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The biology and control of the clover root curculio : *Sitona hispidula* (F.) in Massachusetts with observation on *Sitona flavescens* Marsh.

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THE BIOLOGY AND CONTROL OF THE
CLOVER ROOT CURCULIO, *Sitona hispidula* (F.)
IN MASSACHUSETTS
WITH OBSERVATIONS ON *Sitona flavescens* MARSH.

LAVIGNE 1960

THE BIOLOGY AND CONTROL
OF THE
CLOVER ROOT CURCULIO, Sitona hispidula (F.)
IN MASSACHUSETTS
WITH OBSERVATIONS ON Sitona flavescens MARSH.

by

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Thesis submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

University of Massachusetts, Amherst

DECEMBER 14, 1960

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INTRODUCTION

As a contribution to our knowledge of the insects effecting forage crops in Massachusetts, a study has been made of the biology and control of the clover root curculio, Sitona hispidula (F.) with incidental observations on its close relative, Sitona flavescens Marsh.

Previous to this study, no information was available concerning the distribution, biology, or importance of this weevil as a pest on forage in Massachusetts. Quinton (1956) noted that while in the past, S. hispidula had not been regarded as a major pest on forage crops, the amount of root injury being found in Connecticut fields was causing a revision of opinion. In New Hampshire, Lee (1957) reported finding as high as 54 Sitona larvae per square foot feeding on white clover roots in plots at Durham, N.H. Shaw and Levigne (1957), while comparing the numbers of Sitona larvae feeding on the roots of various legumes found as many as 139 larvae per square foot in alfalfa. Such a high incidence of this curculio in addition to the sudden appearance of the alfalfa weevil, Hypera postica Gyll., created a great deal of concern among entomologists in Massachusetts.

In connection with the regular work on the control of insects affecting forage crops, it was felt that more extensive studies should be undertaken to determine effective control measures for this species. In addition, the workers at the Massachusetts Agricultural Experiment Station felt it advisable to determine more specifically the effect of the clover root

curculio on legumes with special reference to type of injury,
economic importance and the stage or stages in which this
insect would prove most susceptible to control measures.

REVIEW OF THE LITERATURE

Sitona hispidula

Economic Importance

While some difference of opinion has existed among entomologists concerning the economic importance of Sitona hispidula, it is apparent, as more information becomes available, that the destructive potential of this insect is far greater than previously realized.

Brischke (1876) reported finding a clover field in the neighborhood of Dirschau, Germany which had been "burnt out" in spots by the attack of the immature forms of this weevil.

Wildermuth (1908) found S. hispidula attacking clover in the vicinity of Washington, D. C., in Corning, N. Y., and in Marion, Penn. In the latter two areas he noted that "the species were found in numbers large enough to be a decided detriment to the clover crop". Two to six beetles were found at the base of every plant and the damage was readily noticeable. He remarked that while this insect had never been so abundant in this country as to totally destroy a clover crop, there was no doubt that injuries, which heretofore had been either unnoticed or attributed to other insect pests, were probably partly the work of the adults and larvae of this beetle.

Smith (1910) indicated that while S. hispidula was sometimes locally common in New Jersey, it had never occurred in such numbers as to make it actually injurious.

Petit (1914), in Michigan, stated that "the clover snout beetle" (Sitona hispidulus) was reported to have been the source of considerable injury to alfalfa. In New York, Parrott (1914)

noted that this weevil was very common on alfalfa and had done a great deal of damage in young plantings in Seneca and Ontario counties.

Smith (1914) in the course of investigation of a nematode disease of red clover noted that the death of diseased plants was hastened by the work of secondary agents among which was included S. hispidula.

Webster (1915a) noted that while the depredations of this weevil were very infrequent at the time of Wildermuth's (1908) study, within five years the larvae of this same insect were found to be seriously destructive in alfalfa. Webster (1915b) reported serious damage to alfalfa plantings in Maryland where the roots of dying plants were badly scarred. He also noted that similar damage had been reported from Pennsylvania. He felt that its work was so obscure that it completely escaped the attention of alfalfa growers. In the same year, Herrick, in New York and Seder, in Iowa reported serious damage to clover and alfalfa by this species, and Cory, in Maryland, observed that adults of S. hispidula had attacked newly planted lima beans.

In central Russia, Sopotzko (1916) recorded S. hispidula as injuring clover. Pettit (1918) in a brief statement of the entomological work of the year in Michigan reported that the "clover leaf beetle" was becoming common on alfalfa and was attacking all clovers. He noted that entire fields were being destroyed in some regions.

Gossard (IPS, 1921) in Ohio observed that S. hispidula, in combination with Hypera nigrirostrus and a fungus disease, was

making it almost impossible to grow a crop of red clover successfully.

In a study of the bionomics of the weevils of the genus Sitona in Britain, Jackson (1922) reported that S. hispidula was common and widely distributed and wherever present was injurious to clover and lucerne.

In the same year, Jackson (1922) reported that owing to the drought during the summer of 1921, the second growth of clover in hay fields was very backward and the leaves were seriously attacked by adults of Sitona lineata, S. puncticollis, S. flavescens, S. sulcifrons and S. hispidula.

Flint (IPS, 1922)* reported that in Illinois, S. hispidula was causing severe injury to soybeans planted on clover sod. Davis (IPS, 1922) reported the same conditions for Indiana. In Missouri, Burril (IPS, 1922) reported that this insect had riddled 60% of the leaves of soybeans grown in corn following blue grass sod.

The following year, Christie and Reed (1923) reported S. hispidula feeding on young soybean plants. Specimens sent to the U. S. Bureau of Entomology were determined to be S. crinita. However, Christie and Reed felt that there was reason to question this determination since S. crinita was a European species and had apparently not been previously reported from this country.

Davis (IPS, 1923) reported injury to the roots of alfalfa by S. hispidula in Blackford County, Indiana. In Illinois, Flint (IPS, 1923) noted that Sitona (?) larvae had caused serious damage to the roots of old stands of alfalfa in Central Illinois.

*IPS - USDA - Insect Pest Survey Bulletin

In November of the same year, he reported that adults of S. hispidula had caused some damage to newly-sown alfalfa.

Davis (IPS, 1925) noted that in Indiana, where much of the clover sod was planted to soybeans, adults of S. hispidula were causing damage to the new seedlings. At the same time, Flint (IPS, 1925) indicated similar conditions for Illinois.

Jenkins (1926) in Wales reported considerable injury to red clover in the spring by this species, particularly to seedlings.

In a survey of the alfalfa and clover insects in the North Pacific Region, Rockwood (1926) reported that the roots of clover and lucerne growing in the humid western valleys and irrigated districts of arid regions were damaged by S. hispidula.

Metcalf and Flint (1928) reported that clover or alfalfa plants infested by S. hispidula would wilt and often die, especially during periods of dry weather.

In Russia, Grossheim (1928) noted that the destruction of nodules by Sitona larvae completely nullifies the value of legumes in a crop rotation and may also reduce the value of the legume crop.

Hodson and Beaumont (1929) found that late sowings of peas and broad beans in Devon, England, were injured by Sitona lineata and S. hispidula.

Call (1930) reported that in Kansas S. hispidula was undoubtedly the most injurious species of curculionid on alfalfa and presented a "real menace to the alfalfa industry". In the same year, Bigger (1930) noted that in Illinois this insect was a potential

pest of clovers and alfalfa of considerable importance. He reported having found 36, 43, 33, 41, 39, and 37 larvae respectively in square foot samples at different points in a field in Morgan County.

In Illinois, Flint (IPS, 1931) reported that Sitona hispidula adults destroyed 45 acres of clover seeded the previous spring in Scott County. Price (IPS, 1932) stated that the clover root curculio had ruined several alfalfa fields in the vicinity of Frankfort and Independence, Kentucky.

Gorham (1932) reported that S. hispidula adults were attacking the heads and foliage of red clover and causing severe injury in some fields in New Brunswick. Larson and Hinman (1932), while surveying insect populations in pea fields in the Willamette Valley, Oregon following harvest, collected 27 adults of S. hispidula from a 10 foot square plot or the equivalent of 117,612 per acre.

Marshall and Wilbur (1934) reported on a five year study of this pest on alfalfa in Kansas. They found larval populations up to 25.6 per square foot, six inches deep in alfalfa fields. Jewett (1934) found that in Kentucky yields of alfalfa from plants infested for two seasons were reduced as much as 18.6 percent. He noted that there was very little difference in reduction of yield of plants from spring-sown and fall-sown seed.

Dean and Smith (1935) reported that Sitona hispidula increased in numbers on alfalfa from 1923 onward and reached a peak in Kansas about 1930. The dry years following 1930 were apparently unfavorable to it and it was still scarce in 1934.

Procter (1938) in Maine noted that the clover root curculio was a "real pest in places". In the same year, Stirrett (CIP, 1938)* found S. hispidula damaging red clover near Agassiz, Ontario. In Kansas, Smith and Kelly (1938) noted that damaging numbers of adults and larvae were reported from Wabaunsee county in June, 1937.

Shull and Fisher (1940) remarked that while S. hispidula was widely distributed in Idaho, it had been of comparatively little importance there, probably because of the rotation and irrigation systems followed.

In Oregon, Mote (IPS, 1941) reported that S. hispidula caused rather severe damage to a few fields of vetch south of Monroe. Anderson (1942) in the same state stated that farmers were no longer able to grow a good stand of clover after the first year due to the girdling of the roots by the larvae of this weevil. During July 1941 he examined 25 square foot samples taken at random through a 20-acre clover field and found that 86% of the roots showed injury.

Poos (1943) indicated that S. hispidula was generally distributed over the eastern United States and attacked all the common forage crop legumes, i.e. alfalfa, clovers, cow peas and soybeans. It was particularly injurious to young stands of alfalfa and red clover during periods of dry weather.

Smith and Michelbacher (1944) noted that while S. hispidula was common in alfalfa fields in California, it did not appear to be a serious pest.

*CIP - Canadian Insect Pest Review

Lambert (1945) reported this species as being exceptionally numerous along St. Francis River, Quebec and inflicting serious injury to the foliage of sugar maples.

Schwardt et al (1947) reported that the principal species of curculionid in red clover in Skaneateles, N.Y. was S. hispidula which they believed to be responsible for the greater part of the injury observed.

MacNey (1949) reported that in southwestern Ontario, S. hispidula caused moderate damage to red clover.

Elliot (1950), in West Virginia, reported that several species of Fusarium had been isolated from wilted red clover plants showing injuries on the roots caused by the clover root curculio. He felt that these injuries although generally superficial facilitated the entry of root pathogens.

In France, Hoffman (1950) noted that the larvae of S. hispidula attack the roots of various legumes sometimes causing serious depredations.

Gyrisco and Marshall (1950) reported that S. hispidula was of major importance in most years on legumes in New York. However, in 1951 they noted that this weevil did not occur in sufficient numbers to permit any conclusions as to the effectiveness of insecticides applied that year.

In the northern part of California, Lockwood and Gammon (1951) reported that the clover root curculio was responsible for considerable damage to alsike and ladino seed crops.

Packard (1951) remarked that the adults of S. hispidula "eat off soybean plants as fast as they appear above the ground" in

fields where the clover sod was plowed in the spring.

In California, Lockwood (CEIR, 1952)* reported that the larvae of S. hispidula caused heavy damage to roots of alsike clover in Modoc County and was probably a contributing factor in winter killing of clover. He found newly emerged adults up to 28 per square foot. During the same year, he (1952) noted that applications of DDT were significant in preventing heavy losses to alsike clover growers.

Wilson et al (1952) noted that the larvae of S. hispidula have injured a high percentage of roots in Indiana and may cause considerable damage formerly attributed to winter-killing.

Fenton (CEIR, 1953) reported that the clover root curculio appeared in damaging numbers on alfalfa near Rishomingo, Oklahoma. Davis (1953) reported that the "clover root curculio (Sitona hispidula Fab.) began emerging in unusually large numbers in northern Indiana August 25, 1952 indicating the importance of this pest."

Underhill and Turner (1953) noted that in Virginia the larvae of the clover root curculio may cause serious damage to the roots of alfalfa which may result in increase in winter heaving of injured plants.

Guppy (CIP, 1954) reported that S. hispidula adults were very numerous in Ontario and that in one field of alfalfa at Carp on August 14, adults averaged 430/100 sweeps. Damage to the foliage was not serious however.

The University of Maryland Entomology Department (CEIR, 1954) reported one to three larvae per alfalfa plant in late March in

several counties. Morris (CEIR, 1954) in Virginia reported obtaining 2-49 adults per 100 sweeps in Albemarle County in early June. In late June, he found 12-15 adults per square foot sample in alfalfa.

University of Maryland (CEIR, 1954) reported finding 5-6 adults per alfalfa crown in late June on the University farm. In Canada, MacNay (1954) noted that S. hispidula adults were locally numerous on alfalfa in the Ottawa district.

Parks and Coleman (CEIR, 1954) reported that adults of the clover root curculio were seriously damaging young soybean foliage in one field in Sandusky County, Ohio. Pepper (CEIR, 1954) remarked on some serious leaf feeding by adults of this insect on a second cutting clover mixture in Cumberland County, Pennsylvania, in early July. Turner (CEIR, 1954) reported serious injury to red clover in late July in Montgomery County, Virginia. Walz (CEIR, 1954) reported losses in clover fields scattered over Canyon County, Idaho in early August.

In Oregon, Dickson and Every (1955) indicated that while larval feeding of S. hispidula was associated with reduced crop stands, it had not been possible to prove that this decline was entirely due to the insect.

The Entomological Staff at Iowa State College (CEIR, 1955) reported that the clover root curculio destroyed several acres of red clover following first cutting. Morris (CEIR, 1955) reported heavy infestations in Virginia with some damage to clover in several counties. The Illinois Extension Service (CEIR, 1955) reported damage to marginal rows of soybeans from adults migrating

from a nearby clover field in Fayette County in early July. Thomas and Kyd (CEIR, 1955) reported heavy damage to soybean plantings near clover fields in Missouri in 1954.

In Virginia, Morris (CEIR, 1955) obtained up to 19 adults per 100 sweeps in Virginia. Petty (CEIR, 1955) obtained 8-36 per 100 sweeps in southern half of Illinois. Maryland (CEIR, 1955) reported 22-32 per 100 sweeps on red clover in Corchester County. Matthew (CEIR, 1955) obtained up to 18 adults per 25 sweeps in Anderson County, Kansas in April. Anderson and Connin (CEIR, 1955) obtained 2-6 adults per 25 sweeps on alfalfa in the east central area of Nebraska.

Colorado (CEIR, 1955) reported heavy damage to sweet clover by S. hispidula in Larimer County. Johannsen (CEIR, 1955) collected up to 8 adults per 100 sweeps on alfalfa, 2 adults/100 sweeps on red clover and 3 adults/100 sweeps on white clover in late May in Washington. Kyd and Thomas (CEIR, 1955) reported that a few fields of red clover were heavily damaged in the central area of Missouri with counts of 12-24 larvae per alfalfa crown. They also found 3-12 adults per square foot in alfalfa stands in late June.

Maryland (CEIR, 1955) noted that S. hispidula adults were seriously damaging the foliage of soybeans planted after clover in St. Mary's County. Kyd and Thomas (CEIR, 1955) reported considerable adult leaf feeding damage in old fields of red clover in Missouri with from 2-9 adults present per square foot. Indiana (CEIR, 1955) reported serious losses to second year alfalfa by this weevil in several central areas.

Johannsen (CEIR, 1955) recovered 61 adults per 100 sweeps on white clover in the Pullman area of Washington in early October. Davis (CEIR, 1955) reported that S. hispidula caused serious losses to second year alfalfa in areas of central Indiana.

Following complaints of loss of alfalfa stands in Virginia, Underhill et al (1955) found, through various survey methods, that S. hispidula was responsible for a large portion of the damage. They reported that plants injured by the larvae of this curculio lost vigor resulting in lowered yield and stand. Most of the root injury occurred between March and June.

Examination of the roots of winter heaved plants and those not winter heaved revealed that 86% of the former and 80% of the latter had sustained some injury. However, the injury to winter heaved plants was much heavier. Preliminary examination did not show any correlation between injuries made by the weevil and the entry of root-rot organisms.

In Bulgaria, Grigorov (1956) found that S. hispidula was harmful principally to clovers. While ordinarily the damage by the adults is small in the environs of Stara Zagora, in April 1952, about 75% of the leafy mass of the young sprouting clover was annihilated by adult weevils. The feeding of the larvae permits the penetration of various fungi and bacteria. He found that the density of the larval populations increased with the length of time the stand was maintained. Also the greater the density of the larvae in the soil, the greater is the damage to the roots. Thus in first year clover only 36% of roots were damaged, second year clover - 95%, and third year - 99.2%.

Quinton (1956) notes that while in the past, S. hispidula has not been regarded as a major pest on forage crops, the amount of root injury which can be found in Connecticut fields would indicate that large populations have been present.

Johnson (CEIR, 1956) reports that in Georgia in 1955, S. hispidula larvae caused heavy damage to alfalfa and adults damaged crimson clover seedlings in the fall.

Brown (CEIR, 1956) reported that adults were causing severe local damage to seedling alfalfa in the Umatilla County, Oregon in late April. Robb (CEIR, 1956) reported, that in Wyoming where no control measures were practiced, the adults averaged 1-4 per alfalfa crown. Johannsen (CEIR, 1956) in Washington collected 5 adults per 25 sweeps on red clover. Tippins (CEIR, 1956) in Georgia found 30 adults per square foot under combine trash of crimson clover in Fayette County.

Gittins (CEIR, 1956) reported that in Idaho adults were more abundant in alfalfa than usual averaging six per sweep. He found larval injury on all tap roots sampled in late June. Anderson (CEIR, 1956) in Nebraska averaged 40 adults per 100 sweeps in alfalfa in the northeast area. In Georgia, Johnson (CEIR, 1956) also averaged 40/100 sweeps on alfalfa in Washington County. Morris (CEIR, 1956) reported heavy damage to alfalfa roots in one Madison County field.

Hansen and Dorsey (1957) found an average of 56.5 adults of S. hispidula in check plots in West Virginia while carrying on insecticide tests in 1956. Gyrisco et al (1957) in New York considered that an average of one adult caught per net sweep was sufficient to cause commercial injury.

In Massachusetts, Shaw and Lavigne (1957) compared the number of Sitona larvae found in different legumes in square foot samples six inches deep. They obtained the following results: alfalfa, 139 larvae/sq. foot; ladino clover, 119; white clover, 95; and birdsfoot trefoil, 29.

Lee (1957), at Durham, New Hampshire, obtained numbers as high as 54 larvae per square foot feeding on white clover roots.

Turner (1957), in Virginia, reported obtaining up to 22 larvae per square foot of soil in many alfalfa fields. In preliminary control studies with soil insecticides, he found that dieldrin at the rate of two pounds per acre yielded an increase in green hay of 44% over the untreated plots, presumably because of the protection given to the root against the larvae of S. hispidula.

Filmer (1957) found S. hispidula present in all red clover fields in New Jersey causing moderate to severe root injury.

Morris (CEIR, 1957) in Virginia, collected 26 adults per 100 sweeps in a Botetourt County alfalfa field in late March. In Idaho, Portman (CEIR, 1957) reported counts of 4-16 adults per crown in many alfalfa fields in Canyon County, Idaho, in early July. Adult populations were generally high on red clover and new seedling alfalfa preventing regrowth of second cutting alfalfa. Waters (CEIR, 1957) in the southern areas of the same state reported collecting from 1-14 adults per sweep in red clover seed fields.

In Washington, Johansen (CEIR, 1957) reported that heavy adult populations of Sitona hispidula and S. cylindricollis migrating during July and August became household pests in the Pullman area. Milliron (CEIR, 1957) reported that, during 1957

in Delaware, adults were common in alfalfa and clovers during spring, late summer and fall resulting in noticeable leaf injury.

Guppy (1958) reported that S. hispidula was not considered of great economic importance on clovers in southwestern Ontario. In Oregon, however, Dickason et al (1958) considered the clover root curculio to be a major cause for the decline of alsike clover seed yields because of its effect on plant vigor and stand.

