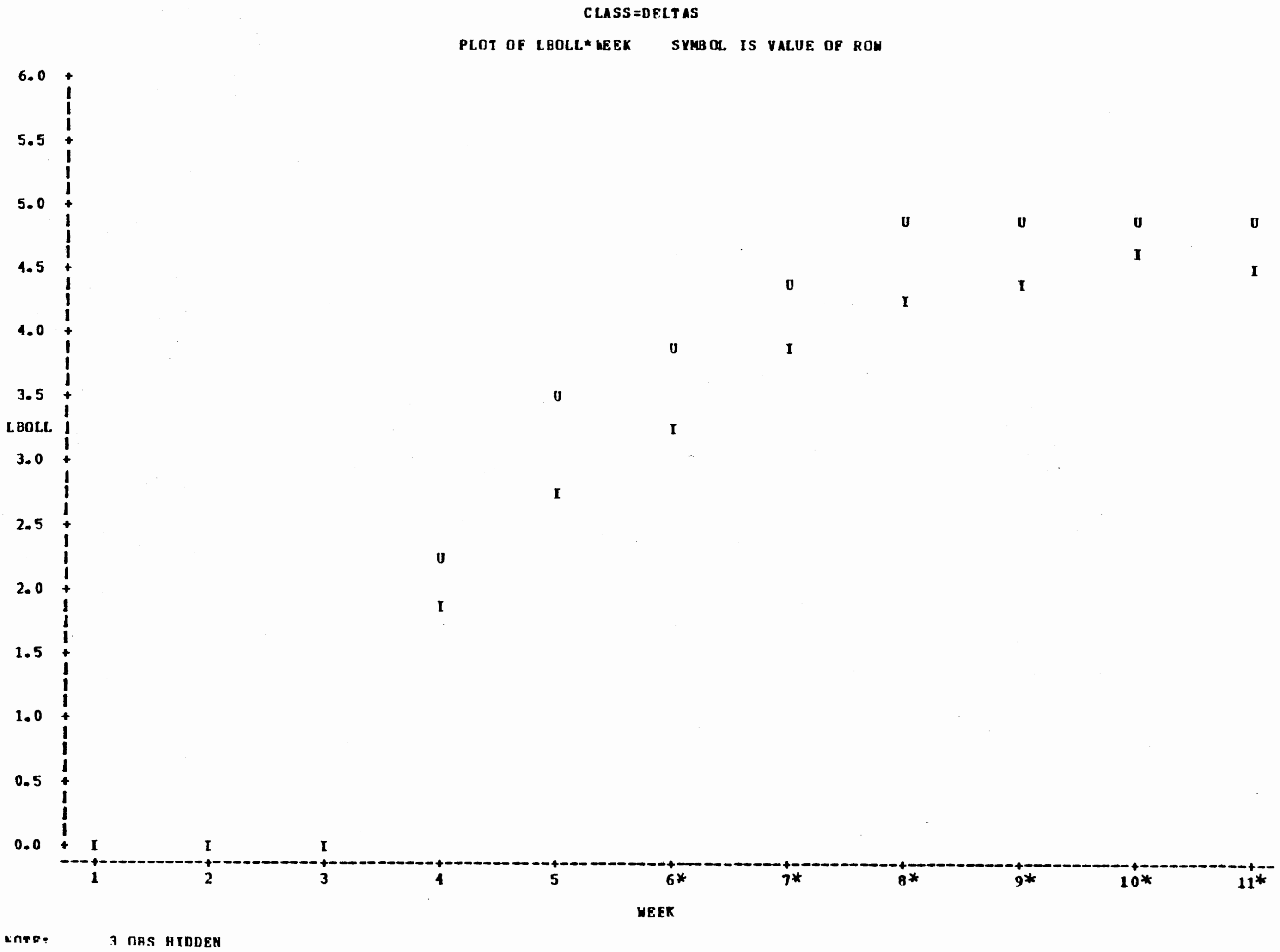
*Indicates dates when square numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 28. Log Value of Squares by Week in the Class "Southeast"



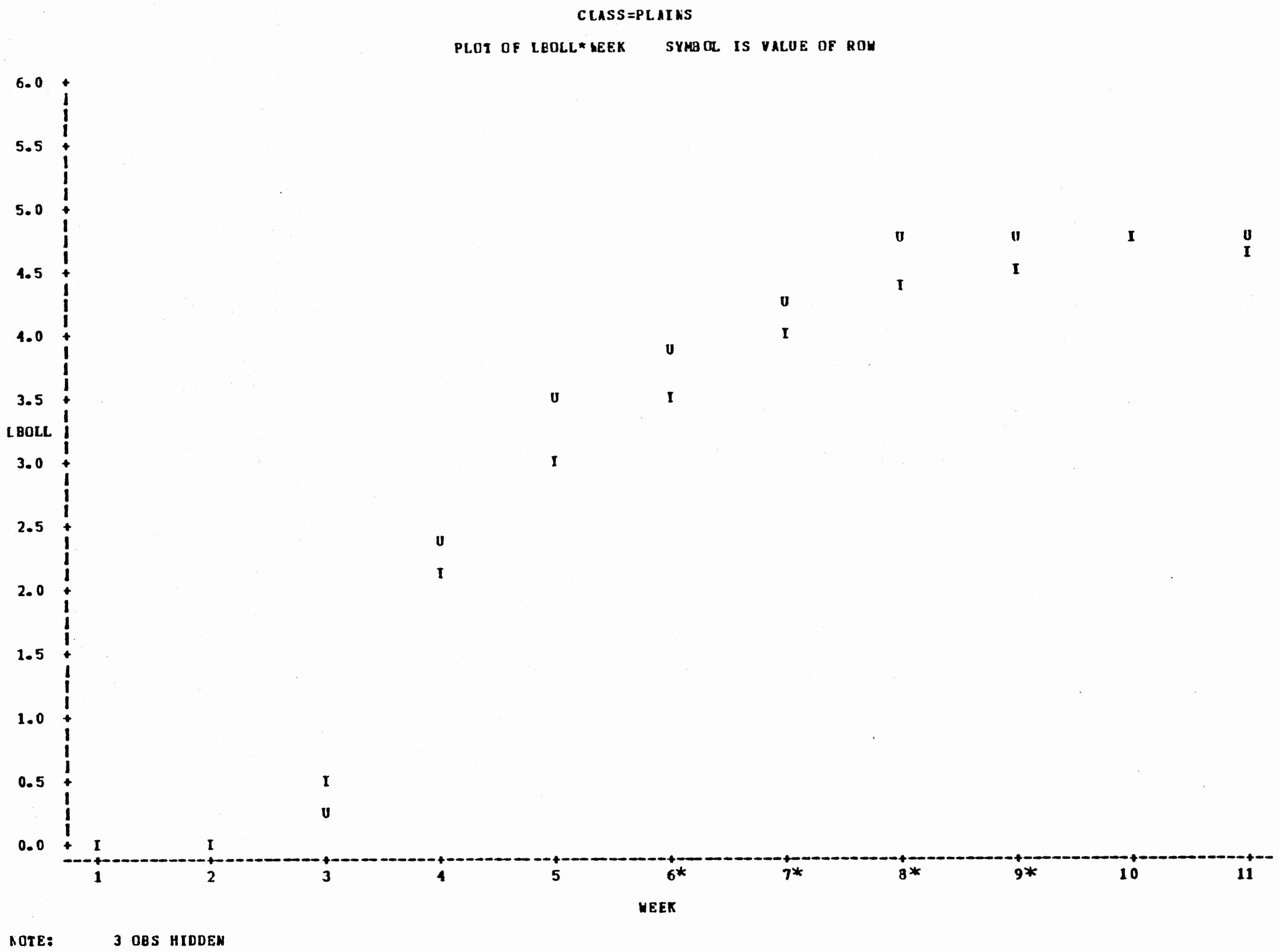
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 29. Log Value of Bolls by Week in the Class "Acala"