In southwestern Idaho, Gittins (CEIR, 1958) reported that adult populations of S. hispidula varied from 4-16 per crown of alfalfa in early July. By Mid-July, he noted that larval populations of S. hispidula were as high as 40 per sq. foot in red clover seed fields near Nampa and Roswell. Dickason (CEIR, 1958) noted that during 1958, S. hispidula had caused more damage to first year seed crop alsike clover in Klamath County than in any year during the observation period 1953-1958.

Niemezyk (1958) reported that injury to red and mammoth clover by clover root curculios is common in Michigan. Out of 1405 roots from first year clover crops, 72% showed typical injury: 57.8% light, 27.7% moderate, and 14.5% heavy.

Under New Jersey conditions, Lau (1958) found that in a survey of seedling and second year red clover fields, greater numbers of Sitona larvae occurred in the second year fields. In 1956, he obtained counts of 55-93 larvae per square foot in seedling fields. In 1957, he obtained counts of 70-124 larvae per square foot in 2nd year growth. He further obtained a fairly strong direct correlation of sitonids and feeding scars in his red clover studies.

Quinton (1959) reported that in mixed stands Sitona injury was most abundant on clover. In Pennsylvania, Graham and Newton (1959) concluded from the results of two experiments conducted in the greenhouse that there was a definite relationship between injury to red clover roots caused by the larvae of Sitona hispidula and the incidence of crown and root rot of red clover. Lee (1959) found adults of S. hispidula in appreciable numbers in white clover fields in New Hampshire.

Taxonomic Position of Sitona hispidula

The clover root curculio belongs to the family Curculionidae and is known by the specific name Sitona hispidula (F.). This weevil has also rather uncommonly been referred to as the clover snout beetle (Pettit, 1914), the clover leaf beetle (Pettit, 1918) and the clover leaf curculio (Hudson, 1926). This insect was originally described as Curculio hispidulus by Fabricius (1776). In 1817, Germar established the genus Sitona and selected Curculio hispidulus F. as the type species. While many of the early authors regarded this species as Sitona hispidula Germar, the establishment of the rules of zoological nomenclature clearly indicated that the correct authority was Fabricius.

The lack of adequate communication between early coleopterists and inadequate descriptions resulted in the occurrence of several synonyms. Schoenherr (1833-1845) in the second volume of Genera et Species Curculionidum noted the following synonyms: Curculio crinitus Herbst 1795, Curculio trilineatus Don. Bougt. (date unknown), Curculio hirtus Linn. 1790.

In 1864, Allard reported that his examination of Sitona haemorrhoidalis Gyll., recorded by Schoenherr, led him to the conclusion that this name was a synonym of S. hispidula. He also noted that he had received specimens of this same species from M. de Motschulsky under the following names: S. salinus, Holland; S. crassiusculus, Hungary; S. caucasicus, Russia; S. atomarius, Russia; S. porcicollis, western Siberia.

In 1871, Gemminger and de Harold (1820-1887) included S. hirsutulus Sturm, 1826, as an additional synonym. However,

Marsham, 1802, had previously described a Curculio hirsutulus whose description coincided with that of S. hispidula and hence Sturm's designation is a homonym. Van Emden (1939) recorded S. trisulcatus Gyll. as another synonym. In Faune de France, Hoffman (1950) recorded S. haemorrhoidalis Gyll., S. hirtus Gmel., S. pallipes and S. trisulcatus as being the synonyms of S. hispidula.

In 1834, Schoenherr, in *Genera et Species Curculionidum*, described the variety tibiellus. Bedel (1881-1888) noted that while this variety was very rare, it was known to occur throughout Europe and also in Syria and Siberia. Hoffman (1950) also recorded S. tibiellus as the only known variety of S. hispidula.

Distribution of Sitona hispidula

As has been noted previously, Sitona hispidula has long been common throughout Europe and Russia. References to its occurrence by Schoenherr (1833-45), Stettin (1858), Allard (1864), Bedel (1881-88), Hamilton (1894) and others testify to this fact.

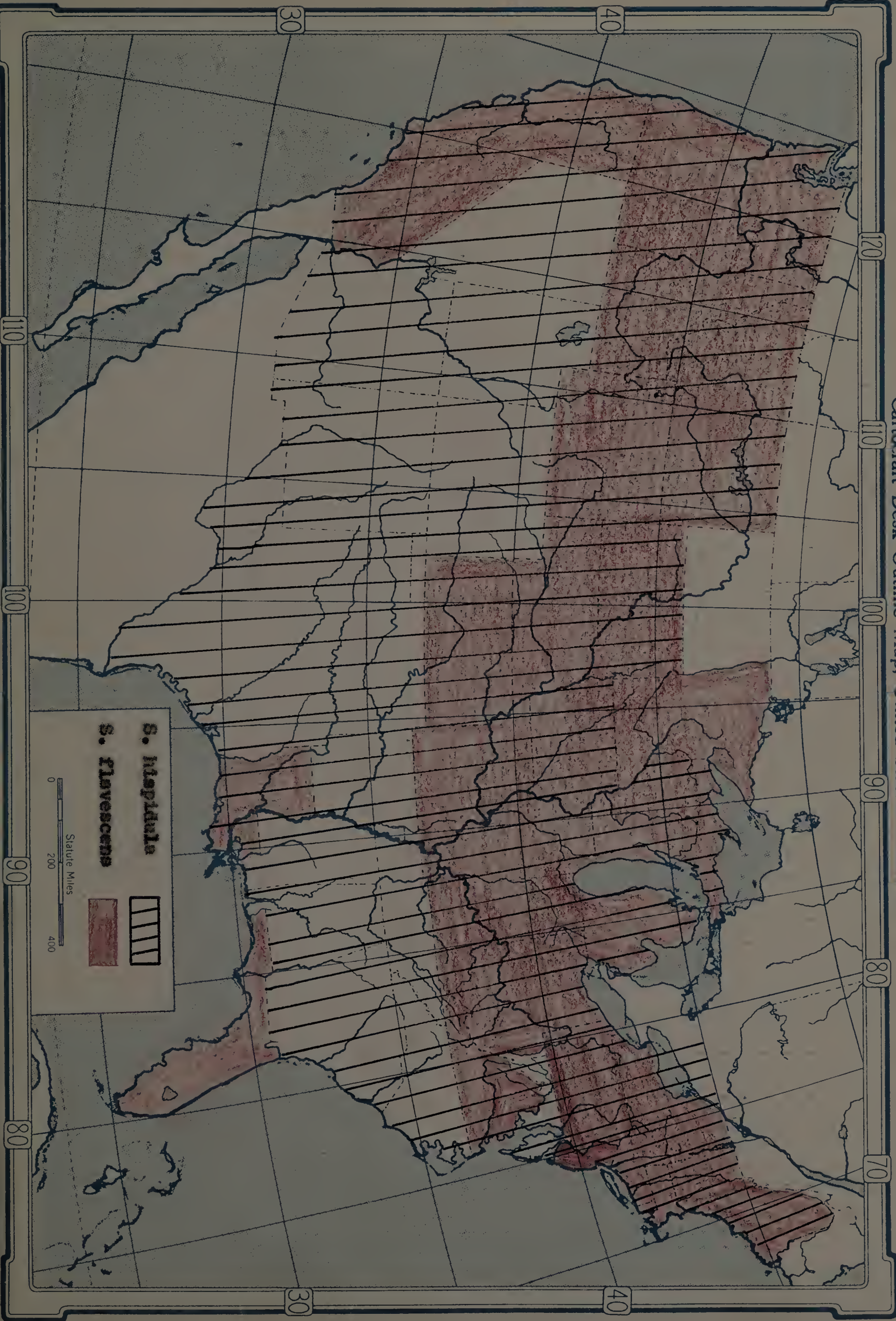
The appearance of this curculio in North America is apparently of relatively recent date. According to most authorities, Le Conte and Horn (1876) were the first to record this species in America. They reported it occurring abundantly at the sea shore near Long Branch, N.J. in July about the roots of grass growing on the dunes. However, Hitchcock (1835) in his "Catalogues of the Animals and Plants of Massachusetts" recorded the presence of Curculio crinitus which is considered by some to be a synonym for S. hispidula. Henshaw (1885) also listed S. hispidula under the name crinitus in his "List of The Coleoptera of America, North of Mexico". Between 1876 and 1887 according to Schwarz (1890), this weevil was found in New York and Maryland as well as in New Jersey. In 1890, he reported the sudden appearance of this species in Washington, D. C. and also noted that specimens had been collected in Pennsylvania. Hamilton (1894) noted that it had spread inland as far as Pittsburg, Pennsylvania. Hatch (1953) indicates that S. hispidulus F. was introduced into western Washington in 1903. It appeared in Trenton, Ontario for the first time in 1904 according to Fletcher (1904). Wildermuth (1910) noted that in 1909, adults were found at Old Orchard Beach, Maine and Pullman, Washington.

Webster (1915) compiled a map showing the distribution as of that date. He showed that it had spread as far north as Maine, as far south as North Carolina with an additional record for Mississippi, as far west as Illinois with additional records for Colorado, Utah, Idaho, Oregon, and Washington. Van Dyke (1917) recorded it from California for the first time. Long (1920) recorded it also from Minnesota, Iowa and Florida. Since that time it has spread throughout the United States. The map on the following page shows its distribution in the United States as of December 1958, based on reports of state entomologists, USDA Insect Pest Survey Reports, and a survey of the literature. Thus far there are no records for this weevil from the following states: North Dakota, Minnesota, Florida, Alaska and Hawaii.

A map showing the known distribution of Sitona hispidula (F.) in Canada was compiled in 1959 from records available at the Divisional Headquarters of the Canadian Department of Agriculture. This map, published in The Canadian Insect Pest Review (1959), indicates that S. hispidula has been recorded from the following provinces: British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia.

Recorded Distribution of *Sitona hispidula* and *Sitona flavescens* in The United States as of December 1958.

Cartocraft Desk Outline Map, United States. No. 7001



Biology - Sitona hispidula

The earliest reference to stages in the life history of Sitona hispidula other than the adult was made by Brischke (1876). While digging in a "burnt out" clover field, he recovered adults of S. hispidula and larvae and pupae which he assumed to be the same. From live pupae thus obtained, he was able to rear out adults of S. hispidula.

Wildermuth (1910) summarized the knowledge previously accumulated concerning this weevil and carried out the first American biological study on this insect since its introduction in 1876. He found that the insect hibernated in the adult form and became active with the first days of spring. These hibernating adults began to die off about the latter part of May or first of June. He further observed that eggs were laid both in the spring and late fall, the female depositing eggs promiscuously on the leaves and ground. Great difficulty was experienced in getting eggs to hatch in the rearing vials. He ascertained the total period from egg to adult, 38-43 days; the egg period, 13 days; the pupal period, 8-10 days, and thereby determined the larval period by the simple expedient of subtraction. He also determined that no fall brood occurred in the neighborhood of Washington D. C.

Gossard (1911) also considered that there was probably no fall brood of larvae in the case of this species under Ohio conditions, although eggs might possibly be laid in the fall. He too found that the adults hibernate under rubbish on the ground and lay their eggs in the spring.

Under New York conditions, Parrot (1914) indicated that S. hispidula hibernates as an adult, becomes active with the first warm days of spring and soon thereafter begins to lay eggs.

Webster (1915), quoted much from Wildermuth (1910) in a bulletin on "Alfalfa Attacked by the Clover Root Curculio", and further ascertained that the adult beetles preferred alfalfa leaves to red clover when held in confinement. He recorded a field mating of S. hispidula adults on September 12, 1914.

In a bulletin concerning insects injurious to alfalfa, Deen (1916) indicated the occurrence of this pest in Kansas and essentially repeated the gist of Wildermuth's report on the life history.

Blatchley and Leng (1916) noted that callow beetles, hatching from eggs laid early in the spring appeared in May and June. On this basis, they surmised the possibility of two broods occurring each season.

The next year, Van Dyke (1917) recorded having observed some thirty adults of S. hispidula crawling up the side of a house, evidently migrating from the white clover in the adjacent lawn. Parks (1920-21) provided a brief resumé of the life history of this insect in Ohio. Reppert (1921) took considerable numbers of adults by sweeping alfalfa fields during the summer. He reported that in Virginia, eggs are deposited as soon as plant growth starts in the spring and the adults which emerge from pupation that spring feed until winter.

Jackson (1922) carried on extensive breeding experiments with Sitona hispidula during which she made observations on the

life history of this species in England. She noted that the adults live up to 12 months, after having emerged from the pupal stage between July and September. These adults commenced to lay eggs six to eight weeks after emergence and continued to lay throughout the fall. While a few eggs were laid during winter, vigorous oviposition did not occur until spring. She further observed that eggs laid in late autumn did not hatch until the following spring. A few eggs laid in September and all those laid in spring and summer hatched in about 25 days. The larvae which hatched from spring laid eggs fed from 11-14 weeks with a pupal period of approximately four weeks. In addition the last few eggs laid by the old females in July produced full grown larvae and pupae by the end of October which, however, perished during the winter. Miss Jackson also observed that adults continued to feed through to February despite continuous frost during this period. In the course of dissecting adult specimens, she discovered that two forms of the species existed, one with fully developed wings and the other with very small vestigial wings incapable of flight.

Pettit (1924) made brief mention of the overwintering of adults and larval feeding in Michigan.

Egg studies were carried on by Hudson (1926) correlating temperature with the length of the egg stage. He noted that under field conditions as the average temperature became warmer, the length of the egg stage was reduced. He further found that the average egg production per female in the spring, under Ontario conditions, was 69 eggs per female, with a maximum of 165 eggs per

female. Under field conditions, he considered that the cycle from egg to adult took six to seven weeks. He noted too that adult winter mortality probably resulted from lack of sufficient cover.

While working at the Kiev Polytechnical Institute in 1915, Grossheim (1928) also conducted some experimental work on the length of egg development in relation to temperature of various Sitona sp. His data for Sitona hispidula agrees in essence with that of Hudson (1926). He further observed that in comparison with other Sitona species the eggs of S. hispidula are slow in development. Under Russian conditions, he found that the life history of this weevil did not differ significantly from that reported by Wildermuth. Because he found S. hispidula adults laying eggs in the fall as well as in the spring, he assumed the possibility of early instar larvae overwintering in bacterial nodules or in the soil; however, he was unable to furnish proof of this assumption. He considered S. hispidula as a one crop pest which attacks primarily clover. He contended that this weevil lays its eggs only on clover and that the larvae develop only on clover.

Jackson (1928) in England had continued her breeding experiments with S. hispidula to determine the genetics of the long and short-winged forms. While she had examined several hundred specimens from North America, she was unable to find any brachypterous forms. During her breeding work she noted that considerable variation occurred among females in the length of time which elapsed between the appearance of adults and the time

oviposition commenced. The majority of those females which emerged in August began to lay eggs in October or November irrespective of whether they had been mated or not. The males, took much longer to reach sexual maturity, some not attaining this state until the following summer. It was found that the eggs of a female with which a sexually mature male had copulated turned black within three days after laying while unfertilized eggs remained white. She noted further that the weevils mated readily and frequently in captivity and often remained for a day or longer in the copulatory position. Miss Jackson found that spermatozoa remained potent in the receptaculum seminis of the female up to 13 months after mating.

Metcalf and Flint (1928) reported that S. hispidula passes the winter in the egg, larval and adults stages, but mostly as young larvae. These larvae subsequently develop by feeding on the clover roots and crown of the plant in early spring, pupate during late March and April, and emerge during May and June in the mid west. They indicate that the majority of eggs are laid in the fall, with only a few being laid in the spring, and that nearly all the fall eggs hatch before the advent of winter.

Bigger (1930) reported that in Illinois no eggs had been found to hatch in the fall, but that eggs laid in the fall as well as those laid in the spring, hatched in the spring. He found that fall laid eggs required 138-200 days to hatch, while eggs laid early in the spring required 17-21 days to hatch but only 15-16 days late in the season. Both cage and field records showed that 80-90% of the eggs were laid on the soil. He further noted

that approximately 73.5% of the eggs were laid in the spring while only 26.4% were laid in the fall. Adults were found to be most active at temperatures of 50-70°F. and while they seldom fly, they are capable of flights over half a mile in distance.

Smith (1931), who derived much of his information from Jackson (1922), reported that in England there was only one generation a year and that egg laying may continue during the winter.

While collecting pea weevils from their winter hibernating quarters, Larson and Hinman (1932), in Oregon, collected adult specimens of S. hispidula hibernating beneath the tree lichen, Usnea plicata mostly on Oak.

Marshall and Wilbur (1934) made close observations on the actual feeding processes of the larvae by placing the larvae in sifted soil between two glass plates. Note was also made of the pupal activity in constructing the pupal chamber. They found that the larvae could live up to 34 hours in water. Under field conditions they noted that females oviposited from April to November with the exception of August. These workers found that under their conditions the egg stage lasted 6-9 days; the larval stage, 45-49 days; and the pupal stage 8-16 days. They found that great numbers of adults could be collected during the summer from the underside of a rug spread over white clover.

Jewett (1934) noted that, in Kentucky, egg laying by overwintering adults began in March and continued through the first week of June. He observed that eggs laid in the spring hatched in two weeks but that eggs laid in the fall hatched the following

spring. He found that the life cycle from egg to adult required approximately 40-45 days. He further reported that the beetle hibernated only in the egg and adult stages.

In a bulletin on the "Insects Injurious to Alfalfa in Kansas", Dean and Smith (1935) noted that the dry years from 1930-1934 were unfavorable to S. hispidula. They reported that while there is only one generation a year in Kansas, there is an overlapping in life cycles so that at most seasons of the year all stages may be found.

Anderson (1942) noted that egg laying ceased about mid June in Oregon and resumed again about mid August to November. He also reported that in Oregon, eggs laid in the fall do not hatch until spring.

In California, Lockwood (CEIR, 1952) found a few last instar larvae and pupae in the upper inch of soil in a three year old clover field in late October. Dissection of females collected in Modoc County at this time showed 60% with fully developed eggs.

Portman and Barr (1952) gave a brief summary of the life history of S. hispidula in Idaho.

In Ohio, Herron (1953) reported that females of S. hispidula produced fertile eggs in autumn, winter, and spring when brought into the laboratory. He noted that the peak of emergence for the spring generation of adults of this weevil slightly preceded the peak for the sweet clover weevil (i.e. the latter half of June). However, he further noted that the larvae may be recovered from white clover much later than larvae of the sweet clover weevil.

Johansen (CEIR, 1954) noted mating occurring in the Pullman area of Washington in October.

Dickason and Every (1955) reported that in Oregon the majority of eggs are laid in the spring and the larvae, which subsequently hatch, feed on the roots of legumes about three weeks before pupating in small earthen cells.

Underhill et al (1955) reported some unpublished data on oviposition for 1920 wherein approximately 60% of the spring eggs were laid in April, 35% in May, and 5% in June. The maximum number of eggs laid per female was 498 with an average of 218. During 1952, it was observed that after the emergence of adults in the latter part of June and the first part of July, they disperse in all directions within and outside of the field. In collections made during the summer of that year, as many adults were caught in pastures and fields around the alfalfa field as were caught in the alfalfa field itself. They further noted that while these insects are relatively poor fliers, some do fly into the fields, but most of the adult dispersal is by crawling.

Garman et al (1956) reported one generation per year for S. hispidula in Connecticut.

During his investigations of Sitona sp. in Bulgaria, Grigorov (1956) made an extensive study of Sitona hispidule. He noted that adults derived from larvae which overwintered appeared towards the end of May while the new generation of adults, derived from spring eggs, did not appear until June. In the field, copulation and egg laying continued from September until the end of November. At this time the temperature of the ground air was recorded as 4.8°C. In mid January, he observed a copulating pair while the surface temperature was -5°C. He too concluded that S. hispidula

overwinters as adult, egg and larvae. In his studies, he found that one female can lay from 300-900 eggs, and that egg laying is more intensive in the spring continuing to the end of June. He determined the length of embryonic development of S. hispidula in relation to different temperatures. Under Sofia conditions he noted that the egg stage lasted from 20-25 days; larval stage, 50-60 days; and pupal stage 10-15 days.