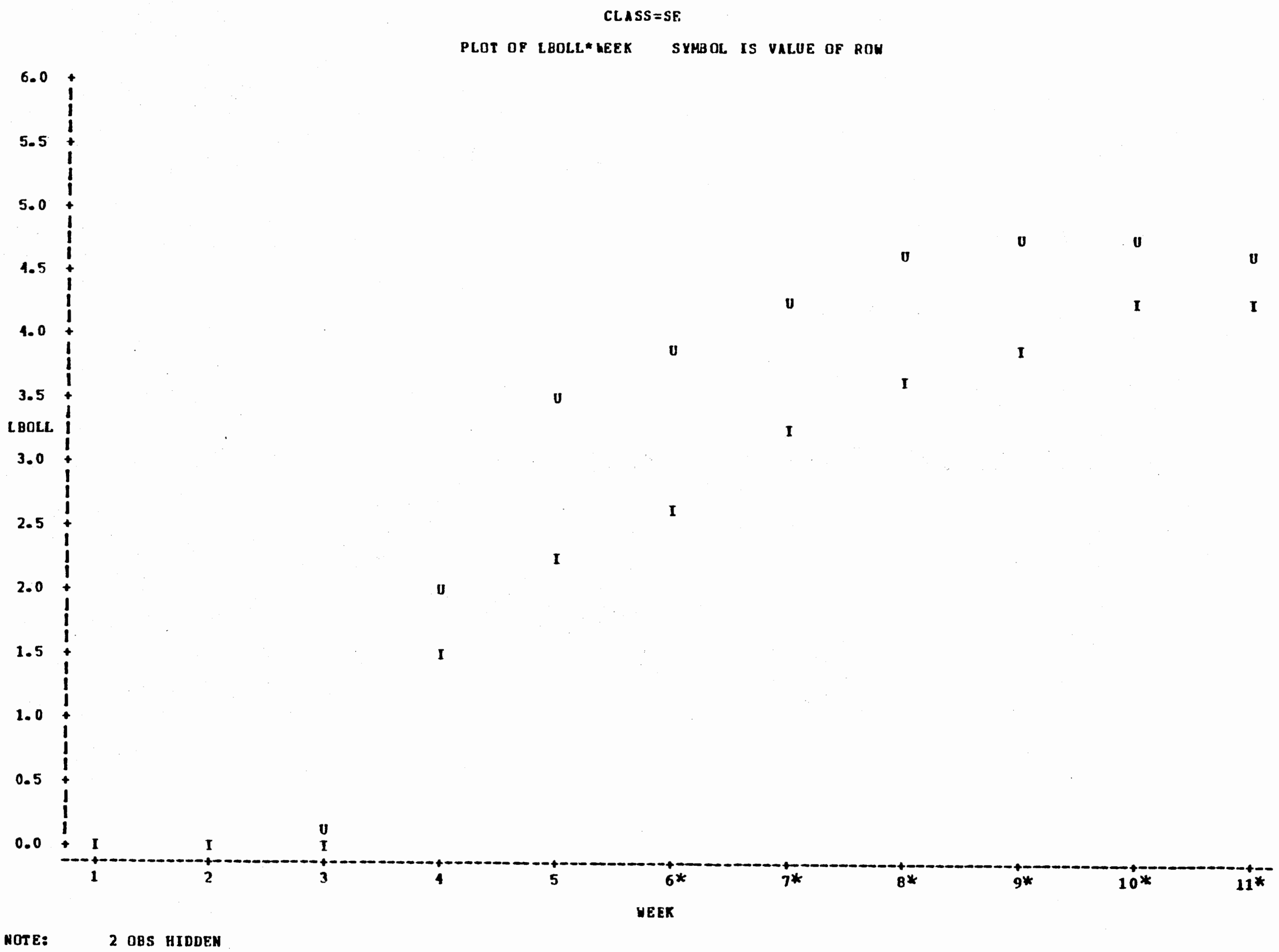
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 30. Log Value of Bolls by Week in the Class "Delta"



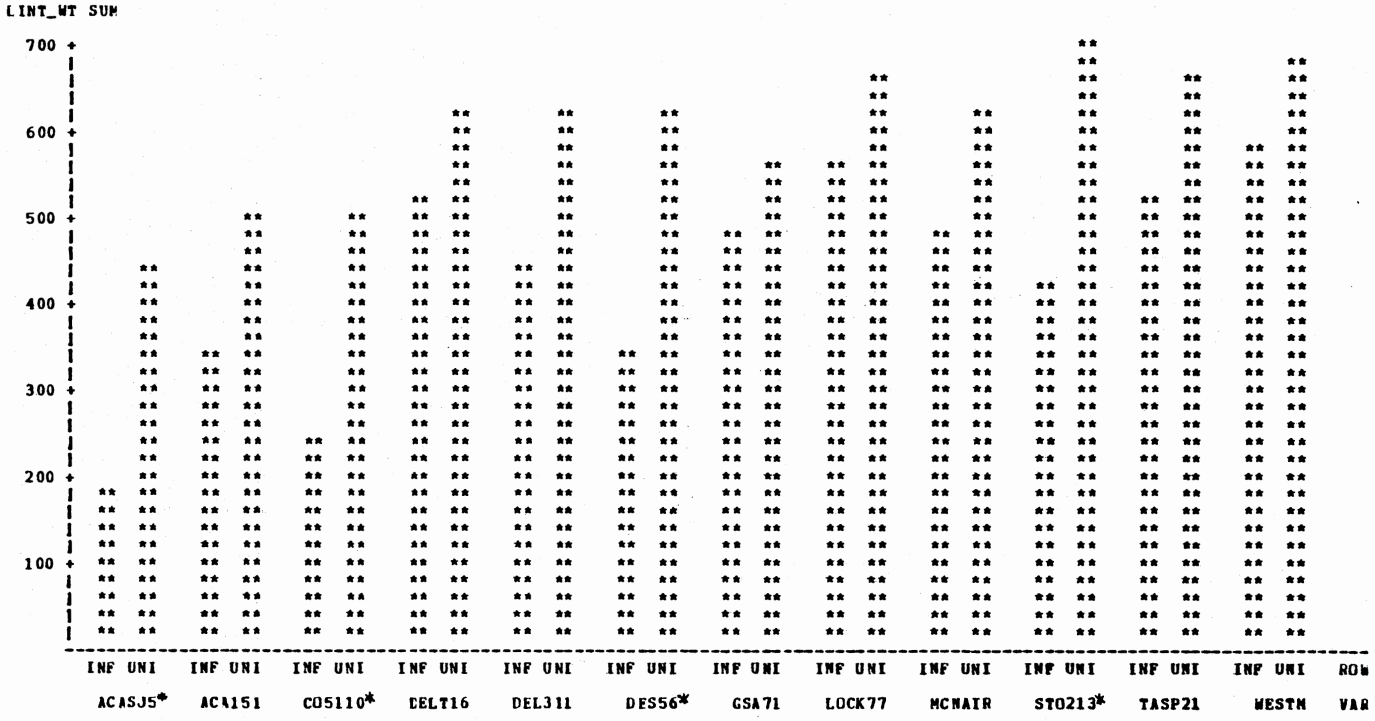
*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 31. Log Value of Bolls by Week in the Class "Plains"



*Indicates dates when boll numbers in infested (I) and uninfested (U) rows were significantly different at the 0.05 probability level

Figure 32. Log Value of Bolls by Week in the Class "Southeast"



*Indicates a significant difference between infested (INF) and uninfested (UNI) rows within a particular cultivar (0.05 probability level)

Figure 33. A Comparison of Lint Weight (grams/3 row meters) Between Infested vs. Uninfested Rows for 12 Cotton Cultivars

VITA

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Doctor of Philosophy

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