Kerr and Stuckey (1956) reported that S. hispidula adults were more readily collected at night than during the day. Quinton (1956) noted that the life cycle of S. hispidula in Connecticut was essentially the same as that described by Jewett (1934).

Lee (1957), working on insects attacking forage in New Hampshire, reported that larval populations of Sitona sp. reached one peak in early June and another in early October.

Newton (1958) described a simple method for rearing large numbers of larvae of S. hispidula for research uses. While he obtained as high as 78% hatching of eggs only 25% of these could be recovered from the soil after 47 days. Of this 25%, only 65% could be recovered as full grown larvae and pupae. He noted that a more effective collecting method for adults than sweeping was the placing of litter in a Berlese funnel. When eggs were hatched at room temperature, peak hatch occurred on the 10th day. Newsom (1958) noted that while it was quite difficult to rear S. hispidula successfully, fair results could be obtained by rearing the larvae on red clover or alfalfa nodules held on moistened filter paper in salve boxes.

Essig (1958) reported that in western North America, a complete life cycle of S. hispidula requires 40 days and two broods occur annually. Milliron (1958) reported that under Delaware conditions, the larvae of this weevil feed on roots of alfalfa throughout the spring, summer and fall. In Finland, Markkula (1959) noted that S. hispidula adults are able to hibernate through two winters and to lay eggs for two years in succession.

Host Plants of Sitona hispidula

References to host plants of S. hispidula other than clover were relatively rare previous to this century. In 1904, Bargagli compiled a list of the known food habits of the various Sitona species, based on observations by such entomologists as Brischke, Ormerod, Bedel, Hart, Kaltenbach and others. Bargagli recorded S. hispidula as being known to feed on Galega officinalis L., Trifolium pratense L. and Pisum sativum L. In a report to the Maryland State Horticultural Society, Cory (1915) noted that S. hispidula was attacking newly planted lima beans. Hudson (1926) indicated that this species occurred on mammoth clover in Canada.

Metcalf and Flint (1928) recorded it on clovers, alfalfa, soybeans and cow peas in the United States. In Russia, Grossheim (1928) stated that it occurred on sainfoin as well as lucerne, and wild and cultivated clovers. Hodson and Beaumont (1929) reported injury to late sowings of peas and broad beans by S. hispidula and S. lineata in Devon, England.

Larson and Hinman (1932) recorded S. hispidula on peas in Oregon. Wilcox et al (1934) reported its occurrence on strawberries in Oregon but regarded it as of little importance. In 1936, Caesar recorded it on sweet clover in Ontario. Lambert (1945) found it exceptionally numerous along St. Francis River, Quebec inflicting serious injury to the foliage of sugar maples.

Peckard (1951) noted that the clover root curculio was known to destroy soybeans planted on spring plowed clover sod. In Ohio, Heron (1953) found larvae of S. hispidula feeding on the roots of sweet clover. McNay (1953) reported this species

as being numerous on red clover in Ontario. Tippins (1955-CEIR) observed moderate leaf feeding by adults on crimson clover seedlings in Georgia in November. In 1958, the California Cooperative Report (1958-CEIR) noted that adults of S. hispidula damaged corn at Soledad in Monterey County. This species is now considered primarily a pest of alfalfa and the various kinds of clover.

Parasites and Predators of Sitona hispidula

Garman (1907), upon examining the stomach contents of great numbers of crow blackbirds or purple grackle (Quiscalus quiscula), found that this species fed chiefly on soil inhabiting invertebrates. Among fragments of insects found in the stomachs of these birds were those which he tentatively identified as being parts of Sitona hispidula.

While Wildermuth (1910) found that the larvae of S. hispidula were attacked by one of the entomophthorous fungi, he observed no hymenopterous or dipterous parasites attacking it. He postulated that the larvae, because of their slow movements, might be fed upon by predacious beetles.

Webster (1915) reported that the Biological Survey, in its work on the food habits of birds, had found that the following birds fed upon the adults of this beetle: upland plover, killdeer, ruffed grouse, broadwinged hawk, flicker, nighthawk, chimney swift, wood peewee, crow blackbird, meadow lark, Lincoln finch, song sparrow, chipping sparrow, and the white throated sparrow. Of these birds, the chimney swift and the song sparrow were found to be the greatest consumers of this species.

Kalmbach and Gabrielson (1921) reported that the clover root weevil, Sitones hispidulus, was a favorite article of diet of the starling (Sturnus vulgaris Linn.) in the United States.

In her work on the bionomics of the genus Sitona injurious to leguminous crops in Britain, Jackson (1922) reported several parasitic enemies of Sitona hispidula. In the course of her research work, she recorded three Braconid parasites of this

species: Perilitus rutilus Nees, Perilitus aethiops Nees and Pygostolus falceatus Nees (the dark variety described by Ruthe). She also found protozoan parasites of the genus Gregarina inhabiting the alimentary canal of adults of S. hispidula. She indicated, however, that the fungus, Botrytis bassiana (Balsamo) Montagne, appeared to be the most serious natural enemy of this species in Britain and it was found to attack both larvae and adults.

Jackson (1928) conducted a detailed study of the biology of Dinocampus (Perilitus) rutilus Nees on Sitona lineata. During the course of her study, she noted that eggs were deposited in the apical region of the abdomen of S. hispidula.

Bigger (1930) reported that while no larval or pupal parasites were observed in Illinois, a Staphlinid, Stenus sp. was observed feeding on the eggs of S. hispidula in 1926.

Smith (1931) mentioned the Braconid parasites noted by Jackson (1922). He also mentioned that a Scelionid, Anaphes sp., is found parasitizing S. hispidula in Russia.

Marshall and Wilbur (1934) reported that "fungous and bacterial diseases, insect parasites, and predators of the clover root curculio have been comparatively scarce in Kansas up to the present time". In late May of 1928, however, they found that about one larvae in six taken from diggings in alfalfa were diseased. Diseased specimens were subsequently found to have been invaded by nematodes of the genus Diplogaster, which caused the death of the larvae.

Dean and Smith (1935) indicated that under Kansas conditions, natural agencies of control of this weevil were comparatively scarce.

Jackson (1934) recorded some additional parasites of S. hispidula. She dissected a Tachinid larva from material obtained from Ontario. A protozoan of the genus Mycetosporidium and the fungus, Entomophthora coleopterorum were reared from adults.

During his biological observations on the solitary wasp, Cerceris nigrescens Smith (H.A.S.) in New York, Krombein (1936) noted that this species provisions its nests with adults of S. hispidula. He observed that the weevils were not killed outright but only paralyzed, apparently so that they might serve as food for the larvae of this wasp.

Wolcott (1937), while making an animal census of two pastures and a meadow in northern New York, observed a mite nymph of the genus Gamasus attached to the back of an adult S. hispidula.

In a later paper Krombein (1938) observed specimens of the solitary wasp, Cerceris nigrescens, in flight carrying S. hispidula adults. Even after the destruction of nests containing paralyzed adults, the wasp continued to bring captured specimens of this species. Krombein considered that this solitary wasp probably stocks its nests with clover root curculios over a large portion of its range. He postulated that C. nigrescens must be an important secondary factor in the control of S. hispidula since at least a dozen weevils would be necessary to bring one wasp larva to maturity.

Charles (1941), in his preliminary checklist of the entomogenous fungi of North America, lists S. hispidula as being attacked by Beauvaria bassiana (Bals.) Vuill. in Virginia and by Beauvaria globulifera (Speg.) Picard.

Anderson (1942) reported that in Oregon, larvae of S. hispidula were sometimes attacked by nematodes of the genus Diplogaster which caused the larvae of the curculios to dry up.

Berry and Parker (1950) worked on the parasites of Sitona in Europe with especial reference to Camogaster exigua (Meig.) which they reared from S. hispidula (F.), S. humeralis Steph. and S. lineatus (L.). As a result of their work, small numbers of C. exigua, Perilitus rutilus (Nees) and Microctonus aethiops (Nees) were imported into the United States for release under a cooperative project with the North Dakota Agricultural Experiment Station. They reported that, in France, the maximum parasitization of Sitona species by the combined species of hymenopterous parasites has never exceeded two percent in the north and six percent in the south.

In the Pacific Northwest, Rockwood (1951) reported that 20% of a large field sample of S. hispidula was found to be infested by a species of Beauvaria in March of 1937. He also reported the growth of "long stringlike strands of an anastomosed hypae" growing out of adults held in soil in a dark cellar. He postulated that they might have grown into the short headless Cordyceps had they been placed in a sufficiently lighted environment. Thompson (1954) recorded the occurrence of a larvae of Hyalomyodes triangulifera Loew. in the body cavity of an adult of Sitona hispidula taken at Strathroy, Ontario in 1928. This parasite is common to eastern Canada and has been recorded from several other coleopterous hosts.

Grigorev (1956) found that Pygostolus falcatus Nees was the most common parasite reared from adults of S. hispidula

near Sofia, Bulgaria. He reported that ants attack adults of the genus Sitona when the weevils are in a cataleptic state. He further noted that the fungus Botritis basiana develops in the pupae and larvae as well as in the adult forms. He also recorded Microetonus aethiops Nees, Perilitus rutilus Nees and Syntomogaster exigua Meig. as parasites of weevils of the genus Sitona.

Turner (1957) noted that while several parasites of the clover root curculio are known to occur in Europe, there are no known native insect parasites in this country as far as can be ascertained. During the summer of 1953 in Virginia, he found that a large number of newly emerged clover root curculio adults were attacked by the fungus Beauveria globulifera (Speg.) Picard.

Control of Sitona hispidula

According to Wildermuth (1910), the depredations of Sitona hispidula had apparently been too limited and inconspicuous to call for investigations along the line of either "remedies or preventives". He suggested that the system of short crop rotation, which was then so advantageously employed in the eastern United States, had in some measure limited the numbers of this species on clover. He indicated that the growth of alfalfa on the same ground for a period of three to six years probably facilitated the increase of this insect. As possible means of control, he suggested that the clover fields might be burned over during the winter months, when the ground was frozen and the plants would not be injured to any great extent. Inasmuch as the larvae are easily killed when disturbed, he further promulgated the idea of harrowing or cultivating the ground by some method in early spring, thereby destroying a certain percentage of the larvae. However, he noted that a large amount of clover would necessarily be damaged or killed if this method were to be wholly effective.

Gossard (1911) concluded that since the beetles hibernate under rubbish and lay their eggs in the spring, fall plowing or other autumn remedies would probably have little effect on this species.

Webster (1915) indicated that while a short rotation of the alfalfa crop would have a tendency to limit the abundance of S. hispidula in the fields, it would not in any way affect

the continuous breeding of this pest in wastelands. He felt that the limited amount of food consumed by the adults would eliminate the possibility of insecticide control. He took issue with Wildermuth (1910) on the effectiveness of burning over the fields in midwinter, indicating that he felt that while some few hibernating adults might be destroyed, most of them would be so intermingled with the surface soil as to escape injury.

In Iowa, Seder (1915) stated that disking or harrowing of the hayfield as soon as the crop was removed was the only practical method of fighting this weevil. He felt that short alfalfa rotations would not limit its presence because the weevil also breeds along the roadside and in wastelands. He also considered the application of poisons to the plants as useless because of the small amount of foliage eaten by the adults.

Blatchley and Leng (1916) declared that a rotation of crops was one of the best remedies for getting rid of the weevil where it was very destructive.

Christie and Reed (1923), upon observing severe damage on young soybean seedlings planted on clover sod, suggested a rotation in which soybeans do not follow clover as a means of control of S. hispidula.

Herrick (1925) offered no new solutions to the problem of control of this insect merely indicating that infested clover should not be allowed to stand beyond the second year and that infested fields should be plowed immediately following hay

removal. Call (1927) suggested placing a rug on infested lawns overnight as a possible means of controlling Sitona hispidula adults. The adults seemed to congregate on the underside of the rug and could easily be picked off.

Metcalf and Flint (1928) noted that up to that time practically no effective control measures had been formulated. They too favored a rotation system which would put the infested fields into a grass or cultivated crop, thereby driving out the beetles. They indicated that if the land is plowed late in the fall or early in the spring, practically all the weevils in the field would be destroyed.

Ripper (1937) in Vienna, was the first to advocate the use of chemicals as a practical control measure. He suggested that where a severe attack was expected by Sitona lineata, S. crinita or S. hispidula in the spring, a trap crop of winter peas should be sown in September. The leaves would then be large enough at the spring migration time to be treated with an insecticide such as calcium arsenate dust. On lucerne or clover, he reported that the weevils could be caught at night by a suitable machine, i.e. a horse drawn type, in which a horizontal board would sweep them into a bag.

Anderson (1942) suggested controlling S. hispidula by crop rotation, i.e. clover with wheat. He reported that some success was attained by plowing late in the fall or early in the spring thus destroying overwintering beetles.

Poos (1943) indicated that crop rotation or plowing of infested fields immediately following hay removal was somewhat effective.

Marshall et al (1949) while working on the control of the clover root borer in New York observed that both DDT and BHC (gamma isomer) were effective in controlling the adults of S. hispidula with DDT giving the better results. Packard (1951) suggested that treatment of the newly sprouted crop of soybeans with a dust containing 5-10% DDT might prove to be effective against this weevil. He also reported that no injury occurred on soybeans planted on clover sod ground that was plowed the previous fall or early winter.

Lockwood and Gammon (1952) in California reported control of the clover root borer and the clover root curculio with two applications of DDT dust applied at the rate of $1\frac{1}{2}$ lbs. actual per acre. MacVicar et al (1952) in Canada noted marked decreases in populations of Sitona hispidula adults following the application of DDT, DDT plus toxaphene, and DDT plus methoxychlor.

In Kentucky, Anon. (1953) reported that no practical method had been found for the control of the larvae of S. hispidula although dusting or spraying with lindane, chlordane, aldrin or parathion reduced infestations of adults during their spring flight.

Underhill and Turner (1953) obtained good control of Sitona hispidula larvae with soil applications of aldrin (4 lb./acre), dieldrin (2 lb./acre), heptachlor (4 lb./acre) and chlordane (10 lb./acre). Satisfactory control of adults was also obtained with sprays of toxaphene at one pound/acre and aldrin and dieldrin at two pounds/acre when applied following the second cutting of alfalfa.

In Oregon, Dickason and Every (1955) reported that an application of DDT at the rate of one pound per acre applied in early spring to the surface of the ground gave effective control of adults prior to egg laying. They indicated that where the fall was warm, fall applications of insecticides would be preferable.

Underhill et al (1955) used soil insecticides in the wettable powder form mixed with moist sand in Virginia to control the immature forms of S. hispidula. Utilizing root injury as an index for control, they reported that aldrin, dieldrin, and chlordane gave good results when applied prior to seeding or later during the fall. They found that fall activity and migration of the adults appeared to coincide with the excellent control obtained by fall applications. Spring application of these same materials resulted in poor control. However, they noted that heptachlor, which was included only in the spring treatments, gave good control.

Grigorov (1956) in Bulgaria treated the species of Sitona as a group when considering methods for their control. He indicated that the "chemical battle with Sitona hispidula must be begun in the fall before egg laying and be continued in the spring. Some of the chemicals suggested for the control of Sitona species are the following: DDT, Hexachlorane, parathion lead arsenate and paris green.

Kerr and Stuckey (1956), in Rhode Island, reported that spring applications of DDT, lindane and chlordane in 1951 were ineffective in reducing adult populations of S. hispidula. However, DDT applied in June, July, and August of 1952 was found to be effective in controlling adults.

Peairs and Davidson (1956) recommended the treatment of new seedlings of alfalfa and clover with aldrin, dieldrin, heptachlor, lindane, chlordane or toxaphene for the control of S. hispidula. On established stands, they recommended an early application of these same insecticides to avoid residue problems.

Hanson and Dorsey (1957) reported that, in West Virginia, they obtained more than 90% control of Sitona hispidula adults by early season application of granular heptachlor and dieldrin at the rate of one half pound of actual insecticide per acre. Filmer (1957) in New Jersey also obtained good control of Sitona spp. with applications of dieldrin and heptachlor granular materials at the rate of one pound actual per acre. Also working with granular materials for their control, Turner (1957), in Virginia, found that dieldrin, heptachlor and chlordane applied at the rates of 4, 4 and 10 lbs. respectively resulted in excellent control of S. hispidula when applied in early fall or early spring. In a later test, he found that these same insecticides could be reduced to 2.5, 2 and 5 pounds per acre without reducing the effectiveness of the treatments. He noted that while dieldrin had a residual effectiveness of three years against this pest, the other two materials were only effective for a single year. When heptachlor and dieldrin were applied as a spray at the rate of one pound actual per acre, only a fair degree of control was achieved. Good control was also obtained with isodrin and parathion at the rate of 2 and 5 pounds actual per acre respectively.

Gyrisco et al (1957) in New York recommended parathion at the rate of one pound per acre for use on forage crops to be fed to cattle. In their 1958 recommendations, they included lindane, with certain restrictions, in their list of recommended materials.

Dickason et al (1958) working on the control of the clover root curculio on Alsike clover in Oregon, reported that early spring application of DDT at the rate of one pound per acre controlled adults and reduced root injury. They also found that an emulsifiable concentrate heptachlor applied at the rate of four pounds actual per acre in 1955 gave excellent protection throughout the first seed year. Portman and Manis (1958) reported that an application of aldrin or heptachlor to the soil surface just prior to the emergence of adults showed promise in reducing damage from this pest under Idaho conditions.

Essig (1958) stated that crop rotation was the best means for the control of Sitona hispidula.

Lau (1958) obtained good control of Sitona larvae with dieldrin applied at the rate of five pound actual per acre in the soil before seeding. Better results were obtained when this application was preceded by a fall application of dieldrin at one pound per acre. He found that both heptachlor and dieldrin gave the most consistent control of Sitona larvae and the reduction of feeding scars.

Dickason (1959) in a personal communication indicated that both heptachlor and aldrin at two and four pounds per acre gave good control of Sitona hispidula. He noted that statistically heptachlor at four pounds per acre was significantly better than

DDT at five pounds per acre, aldrin at two and four pounds per acre and heptachlor at two pounds per acre.

Sitona flavescens

Economic Importance of Sitona flavescens

Riley (1882) made the following comment regarding the economic importance of Sitona flavescens in the United States. "As an interesting fact in connection with imported clover enemies, we would mention that several species of the Curculionid genus Sitona especially S. flavescens and S. lineellus, which in Europe are injurious to clover and lucerne and which have long since become naturalized in our country have never been reported here as injurious although they occur quite commonly in some localities."

Webster (1887) noted that in Indiana white clover and alsike clover had been seriously injured by the adults of S. flavescens. While he found no evidence that the larvae fed on the roots of clover, he advanced the theory based on the numbers of larvae he found in the soil surrounding the roots.

Osborn and Gossard (1891) reported the appearance of S. flavescens in injurious numbers upon red clover in Iowa. They felt that from the nature of the damage they did, these weevils were probably as injurious to clover as any single species of grasshopper and had undoubtedly been responsible for some of the injury charged to other insects.

Hamilton (1894) noted that S. flavescens damaged several species of Trifolium in Europe and North America.

In Illinois, Folsom (1909) while studying the life history of S. flavescens commented that while this species had rarely been reported as injurious in this country, it needed to be

watched carefully. He noted that in Europe it had occasionally caused serious damage to clover.

Wildermuth (1910) noted that in this country S. flavescens was the only Sitonid other than S. hispidula which had proved to be destructive.

In Michigan, Pettit (1910) reported two occasions of marked injury to white clover by S. flavescens. These weevils in one instance were said to rapidly destroy freshly made lawns. Gossard (1911) reported that in Ohio the chief damage to clover was inflicted by the older larvae feeding on the roots. O'Kane (1912) reported this species as being occasionally injurious to clover. Herrick (1915) also mentioned this species as being injurious to clover and alfalfa.

In central Russia, Sopotzko (1916) reported that although S. flavescens was mostly found on vetch, it also injured clover.

Dean (1916) reported that in Kansas some of the larvae of S. flavescens may bite out the roots at the crown of alfalfa and clover plants, causing the plants to wilt. Crosby and Leonard (1916) commented that while the lesser clover leaf weevil, S. flavescens, was generally distributed in New York and occurred in considerable abundance, its injuries had never been of such a nature as to call for special remedial measures. They felt that this insect augmented the injury caused by S. hispidula.

Blatchley and Leng (1916) noted that S. flavescens was very injurious to clover in England. Jackson (1920) also recorded this species as being injurious to leguminous crops in Britain. She (1922) reported in conjunction with other Sitona

spp. as seriously attacking the leaves of clover and generally holding back plant growth during a drought in the summer of 1921.

Pettit (1924) remarked that S. flavescens had not called for very active control measures in Michigan up to that time. In Wales, Jenkins (1926) noted that S. flavescens in conjunction with S. hispidula caused considerable damage to clover in the spring, especially on new seedings.

In Russia, Grossheim (1928) reported S. flavescens infesting lucerne and clover. In the vicinity of Leningrad, Yaroslavtzev (1930) recorded this weevil on clover.

Smith (1931) noted that S. flavescens habitually attacked clover and pulse crops in England. Osborn (1939) noted that while this curculio had caused injury to clover crops in the northern states, it had apparently never taken a very prominent place among Ohio species.

In South Dakota, Severin (1939) reported injury to grass lawns in June. The lawns were found rather heavily infested with adults and larvae, the latter numbering as many as 4-5 per square foot. Hutson (1941) reported that S. flavescens had been "very troublesome, feeding on sweet clover on experimental plots" at East Lansing, Michigan.

Armitage (1949) noted that while S. flavescens had been widely distributed throughout California for 42 years, it had never been recorded as an economic pest. Elliott (1950) lumped S. flavescens and S. hispidula together in considering the damage done by larval Sitonids. However he noted that the majority of specimens collected in West Virginia had been identified as S.

flavescens.

While Gyrisco and Marshall (1950) included S. flavescens in their control program for alfalfa and red clover insects, they noted that this species did not occur in sufficient numbers to warrant any conclusions about the effectiveness of the insecticides. The following year, however, they (1951) found sufficiently large populations of this curculio to warrant testing of insecticides against it.

Starnes and Filmer (1952) concluded that while some injury was caused by the larvae feeding on the roots, S. flavescens did not cause sufficient damage to warrant control measures.

Grigorov (1956) was the first to report S. flavescens as a pest of clover in Bulgaria. He noted, however, that ordinarily under their conditions this species had no economic importance.

In Connecticut, Quinton (1956) considered the two species S. hispidula and S. flavescens together noting that the amount of root injury found in the fields indicated a higher population than was previously indicated. In New York, Muka (CEIR, 1957) reported that in the summer of 1956, S. flavescens had appeared in destructive numbers. A co-worker, Gyrisco (1957) considered that one adult per sweep constituted an economic menace.

Kerr (CEIR, 1957) reported severe feeding on clover by S. flavescens adults and the presence of large numbers of Sitonid larvae under clover at Kingston, Rhode Island. In Massachusetts, Shaw and Lavigne (1957) noted that the high populations of Sitona larvae obtained in various legume plantings would seem to indicate that these insects, S. hispidula and S. flavescens,

might be of major importance in the failure of certain legumes to maintain stands in the state.

Filmer (1957) reported that in New Jersey both S. hispidula and S. flavescens were found to be present in large numbers in red clover and their larvae were causing moderate to severe root injury. In New Hampshire, Lee (1957) found sufficient numbers of S. flavescens throughout the state to indicate that it was of economic importance. Inasmuch as both species occur generally in New Hampshire, Kilpatrick and Dunn (1958) felt that the girdling of the roots and the presence of root rots was the work associated with the larvae of both species.

Niemczyk (1958) working on the magnitude of injury to red and mammoth clover recorded the larvae of both species of Sitona as causing severe root scarring and gouging in 72% of the samples. Lau (1958) lumped the larvae of the two species when considering their relation to root necrosis but observed that 83.5% of the adults collected were S. hispidula. Kerr (CEIR, 1958) reported that during 1957 foliage feeding by S. flavescens and S. hispidula was severe in localized areas in Rhode Island.

Taxonomic Position of Sitona flavescens

While Sitona flavescens Marsh, a close relative of S. hispidula is generally accepted as having been described by Marsham in 1802, the present author is somewhat sceptical of the authority. In the 13th edition of Systema Naturae, Linnaeus (1790) listed Curculio obsoletus Gmel. The name obsoletus has been considered by some authorities as a synonym for flavescens (Schoenherr, 1833-45; Allard, 1864; Gemminger and de Harold, 1871 and Blackwelder, 1944-57). However, Van Emden (1939) regarded it as of questionable status.

Gyllenhal (1790) described a weevil as Curculio caninus Gyll. which was subsequently listed by Panzer (1795) and von Paykull (1800). This species has also been considered by some authorities to be synonymous with flavescens, (Stephens, 1829; Schoenherr, 1833-45; Allard, 1864; Gemminger and de Harold, 1871; Bedel, 1881-88 and Blackwelder, 1944-57). At variance, Van Emden (1939) and Hoffman (1950) gave this appellation questionable status.

It seems logical to the author that the early writers would have had access to a fairly good description if not peratypes through correspondence with the authors previously mentioned by their associates. With the weight of opinion being in favor of the earlier names, this author would consider that Sitona flavescens Marsh should be considered a synonym of S. obsoletus Gmel. However, without access to the original type specimen, it is impossible to determine with certainty the correct name.

Considerable synonymy occurred in the years following the description by Marsham. Stephens (1829) recorded Curculio lineatus

Bonnd., C. canina Gyll. and Sitona octopunctatus Gyll. as synonyms. In 1834, Schoenherr (1833-1845) also included Curculio obsoletus Linn. Allard (1864) noted that he considered to be synonyms specimens sent to him with the appellations Curculio cuprescens Ziegler, C. muscorum Ziegler, Sitona conicus Motsch., S. axillaris Motsch., and S. alpinus Motsch. Gemminger (1891) and de Harold (1820-1887) regarded only S. caninus and S. obsoletus as true synonyms and listed the following six species as varieties:

lineatus Bonnd.
subrufus Gmel.
longiclavis Steph.
nigriclavis Marsh.
octopunctatus Fährs
sulcifrons Sturm

However, he considered S. lineatus and S. subrufus to be synonymous. LeConte and Horn (1876) added Sitona lepidus Gyll. to the list.

In his first volume on the Coleoptera of Canada, Provancher recorded Sitona belle as being synonymous with S. lepidus. In his second volume he indicated that S. lepidus must cede its position to S. flavescens due to priority.

In his synonymy, Bedel (1881-1888) recognized no varieties but considered S. longiclavis Steph., S. octopunctatus Gyll., S. lepidus Gyll., and S. longicollis Fährs to be the same species. Van Emden (1939) recorded eight synonyms, three of which he considered to be questionable: S. longiclavis, S. nigriclavis, S. octopunctatus, S. sulcifrons, S. corecyreus, S. caninus (?), S. obsoletus (?), and S. persulcatus (?). He also included six appellations which he considered to be varieties: S. cinnamomeus, S. lepidus, S. longicollis, S. nigrescens, S. subcordatus, and

S. subrufus. Blackwelder (1944-57) did not make note of any of the varieties listed by Van Emden and he recorded all the synonyms listed by Van Emden with the exception of S. coraycus. Hoffman (1950) showed considerable disagreement with Van Emden listing S. nigrescens as the only variety of S. flavescens. He considered S. longiclavis, S. nigriclavis, S. octopunctatus, S. sulcifrons, S. longicollis, S. lepidus, S. persulcatus, S. subcordatus, and S. subrufus to be true synonyms but was in doubt as the position of S. obsoletus.

While Sitona flavescens has been commonly designated as the flavescens clover weevil (Osborn and Gossard, 1891 et al), other common names have appeared in the literature, i.e. the yellow clover weevil (Armitage, 1949), the lesser clover weevil (Crosby and Leonard, 1916; Starnes and Filmer, 1945), the clover Sitones (Gossard, 1911; Herrick, 1915), the white clover stem weevil (Pettit, 1910), and the clover root curculio (Garman et al, 1956).

Distribution of Sitona flavescens

Sitona flavescens has long been known throughout Europe and Russia (Schoenherr, 1833-45; Faldermann, 1838; Stettin, 1858; Allard, 1864; Bedel, 1881-88 et al.)

The first appearance of S. flavescens on the North American continent is uncertain. Hitchcock (1835) reported it for Massachusetts under the name of caninus. Melsheimer (1853) recorded lepidus which is also considered a synonym for flavescens in his "Catalogue of the Described Coleoptera of the United States." Crotch (1873) also listed lepidus in his check list of the Coleoptera of North America.

In "The Rhynchophora of America North of Mexico", LeConte and Horn (1876) noted that S. flavescens was abundant throughout the Atlantic States, especially near the seashore. In Canada, Provancher (1877) recorded this species as being very common. Riley (1882) remarked that S. flavescens had long since become naturalized in the United States and was quite common in some localities. Webster (1887) reported that this species had been common throughout the West for years.

The map opposite page 21 shows the recorded distribution of Sitona flavescens in the United States as of December, 1958.

Sitona flavescens - Biology

Webster (1887), working in Indiana, was the first to make biological observations on the life cycle of Sitona flavescens. Adults confined in vials laid eggs during October which hatched within 48 hours at a temperature of 65°F. Larvae were collected from the field during the fall, winter and spring. Prior to pupating in May, the larvae were observed to form a small earthen cell. Adults taken in May did not oviposit. Oviposition was first observed in early August. No larvae were collected in the field between May and early September. Overwintering occurred mostly in the larval stage but some adults were also observed to overwinter. This data is significant because S. hispidula did not make its appearance in this country until 1876 when it appeared on the east coast.

Osborn and Gossard (1891) reported that adults of S. flavescens "love to secrete themselves beneath the rubbish about the roots of plants".

Folsom (1909) made a comprehensive study of S. flavescens under Illinois conditions. He noted that over a period of several years, in which this species was kept under daily observations in the laboratory, oviposition occurred chiefly in September, with some eggs being laid in October and November. He found that the period of embryonic development varied from 13-32 days. Shortly after hatching the young larvae hibernated and then completed their development the following spring. The pupal period, occurring in the spring, required two to three weeks.

Emergence of adults was found to occur from late June to late August. Mating took place chiefly between late August and early November with egg laying resulting in from two to ten days. He noted further that the beetles avoid bright sunlight and do most of their feeding by night.

Gossard (1911) also reported that the eggs are laid throughout the fall months in Ohio and hatched within a few days. He noted that the adults go into hibernation quarters under such cover as the ground afforded at the beginning of winter but he doubted that any survived until spring. O'Kane (1912) stated that Sitona flavescens hibernates as a larva.

Blatchley and Leng (1916), in their treatise on the weevils of Northeastern America, repeated observations made by Webster for the most part. They did observe adults from May 1 to August 26 and stated that both the adults and larvae overwintered.

Dean (1916) reported that under Kansas conditions, Sitona flavescens produced only one generation a year. His observations confirmed those of previous workers in that egg laying occurred largely in September; one-third to one-half grown larvae overwinter; pupation began about late June and on through early September. He doubted that eggs were laid in the spring.

In New York, Crosby and Leonard (1916) indicated that S. flavescens passed the winter in the larval stage, either in the stems close to the crown or in the roots. The larvae became mature during the latter part of May and pupated. The adults emerged in two or three weeks but did not lay eggs until September. These eggs hatched in from two weeks to one month and the larvae became partly grown before the advent of cold weather.

In a bulletin on insects injurious to alfalfa in Virginia, Reppert (1921) made brief reference to the life history of S. flavescens. While he did not obtain specimens from sweepings in alfalfa, he mentioned that on clover the larvae hatched in the fall from eggs laid in September. These larvae passed the winter in earthen cells and completed their growth by the first of June, wherein they spent about two weeks in the pupal stage.

Grossheim (1928), in Russia, reported that egg deposition was observed in both the fall and spring but that females laid very few eggs in the spring. The new generation of adults appeared in July and August. He noted that the highest number of eggs laid in one day by an individual female was 21.

Following a review of the existing literature on the biology of S. flavescens, Lehman and Klinkowski (1942) came to the conclusion that Grossheim had confused two species of Sitona because he claimed S. flavescens laid fall eggs whereas Folsom (1909) hadn't recorded this.

Van Emden (1952) reported that eggs which were deposited in the laboratory on July 20 by adult S. flavescens hatched on August 4. A total of 15 days was required for embryonic development at room temperatures.

Grigorov (1956) reported that in Bulgaria, Sitona flavescens overwinters as adults, young larvae, and eggs. He noted that the new generation of adults appeared during June and that egg deposition took place both in fall and spring. Overwintering of adults occurred mainly in clover fields and reappeared as early as February 20th in 1951. Eggs laid in the fall were found to hatch the following spring.

Under Rhode Island conditions, Kerr and Stuckey (1956) reported equal counts in day and night collections of adult S. flavescens.

Markkula (1959), in Finland, stated that S. flavescens females began laying eggs in mid-May and continued to lay until late October. He recorded an average of 851 eggs per individual female during her life span.

Host Plants of Sitona flavescens

Sitona flavescens is apparently less limited in its choice of food than is its close relative S. hispidula. In France, Allard (1864) reported that S. flavescens developed on lucerne. Various authors have since recorded it as a pest on alfalfa and the various species of clover. Webster (1886) first recorded S. flavescens from Indiana as being abundant and injurious to white and alsike clovers. In France, Xamheu (1896) reported that the larvae of this species feed on the roots of a small grain, Poa annua var. Montagnarde. Champion (1903) noted that in central Spain, S. flavescens Marsh and its variety cinnsomous All. were chiefly found on Genista florida.

In 1904, Bargagli compiled a listing of the plants upon which this species had been observed to feed. He listed the following as host plants: Vicia faba L., Pisum arvense L., Trifolium pratense L., Galega officinalis L., and Lotus uliginosus Schk. In New Jersey, Smith (1910) recorded taking it in salt meadows in early spring. Blatchley and Leng (1916) reported it as being very common in rushes and grasses along the borders of lakes and marshes in northern Indiana. Joy (1932) recorded finding S. flavescens on Ononis arvensis.

Parasites and Predators of Sitona flavescens

Garmen (1907) found fragments of beetles, which he tentatively identified as being parts of Sitona flavescens, in the stomach contents of the purple grackle (Quiscalus quiscula).

Folsom (1909), however, was apparently unaware of this paper and reported that no enemies of S. flavescens had been found up to that time.

Kalmbach and Gabrielson (1921) indicated that S. flavescens, while being an article of diet of the starling (Sturnus vulgaris Linn.) in the United States, was not preyed on as extensively as its relative S. hispidula.

Jackson (1934), during her work on the parasites of the genus Sitona, reared a fungus, Entomophthora coleopterorum, from S. flavescens.

Petch (1944), while studying entomogenous fungi, also noted that Sitona flavescens was attacked by Entomophthora coleopterorum in Ireland.

Berry and Parker (1950) noted that Jackson had reported rearing Perilitus cerealium Hal. from S. flavescens.

Control of Sitona flavescens

Folsom (1909) remarked that in Illinois the cutting of the hay crop had little or no effect upon the larvae or adults of Sitona flavescens. Pettit (1910) reported that a W. D. Regus of Battle Creek, Michigan indicated that a layer of six inches of tobacco waste spread over the ground failed to kill these pests. Pettit suggested that a drenching with kerosene emulsion might prove useful in controlling this insect in infested lawns.

According to Gossard (1911) in Ohio, plowing second year clover in the fall or early spring destroyed practically all of the larvae. He felt that, at that time, no other measures were necessary.

O'Kane (1912) reported that dusting or spraying with paris green or arsenate of lead killed Sitona flavescens adults.

Dean (1916) suggested that probably the most effective method of control would be late fall and early spring disking of alfalfa which would not only expose the larvae to the effects of weather but would crush many of them. Reppert (1921) concurred with this approach for Virginia conditions remarking that this was "the only means of control that could be recommended."

Osborn (1939) noted that very likely the usual crop rotation had some bearing on the multiplication of this weevil. He suggested that probably the best results in change of crops would come with plowing directly following harvest.

Gyrisco and Marshall (1950) found that under New York conditions, one percent parathion applied at the rate of forty-five pounds of dust per acre was the most effective insecticide for the

control of Sitona flavescens. They reported that five percent chlordane, five percent TDE, and three percent gamma isomer of BHC did not give any control of this weevil. In further studies, Gyrisco and Marshall (1951) reported that parathion (0.75 lb. actual/acre) and dieldrin (0.85 lb. actual/acre) applied as dusts gave 98% control of this pest. They found that aldrin (0.85 lb./acre) and BHC (0.45 lb./acre) were relatively ineffective in controlling adults.

Kerr and Stuckey (1956), in Rhode Island, reported that DDT applied in June, July, and August of 1952 was effective in reducing populations of S. flavescens adults.

Peairs and Davidson (1956) recommended treating new seedlings with aldrin, dieldrin, heptachlor, and lindane at the rate of 0.5 - 0.75 lb. of actual per acre and chlordane, toxaphene, or DDT at the rate of 2-3 lb. actual per acre. They suggested that these materials be applied early in the spring to avoid residues on forage or hay crop.

Gyrisco et al (1957) recommended dieldrin and aldrin at 0.75 - 1.0 lb. actual/acre for use against these curculios on legumes to be used for seed purposes only. They recommended parathion at one lb./acre for use on forage. In their recommendations of 1958, they included lindane at the rate of 0.5 lb. actual per acre.

METHODS AND PROCEDURES

Studies were carried on both in the laboratory and in the field to determine the life history and habits of the clover root curculio, Sitona hispidula, under Massachusetts conditions. During the same interval, observations were made on certain aspects of the biology of S. flavescens. Laboratory studies were largely confined to the spring and fall of 1958. Laboratory work planned for the spring of 1959 was not carried out due to the lack of available material. Field studies were carried on throughout 1958 and the spring of 1959. Field surveys were carried on weekly during the growing season over a period of two and a half years in conjunction with surveys for other insects attacking forage crops.

Laboratory Studies

Laboratory studies were conducted in the writer's office and in the ecology laboratory at the University of Massachusetts. The daily temperature in the writer's office ranged from 65-82°F. depending on the time of day and the season. In the ecology laboratory, cabinets were used in which the temperatures were thermostatically controlled.

It was found that eggs could easily be obtained by confining adult females of both species of Sitona in petri dishes. The bottom of the dishes were covered with filter paper of the appropriate size. Three or four leaves of alfalfa were placed in each container for food. The filter paper was moistened daily so as to prevent the leaves from drying. One female was placed in each petri dish, the number depending on the availability of adults in the field. Eggs were removed regularly every three days to permit determining the number of eggs laid by each female.

In experiments to determine the effect of temperature and humidity on the length of time required for hatching of eggs of Sitona hispidula, different methods had to be used. Certain chemicals when confined in a container and immersed in distilled water at a given temperature provide a known humidity. A table follows indicating the chemicals used, the temperatures under which they were confined, and the humidities which they provided. The chemicals were placed in the bottom of glass pint canning jars in varying amounts depending upon their solubility in water. The amount of distilled water added was sufficient to just cover the bottom of the jar. Eggs, in groups of approximately thirty,

were placed in the bottoms of paper cups in which holes had been punched from the outside with a lead pencil. The ragged edges jutting inward prevented the eggs from rolling out. The particular cup size was such that the lip of the cup hung over the lip of the jar. Pint jar rubbers were then placed over the lips of the jars and the glass covers were affixed tightly by means of metal clamps.

<u>Chemicals</u>	<u>Temperature</u>	<u>Humidity</u>
K ₂ HPO ₄	23-25°C	93%
KCl	"	85%
NaCl	"	78%
NaBr	"	56%
K ₂ SO ₄	25-27°C	96%
KNO ₃	"	93%
KCl	"	86%
KBr	"	83%
NaCl	"	78%
K ₂ C ₄ H ₄ O ₆	"	72%
CoCl ₂	"	64%
NaBr	"	56%

In order to obtain the required temperatures, both cabinets and a water bath were used. For those temperatures 23°C. and above, it was necessary to place the jars in cabinets. Electric light bulbs were thermostatically controlled to maintain the proper temperatures. In order to obtain a constant temperature of 19°C., it was necessary to place the jars within a bell jar

which was then covered and immersed in a water tank. The water temperature was controlled by a refrigeration unit.

In one experiment, the relative humidity was maintained at 100%. Two samples of approximately 30 eggs were placed in each of four temperature ranges: 19°C., 23-25°C., 25-27°C. and 31-33°C. In a second experiment, two temperature ranges were used: 23-25°C. and 25-27°C. The humidities were varied ranging from 96% to 56%. One sample was used at each temperature and humidity. In both of the above experiments, the percentage of hatch was determined at the end of thirty days. Since many of the larvae were able to escape through the holes in the bottoms of the cups, hatching was determined by examination of the eggs under the microscope. The ends of eggs from which larvae had hatched were chewed out leaving fragments around one end of the empty shell, whereas the unhatched eggs were either whole or flattened in the middle from desiccation.

In two other experiments, the eggs were kept 24-26°C., 27°C. and 31-33°C. In both cases, the relative humidity was maintained at 100%. The samples were examined daily to determine the rate of hatching under the different temperature conditions. In the former experiment only one sample was utilized at each temperature, while in the latter, five samples were used.

To determine the effects of storage on the hatching of eggs, vials of water containing eggs were stored under two different conditions. One series of eggs was frozen in the deep freeze. The second series was stored in a refrigerator at 8-11°C. Both series remained stored for a period of four months, November to April.

In order to determine the effect of storage on adults, specimens were placed in dirt and stored for four months in a refrigerator at 8-11°C. One series was stored in a plastic bag and the other series was stored in a quart paper ice cream container. Approximately fifty adults were stored in each type of container.

An experiment was conducted to determine where adults lay their eggs when confined in a petri dish. Seventeen females were confined in individual petri dishes, the bottoms of which were lined with filter paper. Leaves of red clover were used for food.

In an experiment to determine the number of eggs laid in the spring by adult females of S. hispidula, both mating pairs and single females were confined in petri dishes on May 1, 1958 at laboratory temperature. Seventeen mating pairs and fifteen single females were used. The petri dishes were examined every three days until all the adults had died. The same procedure was followed for both Sitona hispidula and Sitona flavescens in the fall of the same year.

During both of these periods, observations were made on feeding, copulation, parasites, and egg development.

Several efforts were made over a year and a half period to rear larvae in the laboratory. Unfortunately all were unsuccessful.

Effort was also expended to attempt to distinguish the larvae of S. hispidula and S. flavescens, one from the other. Because accurate determinations depended on successful rearing, this aspect of the study was also unsuccessful. In order to determine if both macropterous and brachypterous forms of either S. hispidula and S. flavescens occur under Massachusetts conditions, the writer examined all available specimens with the aid of a microscope.

Field Studies

During 1957 and 1958, weekly surveys by sweeping were conducted in Hampshire County to determine the presence of adults of Sitona hispidula and S. flavescens. With the exception of three weeks in September, 1957, and two weeks in June, 1958, when the author was making state wide surveys, the survey period each year extended from the beginning of May to the end of October. In 1957, eight fields were included: five pure stands of alfalfa, one grass and alfalfa mixture, one red and white clover mixture, one red clover stand and one field of timothy. In 1958, six fields were included: one stand of pure alfalfa, two alfalfa, clover, and grass mixtures, one alfalfa and grass mixture, one red clover and grass mixture and one red clover, alsike clover and grass mixture. The stand of red clover and grass was plowed under in late June and was thereafter omitted from the survey.

All surveys for adult weevils were conducted in conjunction with surveys of other insects occurring in forage crops.

All fields were approached in a characteristic fashion. Sweepings were taken in the four corners and the middle of each field to avoid excessive trampling of the forage. During 1957, two identical insect nets with 12" diameters were used and fifty sweeps were taken in each field. In 1958, however, in order to make our results more nearly comparable to those of fellow workers, two beating nets with 15" diameters were obtained. On hundred sweeps were taken in each field with these nets. In both cases, one full swing was construed to mean the movement of the net

through a 180° arc and this definition was adopted for all collecting.

Jars containing a layer of plaster of Paris saturated with ethyl acetate were found to give the quickest kill. By using the nets alternately, it was possible to collect in one field and place the section of the net containing the insects in the killing jar and still have a net available even though the time consumed in traveling from one field to another was insufficient for complete kill. The insects were then transferred to wide-mouth quart jars until the return to the laboratory. This method has the advantage of speeding up collections and also enabling the collector to be sure of retaining all the insects collected.

The insects were sorted, counted, and recorded immediately upon return to the laboratory. Specimens of S. hispidule and S. flavescens were removed, sexed, and then placed in glassine envelopes or alcohol for future reference.

Surveys were carried on at approximately weekly intervals during the summer of 1957 and throughout the 1958 season to determine the presence of larvae of Sitona spp. in the soil. Square foot samples of soil, 6" deep were taken in alfalfa fields. The samples were examined in the field by sifting the soil through the hands. Since the larvae are white, they could easily be seen and picked out.

Square foot soil samples were also examined from fields containing other forage crops to determine the relative density of larvae of Sitona spp. in different kinds of forage.

In the spring of 1959, an experiment was undertaken to determine the height that adults of Sitona spp. fly. Two fields

between Amherst and Northampton were used. The fields were directly across the road from each other but separated by a plowed field. One field was largely composed of timothy with some alfalfa and white clover. The other field was composed of mostly alfalfa and ladino clover. Five plywood squares, one foot square, were placed on poles of different heights in each field on April 16. The plywood squares were covered on one side with a material called "Stickum Special". The heights at which the squares were placed are as follows: 3'3", 5'3", 6'8", 8'10", and 10'6". On June 3rd, the squares were removed from the fields. No specimens of either species of Sitona were found on any of the squares.

A further experiment was carried out in a field in South Hadley to determine whether Sitona spp. invade an alfalfa field by flying or crawling. In this case, 19 square foot boards were placed vertically on stakes one foot from the ground throughout the field. The squares were coated with "Stickum Special" to capture flying insects. In addition, 21 quart fruit juice cans were placed around the edges of the field. The cans were sunk into the soil to a depth wherein the lips of the cans were flush with the surface to collect crawling insects. These devices were placed in the field on April 10, 1959 and were examined weekly until June 15th. In no case were specimens of either species of Sitona found.

The failure of both of the above experiments, I feel, must be laid to the fact that the winter of 1958-1959 was exceptionally cold with very little snow cover. This type of environment resulted in the death of the majority of adult weevils in Hampshire

County. During the spring of 1959, no live adults of either species were collected although several different methods were used.

Control Studies

Several experiments were planned and executed over a two year period to determine the effectiveness of various insecticides in controlling both the adults and larvae of Sitona hispidula and Sitona flavescens. Since no apparent differences have as yet been found to separate the larvae of these two species, the larvae are herein dealt with collectively.

An experiment was laid out in early May, 1958 to test the effectiveness of granular heptachlor for the control of Sitona larvae. The writer was assisted in setting up the experiment by Dr. William Colby of the Agronomy Department of the University of Massachusetts. Five plots of alfalfa, 8' by 100' were used. The plots were located on the Eastern States Farmers Exchange experimental farm in Feeding Hills, Massachusetts. Two and one-half per cent granular heptachlor was applied to two plots at the rate of one and one-half lb. actual per acre and to two plots at three lb. actual per acre. One plot was utilized as a check. The granular insecticide was mixed with beach sand and broadcast by hand. The alfalfa, at the time of application, was approximately 10" in height. The applications were evaluated on June 24, 1958 by examining square foot samples in the treated and untreated plots.

In order to determine the time of year when granular applications would provide the most effective control, granular heptachlor was applied to plots at the University Farm in August, 1957 and in April 1958. The August application was made following the second cutting; the spring application was made about the time the first

growth was taking place. The insecticide was tested on four legumes: alfalfa, ladino clover, red clover, and birdsfoot trefoil. Check plots were maintained for all four legumes. All plots were replicated three times. Two and one-half per cent granular heptachlor was applied to all plots at the rate of one lb. actual per acre. The applications were evaluated during the period June 27-July 2, 1958.

In August of 1958, granular Thiodan was applied to plots similar to the preceding ones at the rate of one lb. actual per acre. On May 12, 1959, the three applications were compared to determine their effectiveness in controlling overwintering larvae of Sitona spp. The evaluations were based on 1/3 square foot samples, 6" in depth.

Some preliminary experiments were conducted in July and September of 1958 to determine the relative merits of two formulations of Sevin (50% WP and 45 M), two American Cyanamid compounds (12880 and 18706) and Methoxychlor EC for the control of insects attacking alfalfa. The plots were 20' by 20'. Applications of insecticides were made with 4 gallon compressed air sprayers. The populations of adult S. hispidula and S. flavescens were recorded by sweeping with 15" nets at 24 hours, 7 days, 17 days, and 27 days following application of the insecticides.

In April 1959, granular applications of dimethoate (1 lb. actual per acre), Nematacide (2 lb. actual per acre), heptachlor (3 lb. actual per acre), Thiodan (4 lb. actual per acre) and dieldrin (4 lb. actual per acre) on a third year planting of alfalfa. In a newly seeded field nearby, granular applications of

dieldrin, heptachlor and Thiodan at the rates of $2\frac{1}{2}$, 5, and $7\frac{1}{2}$ lb. actual per acre had been applied the previous August. In both cases, the severity of the 1958-1959 winter and spring was sufficient to kill off 60-90% of the alfalfa, thereby voiding both experiments.

BIOLOGICAL OBSERVATIONS

Description of Stages - Sitona hispidula

Egg

Wildermuth (1910) was apparently the first to publish a description of the egg. However, he credited the actual description to J. A. Hyslop who had immediately preceded him in the study of this weevil for the USDA.

The egg is slightly granular and varies from ellipsoidal to almost spherical. Jackson (1922) reported that the first laid eggs are pointed at both ends and twice as long as broad, with subsequent eggs being more spherical. When first deposited, they are creamy white but turn jet black within twenty four hours at 100% relative humidity. Bigger (1930) indicated that the time required for this change varied inversely with the amount of moisture present.

Data on egg size given in the literature are cited below. The results of measurements taken from 125 eggs in the present study are also included.

	<u># of eggs</u>	(in mm.)		Average	
		<u>Length</u>	<u>Width</u>	<u>Length</u>	<u>Width</u>
Wildermuth (1910)	(?)	0.36 mm. in diam.			
Jackson (1922)	(?)	0.41-0.49	0.34-0.37	(?)	
Grossheim (1928)	8	0.30-0.31	0.24-0.26	(?)	
present study					
fall eggs	25	0.40-0.48	0.34-0.38	0.45	0.36
spring eggs	100	0.35-0.45	0.29-0.38	0.40	0.33

It would appear, based on measurements made by the writer that eggs laid in the spring are on the average smaller than those laid in the fall.

Larvae

Wildermuth (1910) provided the first description of the larvae of Sitona hispidula. Although it was fairly well detailed, it does not provide information which might be used to separate the two species in question. In Russia, Grossheim (1928) gave a brief description of the larval stage and included a detailed dorsal view of the head capsule. In a paper describing some Pacific Coast otiorhynchid larvae, Keifer (1932) utilized the larvae of S. hispidula as characteristic of the genus Sitona. His drawing of the dorsal view of the head capsule agrees essentially with that of Grossheim (1928). Bigger (1934) and Marshall and Wilbur (1934) both included brief descriptions of the larvae but neither are of much use.

Xembeu (1896) provided a brief description of the larvae of S. flavescens as it occurred in France. In the United States, Webster (1887) found his description to be essentially the same. Folsom (1909) gave a slightly more detailed description. Grossheim (1928), however, provided a drawing of the dorsal view of the head capsule. In England, Van Emden (1952) worked on the larval taxonomy of eight species of Sitona including S. flavescens. He provided a very detailed description of the larvae of this species including several illustrations. His drawing of the dorsal view of the larval head capsule does not agree with that of

Grossheim (1928). Since Van Haden's specimens were reared material, the author feels that his work is the most reliable. However, he did not work with S. hispidula and so did not provide characters which would separate the two species.

In general appearance, the larva are creamy white, legless and U-shaped with chocolate brown heads.

With the exception of 1st instar larvae, the writer has no specimens which he can definitely state as being one species or the other i.e. S. hispidula or S. flavescens. The author was unable to find any discernible differences between the larvae in this stage nor was he able to differentiate the later instars.

Pupae

The pupae of Sitona hispidula was first described by Wildermuth (1910). He noted that the pupa was approximately 4 mm. in length and that two very prominent, dark spines with a secondary spine on the outside of each occurred on the terminal segment of the abdomen. Bigger (1934) and Marshall and Wilbur (1934) concurred with his description. In Ohio, however, Herron (1953) reported that all pupal specimens examined by him bear two very small spinules near the base of each terminal spine. He recorded the length of the pupa as averaging 4.3 mm. and 1.2 mm. in width.

Xenbeu (1896) provided a brief description of the pupae of Sitona flavescens and noted that the duration of this stage was 15-20 days. In Illinois, Folsom (1909) gave a more detailed description of this stage. He noted that the ninth segment has two long slender, converging lateral spines, whitish basally and

reddish apically and toothed near the middle.

Without known specimens, the author was unable to differentiate between the two species and a third species which occasionally occurred, Calomyeterius setarius. Some of the pupal specimens examined had two spines at the base of each terminal spine whereas others had one. However, size was no criteria and the setae which occur on the wings of the adult S. hispidula did not occur on any of the pupal specimens which the author observed under a compound microscope.

Adult

The characteristics which differentiate this species from other members of the genus Sitona are as follows: "Piceous-black, shining; above rather densely clothed with minute oval, cupreous and grayish scales, those on thorax arranged to form a narrow median and two broader lateral stripes; antennae, tibia and tarsi reddish; club and femora piceous. Head and beak about as long as thorax, deeply and rather coarsely punctate. Thorax subcylindrical, as wide at middle as long, apex and base truncate, sides feebly rounded; disc coarsely, sparsely and deeply punctate. Elytra one half wider at base and twice as long as thorax; disc feebly striate, striae punctate; intervals slightly convex, each with a single row of stout, inclined, greyish setae. Under surface sparsely clothed with fine prostrate hairs. Length 3-5 mm." (Blatchley and Leng, 1916)

Description of Stages - Sitona flavescens

Egg

Webster (1887) was probably the first to describe the eggs of Sitona flavescens. In his description, he referred to the eggs as being nearly white, with a very slight tinge of yellow. He was obviously unaware that, like the eggs of S. hispidula, the eggs of S. flavescens turn black. Folsom (1909) noted that the eggs of this species, yellowish white at first, became black within two or three days. The present writer has established that, under 100% humidity, the eggs of this species turn black within 24 hours.

The egg is slightly granular, somewhat larger and more nearly ellipsoidal than the eggs of S. hispidula.

Data on egg size appearing in the literature are cited below along with measurements taken by the writer from 34 fall laid eggs.

	<u>Length</u>	<u>Width</u>	<u>Average</u>	
	(in mm.)		<u>Length</u>	<u>Width</u>
Webster (1887)	0.4+	0.4-	(?)	(?)
Folsom (1909)	diameter approx. 0.4			
Grossheim (1928)	0.34	0.28	0.34	0.28
present study	0.44-0.52	0.40-0.45	0.49	0.42

Larva
(see page 77)

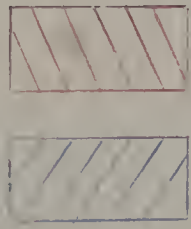
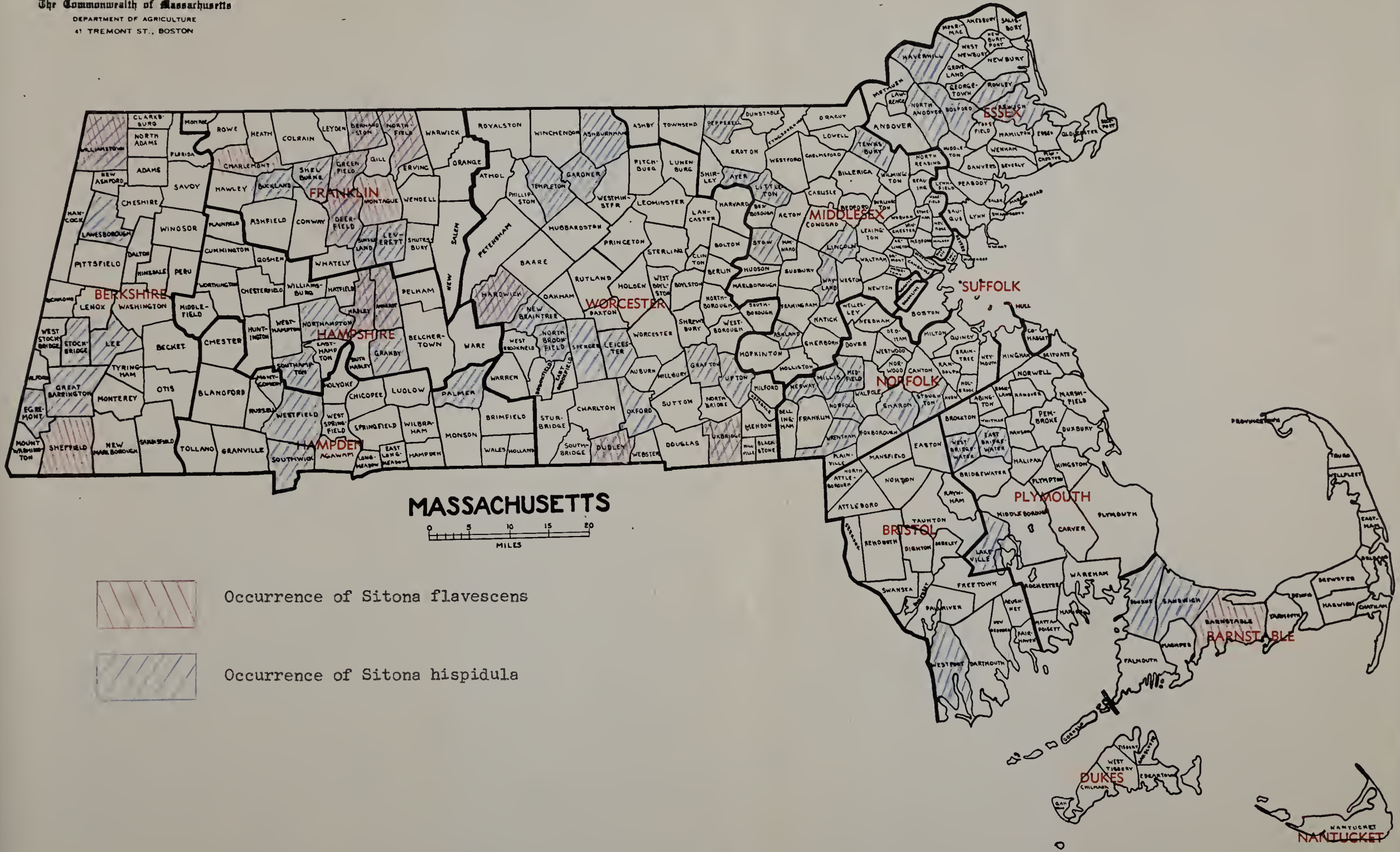
Pupa
(see page 78)

Adult

The characteristics which separate Sitona flavescens from other members of the genus are as follows: "Elongate-oblong. Piceous-black; above densely clothed with rusty brown and fuscous narrow, hair-like scales, the darker ones in fresh specimens forming two indistinct stripes on head and four on thorax; undersurface more sparsely clothed with fine prostrate grayish hairs; antennae, tibiae and tarsi reddish brown; club and femora darker. Beak and head about as long as thorax and, like it, finely and rather closely punctate. Thorax subcylindrical, as wide as long, widest at middle, sides feebly rounded, apex and base truncate. Elytra one third wider at base than thorax, sides parallel to apical fourth, thence rapidly converging; disc very finely striate, the striae with rows of minute punctures. Second ventral segment about as long as the two following united. Length 4.5-5.5 mm." (Blatchley and Leng, 1916)

Distribution of *Sitona hispidula* and *Sitona flavescens* in Massachusetts Based on Collections Made by the Author Between 1956 and 1959.

The Commonwealth of Massachusetts
DEPARTMENT OF AGRICULTURE
41 TREMONT ST., BOSTON



Occurrence of *Sitona flavescens*

Occurrence of *Sitona hispidula*

Distribution of Sitona hispidula in Massachusetts

There are very few references on the occurrence of S. hispidula in Massachusetts. As mentioned previously, Hitchcock (1835) recorded Curculio crinitus, which is regarded by most authors as a synonym for S. hispidula, from the state. In his distribution map for S. hispidula, Webster (1915) indicated a record in the vicinity of Plymouth or Bristol County. This species was known to occur throughout New England according to Britton (1920). Shaw et al (1953) reported it as being very common in the Connecticut valley. The present author has found it to be common on alfalfa in every county in the state. The distribution of both this weevil and S. flavescens in Massachusetts, according to the writer's records, is indicated on the map on the opposite page.

Distribution of Sitona flavescens in Massachusetts

The occurrence of S. flavescens in Massachusetts apparently can be dated previous to 1835. Johnson (1930) listed it as being present on Nantucket, Massachusetts which is an island off the coast. The present author has obtained specimens over a three year's period from the following counties: Hampshire, Barnstable, Worcester, Franklin and Berkshire. Despite the lack of records for some counties, it is obvious that S. flavescens occurs throughout the State since it has been collected in widely scattered counties and is also known to occur in New Hampshire and Vermont. However, it is considerably more common on clover whereas the majority of the collections of the author were from alfalfa.

Character and Extent of Injury by Sitona spp.

The injury to clover and alfalfa by the adults of S. hispidula and S. flavescens consists in the eating of rounded, irregular patches from the margins of the leaves and gnawing the stems and leaf buds of young seedlings. The injury to young seedlings may cause their death or weaken them to such an extent that they make much less growth than when uninjured. The injury to older plants does not appear to affect the plants except when the beetles are so numerous as to cause excessive defoliation.

Larval feeding is the most serious part of the damage done to clover and alfalfa. It is all the more serious since it occurs beneath the soil surface and even when noted is not often recognized for what it is. When first hatched the larvae feed on the bacterial nodules, completely hollowing them out, leaving only an empty shell. As the larvae grow, they consume the small lateral rootlets. The larger larvae attack the taproots causing irregular shaped lesions over much of the root. The plate on the next page provides evidence of the extent of larval injury.

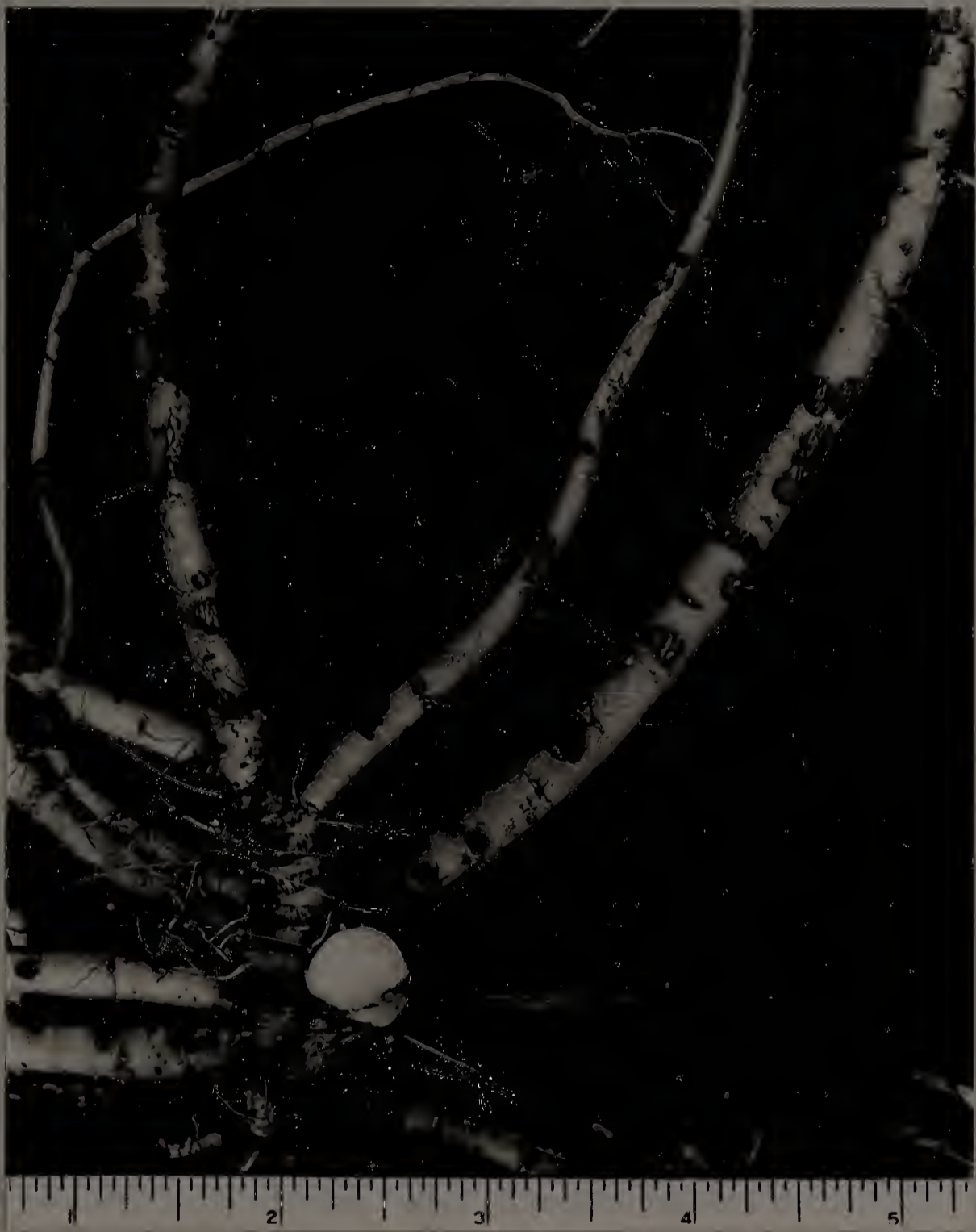


Plate 1. Scars on an alfalfa root resulting from the feeding of Sitona sp. larvae.

Economic Importance of Sitona sp. in Massachusetts

Numerous authors (Burril, CEIR, 1922; Flint, CEIR, 1931; Price, CEIR, 1932; Turner, CEIR, 1954; Iowa, CEIR, 1955; Colorado, CEIR, 1955; Davis, CEIR, 1955; Thomas, CEIR, 1956; Brown, CEIR, 1956; Lockwood, CEIR, 1956; Muka, CEIR, 1957; Barr, CEIR, 1957) have reported serious losses of clovers and alfalfa due to the feeding of adults of S. hispidula and S. flavescens. These authors have recorded up to 30 adults per square foot of alfalfa and up to 1 adult per sweep. Gyrisco et al (1958) indicate that one beetle per net sweep is sufficient to cause commercial injury.

Under Massachusetts conditions, the writer has found that populations of adult Sitonas do not ordinarily occur in sufficient numbers to cause commercial injury to alfalfa and clovers. While the highest number of Sitona hispidula adults collected in 100 sweeps was 245 in one field of alfalfa in Berkshire County, the usual number per 100 sweeps ranges from 1-2 to 35. The highest number of S. flavescens adults collected by the writer has been 56 per 100 sweeps. Where this species has been taken in the State, the usual numbers per 100 sweeps ranges from 1-5. Over a three year's period, the writer has never found more than 4-5 adults of either species per square foot of alfalfa sod.

Various records of larval density have been reported sometimes in connection with damage to the tap roots of clovers and alfalfa. Bigger (1930) reported finding 33-43 larvae of S. hispidula per square foot in a "heavily infested" field. In Kansas, Marshall and Wilbur (1934) recorded an average of 25.6

larvae of S. hispidula per square foot 6" deep in an alfalfa field. Severin (CEIR, 1939) reported that larvae of S. flavescens were causing considerable injury to grass lawns in South Dakota, as many as 4-5 per square foot being present. The University of Maryland (CEIR, 1954) reported 1-3 larvae per alfalfa plant in most counties in Maryland. In June, Kyd and Thomas (CEIR, 1955) recorded 12-24 larvae per crown of red clover in the central area of Missouri resulting in considerable damage. Gittins (CEIR, 1956) noted larval damage on all tap roots of alfalfa sampled in Boise Valley, Idaho. Throughout the season, he noted over 90% larval injury on alfalfa tap roots. In mid-July 1957, he (CEIR, 1957) noted that some red clover seed fields near Hampa and Roswell were infested with up to 40 larvae per square foot. Gyrisco (1957) indicated that 20-40 larvae of Sitona sp. per cubic foot was the usual number found in New York State. Leu (1958) reported on results obtained in his study in New Jersey. In 1956, he obtained 55-93 Sitona larvae per square foot and in 1957, he obtained 70-124 larvae per square foot in red clover fields.

Previous to this study, no attempt had been made to determine the larval population densities of Sitona sp. in Massachusetts. Soil surveys were carried on in June, 1957 to determine the larval populations in different types of legumes. As can be seen from the tables (1, 2, 3) on the following pages, alfalfa soil consistently contained the largest number of Sitona sp. larvae, followed by ladino clover, white clover and red clover, and birdsfoot trefoil in that order. In 1958, in connection with soil insecticide tests comparison of immature Sitonas was made between alfalfa,

Table 1 Comparison of the density of larval populations of Sitona sp. per square foot* collected June 6, 1957 from plots on The Eastern States Experimental Farm, Agawan, Massachusetts.

<u>Legume</u>	<u>Larvae</u>	<u>Pupae</u>	<u>Adults</u>
Dutch white clover	93	10	9 (<u>S. hispidula</u>)
Ladino clover	118	1	0
Birdsfoot trefoil	29	0	0
Alfalfa - Naraganset	136	3	0
Alfalfa - Socislaible	49	0	0
Red clover	90	5	0

* 6" deep

Table 2 Comparison of the density of larval populations of Sitona sp. per square foot* collected June 10, 1957 from the fields on the University Farm, Amherst, Massachusetts.

<u>Legume</u>	<u>Larvae</u>	<u>Pupae</u>	<u>Adults</u>
Alfalfa and mixed grasses	7	1	0
Alfalfa	78	0	1 (<u>S. hiemidula</u>)
Ladino clover	75	10	0
Red clover	36	4	0
Dutch White clover	40	4	0

* 6" deep

Table 3 Comparison of the density of larval populations of Sitona sp. per square foot* collected June 12, 1957 from fields in Hampshire County.

<u>Legume</u>	<u>Larvae</u>	<u>Pupae</u>	<u>Adults</u>
White clover 1st year	2	0	3 (<u>S. hispidula</u>) 1 (<u>S. flavescens</u>)
White clover 2nd year	21	0	0
Alfalfa with ladino on edge, 2nd year	158	9	3 (<u>S. flavescens</u>)
Alfalfa 1st year	2	0	0
Alfalfa 2nd year	1	0	0
Alfalfa 5th year	11	1	0
Alfalfa 1st year	15	0	0

* 6" deep

ladino clover, red clover and birdsfoot trefoil. The results are shown in Table 4. In this case, birdsfoot trefoil had a higher larval population than in the previous surveys. The writer feels that this result may be due to the fact that all plots bordered on each other.

There is an obvious discrepancy between the density of larvae in the soil and the occurrence of adults indicating that some natural factor must be operative in controlling these species in the field. This discrepancy can be explained in part, by the prevalence of the fungus, Beauveria bassiana (Balsamo) Montagne during the 1957 season. The immature specimens collected in the surveys in 1957 were brought into the laboratory and placed in petri dishes containing soil where they were allowed to complete their development. Less than five percent of the specimens were able to complete their development due to the prevalence of this fungus.

Previous workers have shown that the damage to the roots of alfalfa by larvae of Sitona sp. can cause a substantial reduction in hay yield of 18.6% over plants that were not infested. In preliminary control studies with soil insecticides, Turner (1957) found that plots of alfalfa receiving dieldrin at the rate of 2 pounds per acre for the control of S. hispidula larvae yielded an increase in green hay of 44% over untreated plots. While the writer was unable to compare yield results since most of his insecticide treated plots were winter killed, he believes that a substantial reduction in yield probably takes place based on the high population density of Sitona larvae found in the fields

Table 4 Comparison of the density of larval populations of Sitona sp. per square foot* collected June 27-July 2 from experimental plots on the University Farm, Amherst, Mass.

<u>Legume</u>	<u>Larvae</u>	<u>Pupae</u>	<u>Adults</u>
Alfalfa	81	6	0
Ledino clover	46	27	3 (<u>S. flavescens</u>)
Red clover	20	23	3 (<u>S. hispidula</u>) 3 (<u>S. Flavescens</u>)
Birdsfoot trefoil	59	43	2 (<u>S. flavescens</u>)

* 6" deep

examined as compared to the larval populations reported for other states. Even if legume yields are not noticeably decreased in a given year, the danger to legumes in Massachusetts lies on a long term basis. Since the larvae feed to a great extent on the root hairs and taproots, they create openings whereby bacterial and fungal organisms may enter causing crown and root rot. Plate I shows an alfalfa root with typical injury resulting from the feeding of Sitona larvae. The root was collected from a plot of alfalfa at the Eastern States Farmers Exchange experimental farm where the larvae exceeded 50 per square foot. In addition, the feeding of larvae on the bacterial nodules so reduces the availability of nitrogen in a useable form that the length of time a legume may subsist is substantially decreased. This phenomena would especially follow in the case of alfalfa which has a normal growth period of 4-6 years.

Seasonal History of Sitona hispidula in Massachusetts

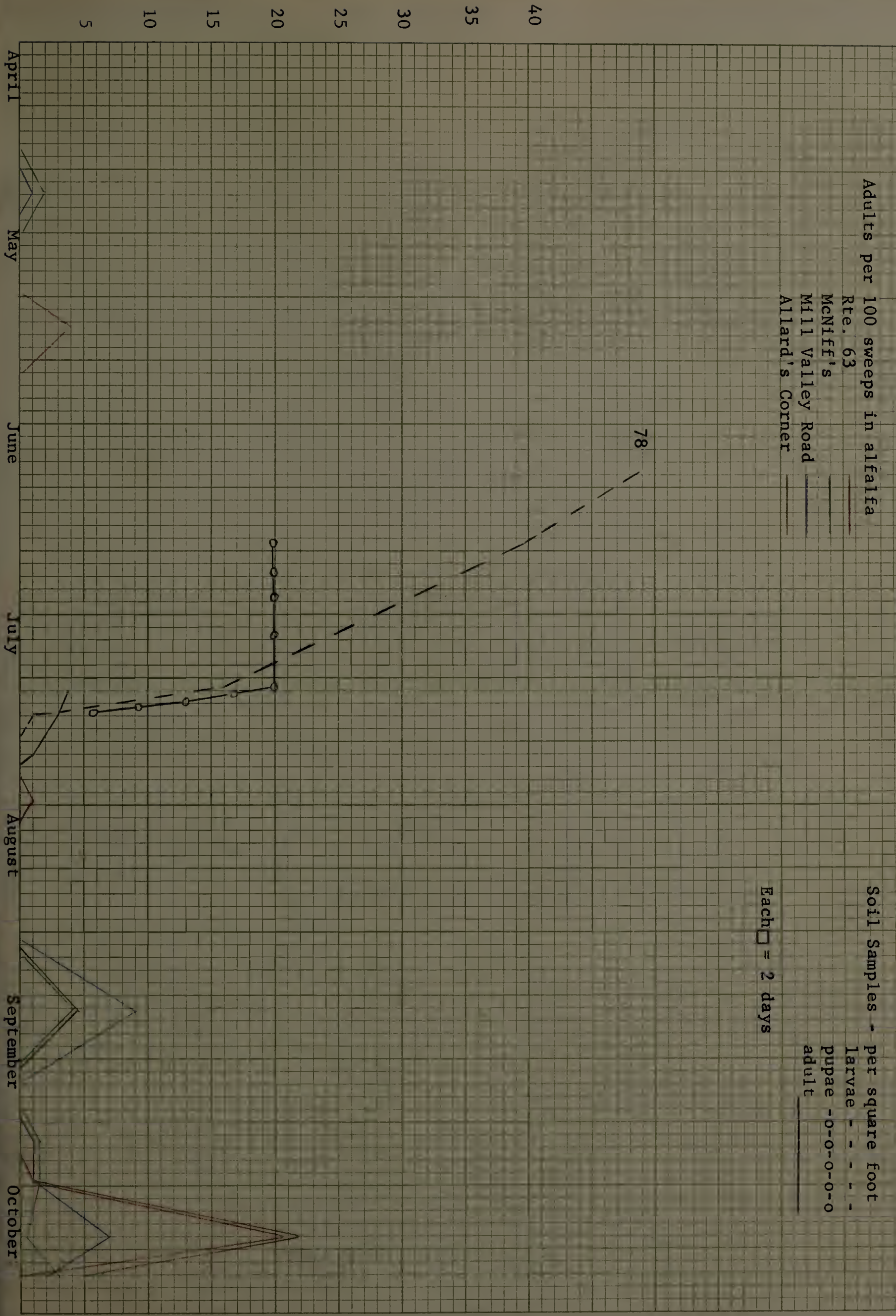
A brief summarization of the seasonal history of S. hispidula, as it occurs in Massachusetts may be recorded as follows. There is one generation a year. The clover root curculio overwinters both in the egg and adult stage. Adults begin to appear with the first warm days of early spring. In 1958, the writer collected adults as early as March 20th. Egg laying probably commences soon thereafter. Fall laid eggs probably begin hatching about the same time. Females brought into the laboratory on April 18, 1958 laid eggs the same day. Copulating adults were observed as early as April 30, 1957 and May 1, 1958. Copulation and egg deposition were still taking place on June 7, 1958. Larval populations in the soil reach their peak density the last week of May and the first week of June. Pupation begins about the first week of June and extends through the end of July. New generation adults begin to appear about the third week in July in the field.

Mating reoccurs in early September and continues throughout the fall. The writer has observed pairs copulating as early as September 8 and as late as November 19th, 1958. Adults brought into the laboratory on September 5th didn't begin ovipositing until October 9th. However adults brought into the laboratory September 28th laid eggs the same day. Oviposition continues throughout the fall. Adult females confined in petri dishes outside the laboratory were still laying eggs up to December 8, 1958. These same adults were still feeding on December 27th on sunny days and were still active on January 23, 1959. These adults

were subjected to outside temperatures as low as -11°F on December 22, 1958 and were able to survive. Apparently, however, continuous subjection to low temperatures without adequate protection is sufficient to kill the adults, as all adults were dead by the end of January.

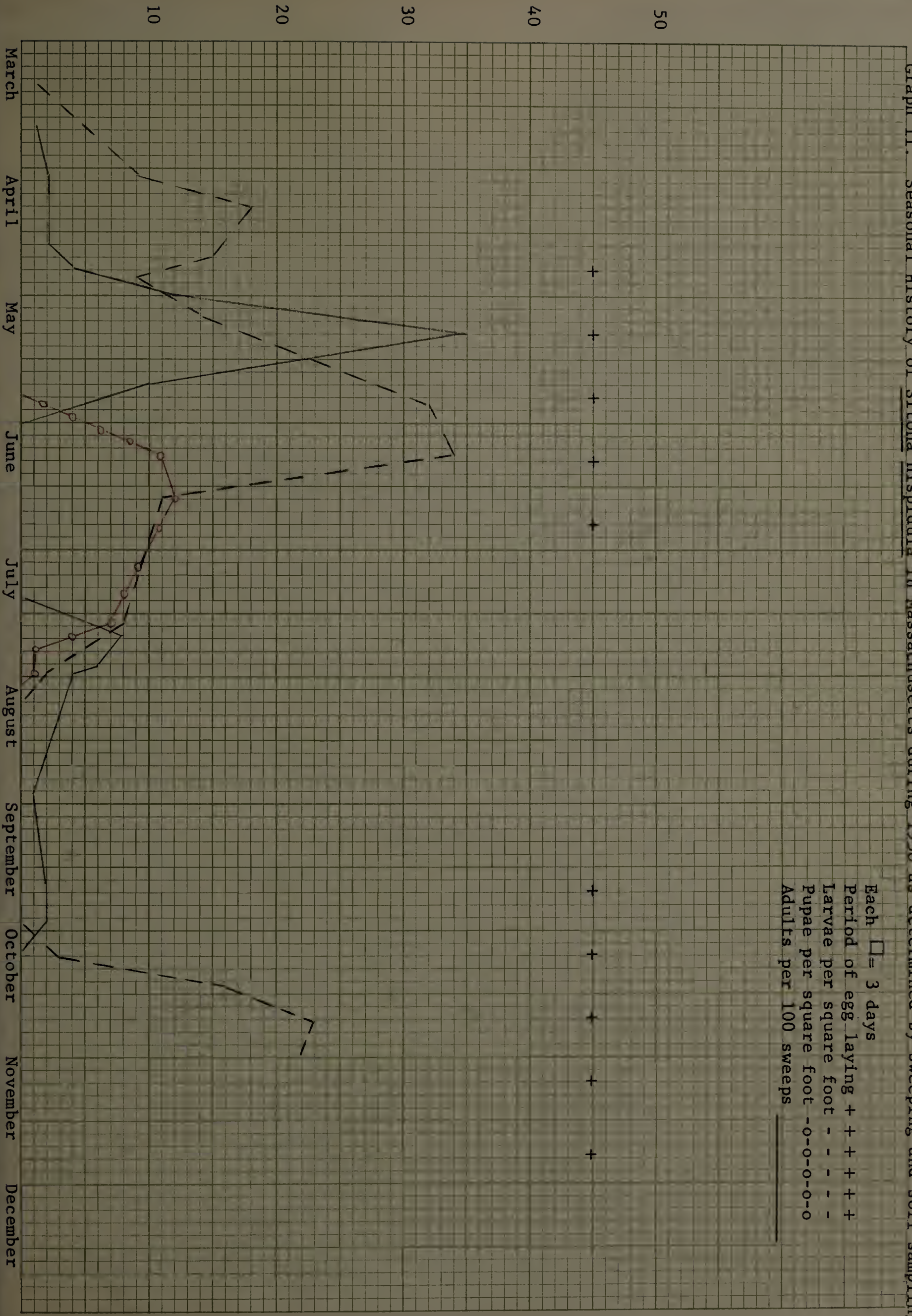
The seasonal history of this curculio during the 1957 and 1958 seasons in Amherst, Massachusetts is given on Graphs I and II. While the author has no way of determining the differences between larvae and pupae of the two species being considered in this study, he is assuming that the populations of larvae and pupae were largely S. hispidula since so few adults of S. flavescens were recovered during weekly surveys by sweeping. The second larval peak recorded in late October of 1958 is believed to be that of S. flavescens.

Graph I. Seasonal History of Sitona hispidula in Massachusetts in 1957 as determined by sweeping and soil sampling.



HCHNI EHL TO SQUARES 01

Graph II. Seasonal History of Sitona hispidula in Massachusetts during 1958 as determined by sweeping and soil sampling.



Seasonal History of Sitona flavescens in Massachusetts

Based on data obtained over a three year's period, it would appear that Sitona flavescens overwinters in the egg, larval and adult stages. Adult specimens of S. flavescens have been collected by the author as early as May 14th in Franklin County. From the number of adults collected in the spring, it would appear that this stage was the least effective in over-wintering by this species. The writer has no record of egg deposition by this species in the spring. The earliest emergence date of adults of this species is June 2, 1959 from larvae collected in the field on May 14 and reared in the laboratory. Adults emerged from June 10-July 2, 1957 from immature stages collected in the field and reared in the laboratory. In 1958, an adult emerged from its pupal state as late as August 4th. Copulation and egg deposition occur in late summer and fall. Hatching of eggs occurs both in the fall and spring. While it cannot be stated definitely, it is believed by the author that the larval population peak in October 1958 on Graph II is that of S. flavescens. Egg deposition by field captured adults occurred from October 8-November 15th in the laboratory. Eggs deposited by adults in early November 1958 were placed in the soil and left throughout the winter. When they were recovered on April 23, 1959, they were still unhatched. When brought into the laboratory and placed in petri dishes at 100% relative humidity, 70% hatched within three days. There is one generation a year.

Ecology

Egg - S. hispidula

The oviposition site of the female clover root curculio apparently remained undiscovered until 1909 when Wildermuth (1910) reported finding eggs in the field adhering to the lower leaves of both red clover and alfalfa. Eighty to ninety per cent of the eggs are deposited on the soil at the base of plants both in cages and in the field according to Bigger (1930). Jewett (1934) noted that eggs were laid on the stems and leaves near the soil or on the soil or trash around the plants. The writer found this to be the case in Massachusetts. The writer was also able to recover eggs from the soil in the fall of 1958 by using a flotation method in which 1/3 square foot samples of alfalfa sod were immersed in water. The eggs floated to the surface of the water and were recovered by examination of the water under a microscope. Some of the eggs proved to be viable and hatched. This method, however, is very tedious and provides insufficient numbers of eggs for experimental purposes.

Adult females confined in petri dishes failed to exhibit any marked egg deposition preference between filter paper and red clover leaves. The writer noted that about 48% were laid on the filter paper and 52% on red clover leaves. Ninety per cent of those laid on the red clover leaves were deposited on the hairy underside of the leaves.

A preliminary experiment was carried on in the laboratory to determine the duration of the spring egg period in the laboratory.

Eggs deposited in petri dishes from May 7-9 in the laboratory hatched on May 22, a period of about eight and one-half days. The relative humidity was 100%. The following table provides the temperature range under which egg development occurred in the laboratory.

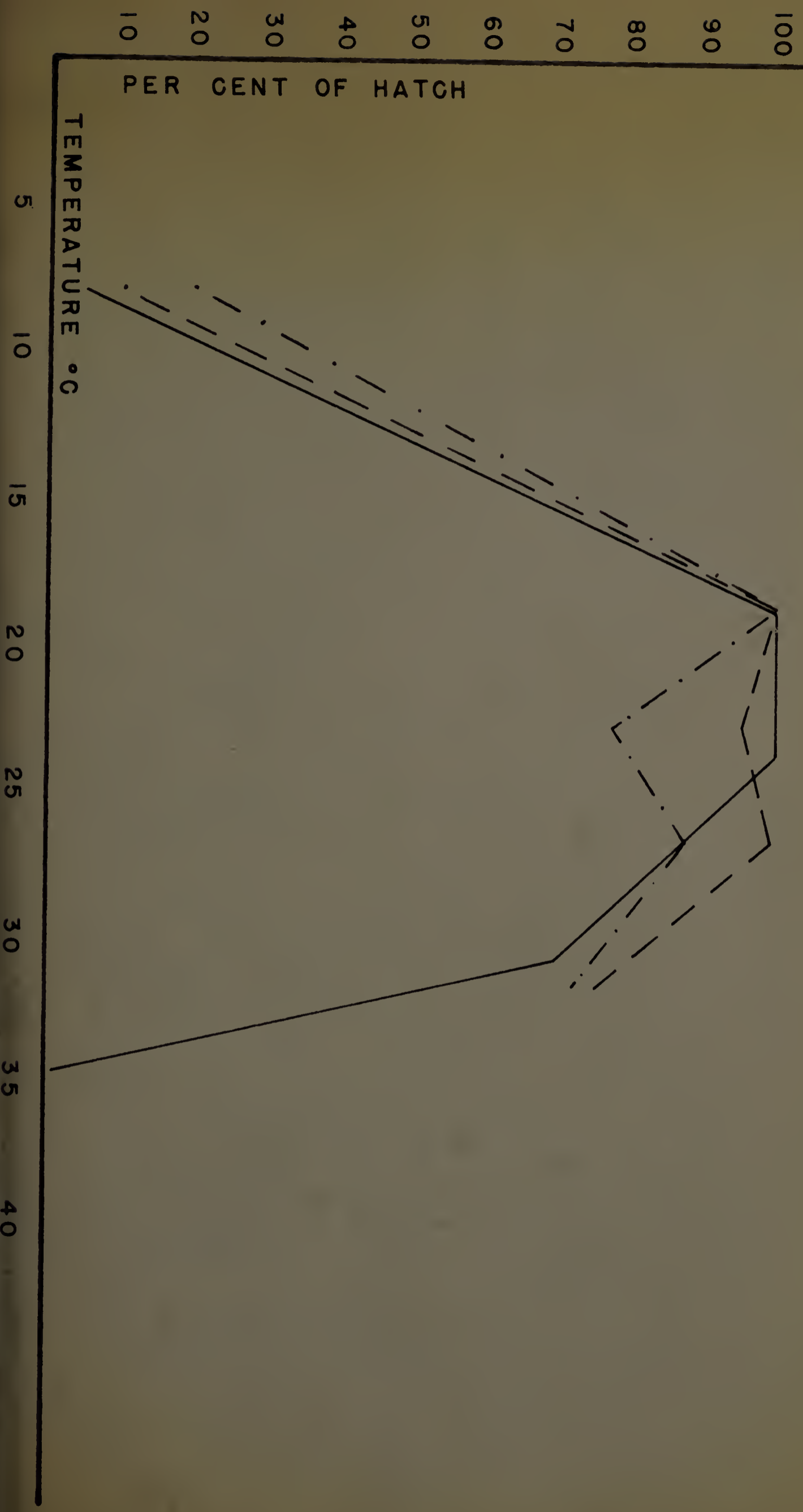
Date	May	7	8	9	10	11	12	13	14	15
Temp. (°F.)	Max.	78	77	79	79	82	82	80	77	75
	Min.	72	75	73	72	77	76	74	69	65
	Mean	74.5	76	75.5	75.5	79.5	79	77	73	70

In order to determine the effect of various temperatures on the duration of the egg period several tests were run.

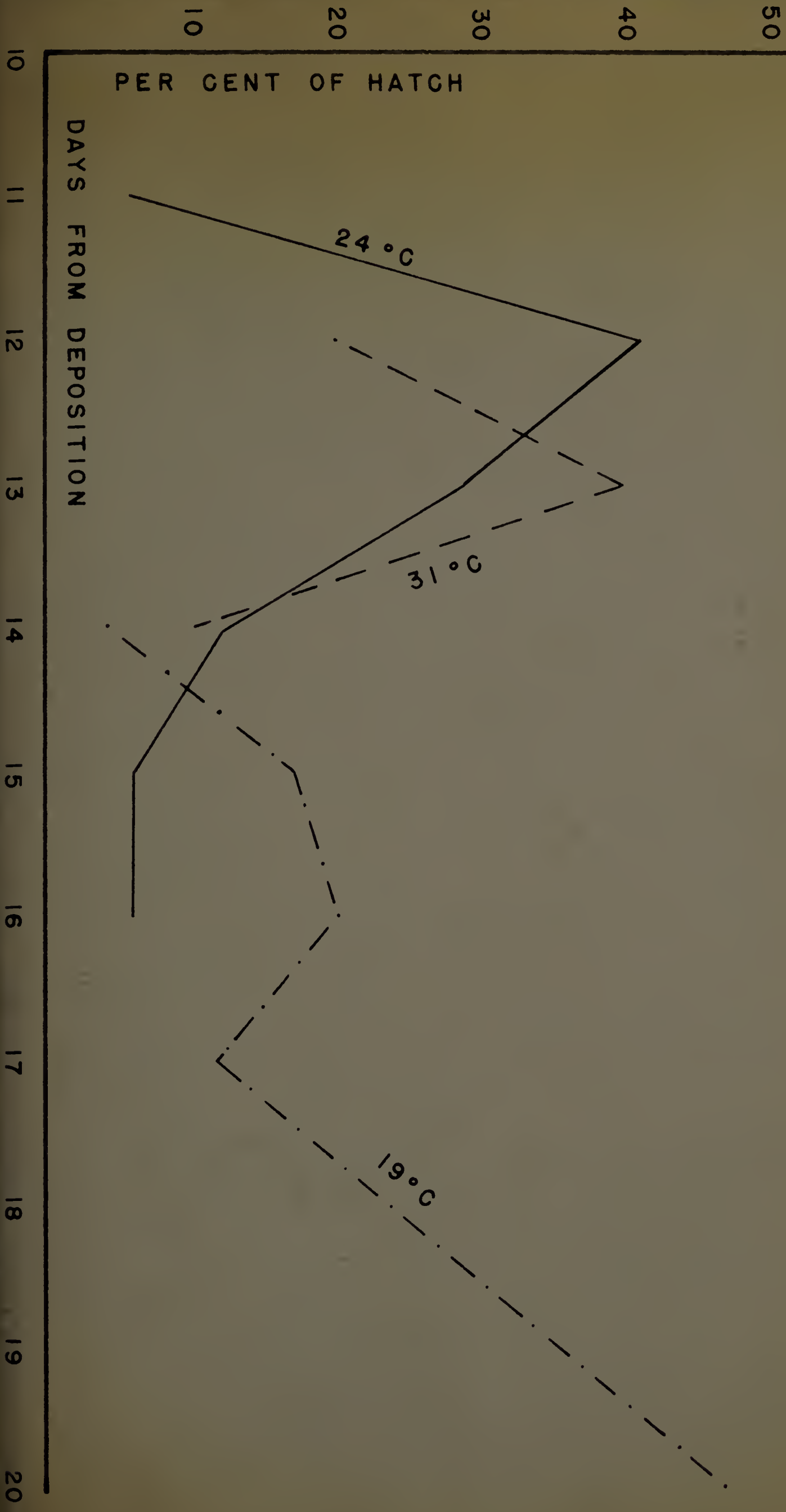
In the first experiment three series of eggs were exposed to different temperatures to determine the percentage of total hatch under these conditions. The results are shown on Graph III. It can be seen from this graph that optimum hatching temperatures extend from at least 19°C. to 27°C.

Several series of eggs were used to determine the effect of temperature on the duration of the egg period. The relative humidity was 100% in all cases. The eggs were examined daily in order to record the percentage of hatch. As can be seen in Graphs IV, V, VI, VII, VIII, and IX, the lower the temperature, the longer the duration of the egg stage. In tests where eggs were confined at 33-35°C, no hatching occurred. The eggs were found to be in a desiccated condition at the end of the experiment.

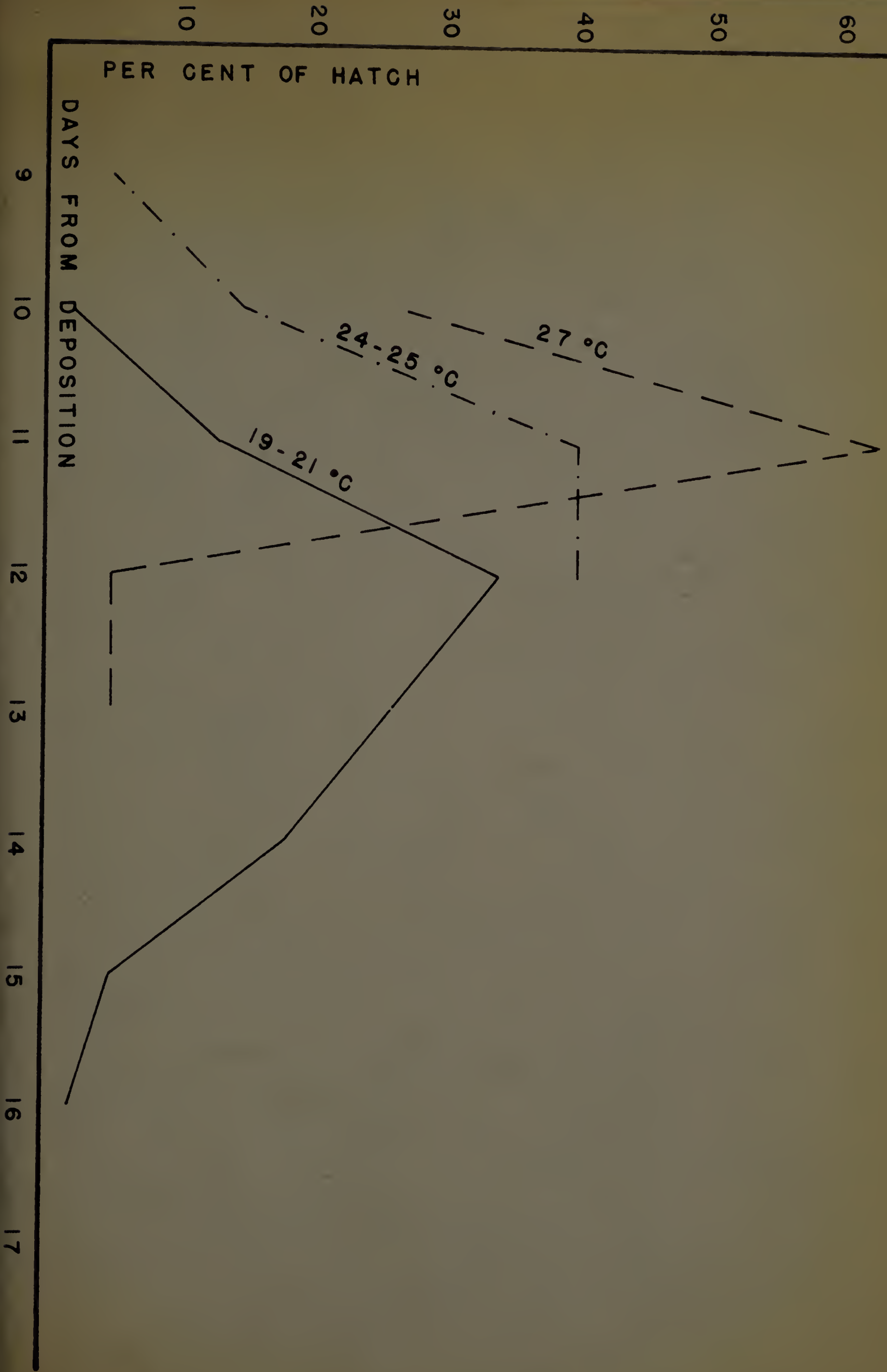
GRAPH III. EFFECT OF TEMPERATURE ON THREE SERIES OF *S. HISPIDULA* EGGS AT 100% RELATIVE HUMIDITY.



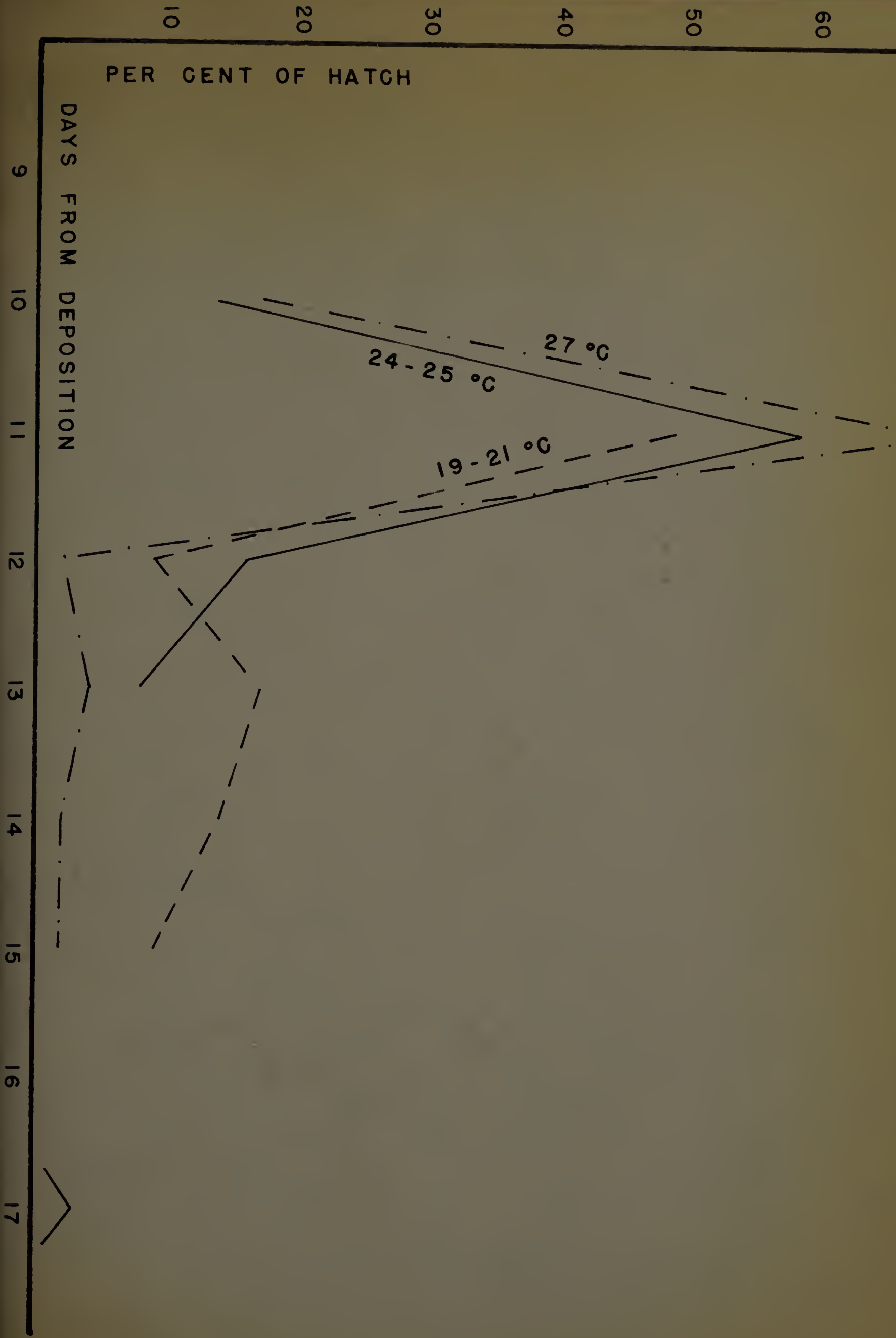
GRAPH IV. EFFECT OF TEMPERATURE ON RATE OF HATCH OF S. HISPIDULA EGGS AT 100% RELATIVE HUMIDITY.



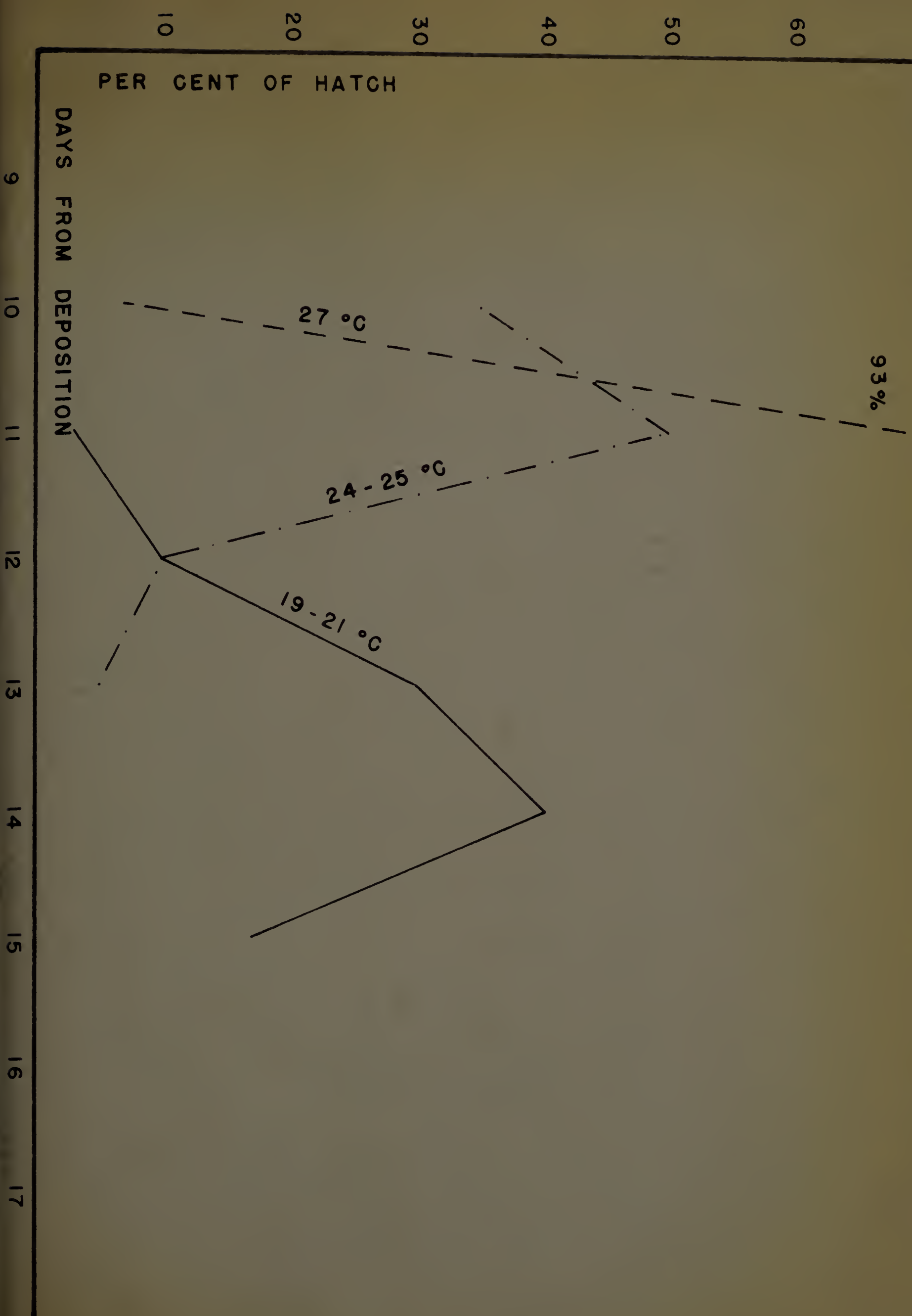
GRAPH V. EFFECT OF TEMPERATURE ON RATE OF HATCH OF S. HISPIDULA EGGS AT 100% RELATIVE HUMIDITY.



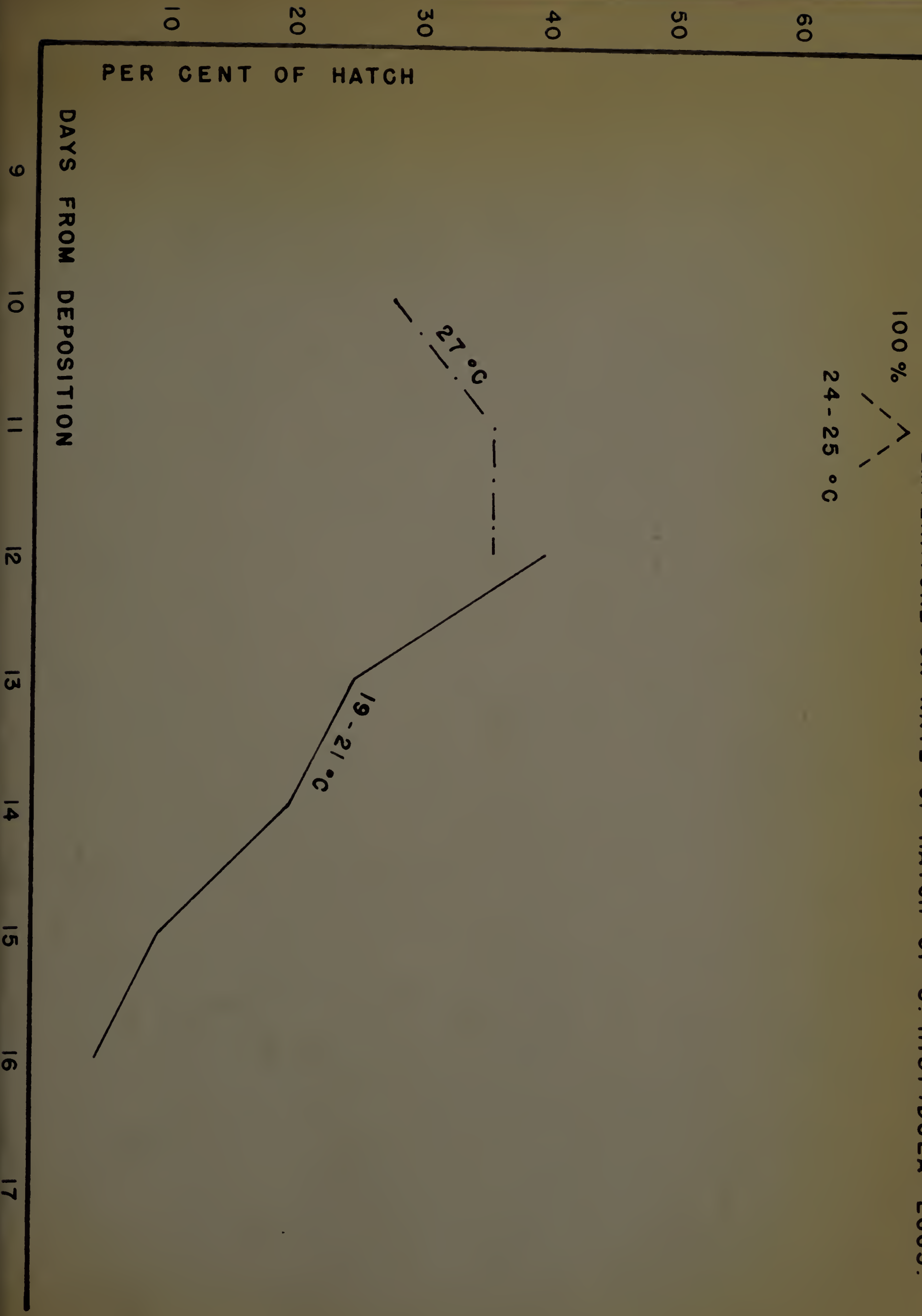
GRAPH VI. EFFECT OF TEMPERATURE ON RATE OF HATCH OF S. HISPIDULA EGGS.



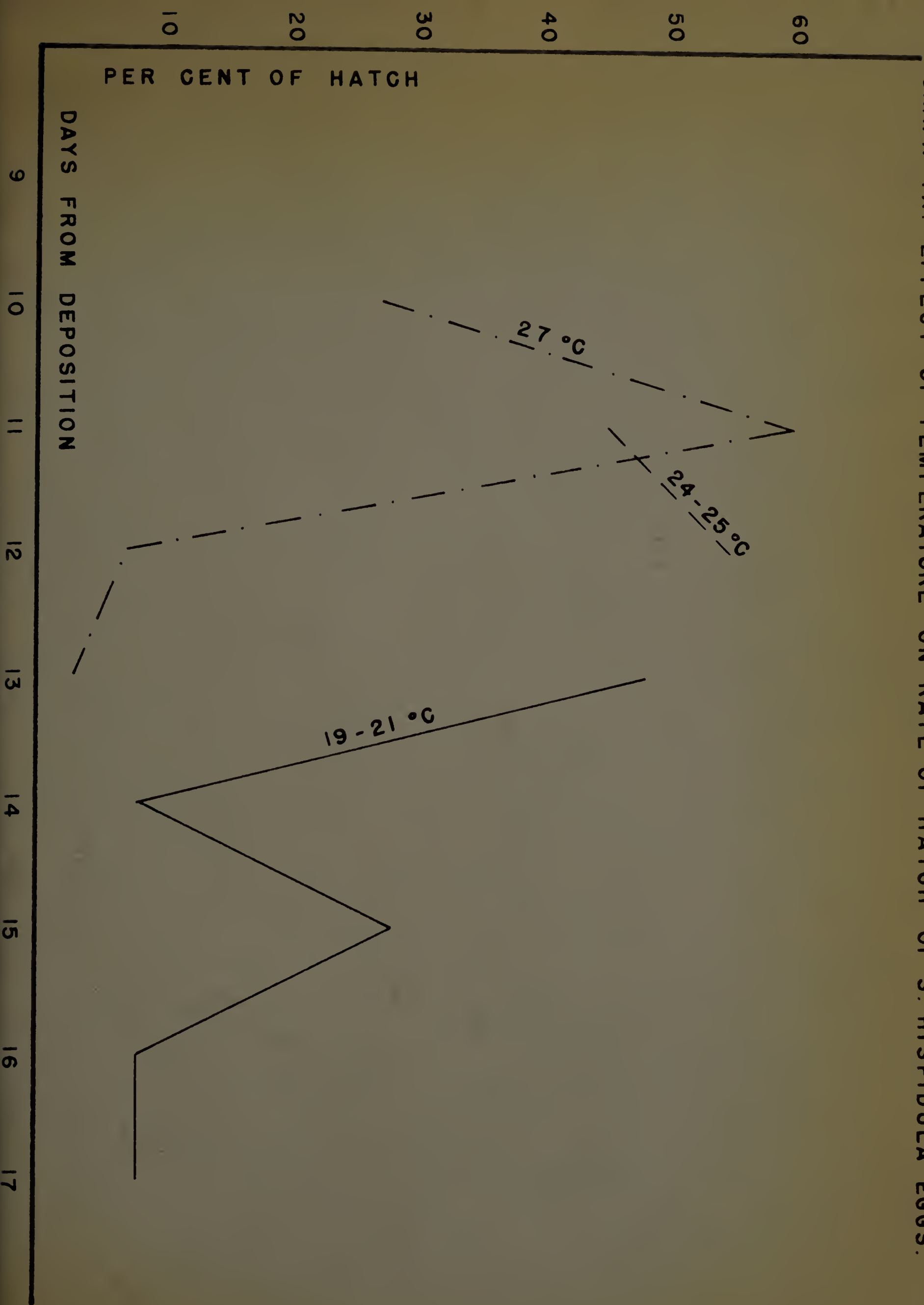
GRAPH VII. EFFECT OF TEMPERATURE ON RATE OF HATCH OF S. HISPIDULA EGGS.



GRAPH VIII. EFFECT OF TEMPERATURE ON RATE OF HATCH OF S. HISPIDULA EGGS.



GRAPH IX. EFFECT OF TEMPERATURE ON RATE OF HATCH OF S. HISPIDULA EGGS.



The results of these experiments coincide in large measure with those obtained by Grossheim (1928) in Russia and Grigorov (1956) in Bulgaria. These data are produced below. Neither of these authors indicate whether their figures are an average or either extreme.

Grossheim

Temperature °C.	35	28	22	18	12	8
Duration of egg stage in days	--	9	19	21	32	-

Grigorov

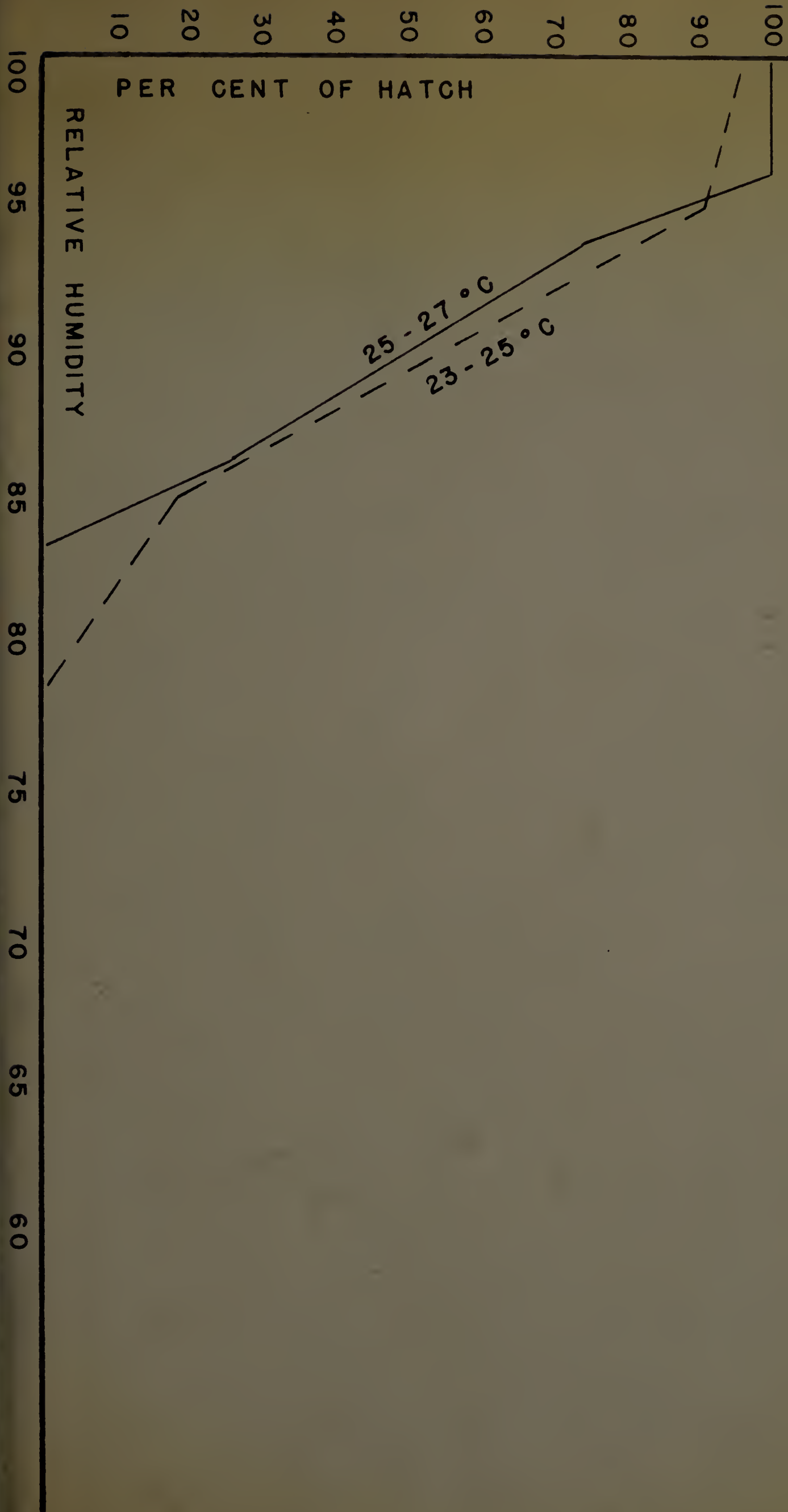
Temperature °C.	35	28	20	15	11
Duration of egg stage in days	--	10	20	30	35

Lavigne

Temperature °C.	33-35	31	27	24-25	19-21	8
Duration of egg stage in days	--	13	11	11-12	15	(?)

In order to determine the effect of relative humidity on the percentage of hatch, eggs were placed in the previously described containers under two conditions of temperature and nine relative humidities (96%, 93%, 86%, 85%, 83%, 78%, 72%, 64%, and 56%). In Graph X, it can be seen that no hatching occurred below a relative humidity of 85%. Optimum total hatch occurred at 100% R.H. and rapidly decreased as the relative humidity was lowered. This experiment would seem to indicate that very moist conditions are

GRAPH X. EFFECT OF RELATIVE HUMIDITY ON HATCH OF S. HISPIDULA EGGS AT TWO TEMPERATURES.



necessary in the field for a significant amount of hatching to take place. This condition is well met in Massachusetts where a combination of melting snow and spring rains suffice to keep the soil very moist.

Since eggs apparently require such a high percentage of moisture present in order to hatch, the writer considered it to be of interest to determine what effect storage in water would have on the percentage of hatch. Consequently three series of eggs were stored in vials of water and placed in a refrigerator at 8-11°C. in early November 1957 wherein they remained until mid-March 1958. The vials were examined on March 18th and the unhatched eggs were placed in petri dishes in the laboratory at a temperature of approximately 75°F. These eggs were re-examined on March 26 and April 1st. The results of this experiment are shown in the following table 5. From these data, two conclusions may be drawn: (1) eggs of S. hispidula hatch at temperatures as low as 8-11°C., (2) eggs of S. hispidula remain viable immersed in water over a four-month period.

Table 5 Effect of storage in water at 8-11°C. on eggs of S. hispidula.

Date laid	Date stored	Dates examined March 18	March 26	April 1	Total # Eggs Stored
Nov.9-12	Nov. 12	14 dead larvae in vial	no hatch	no hatch	70
Nov.9-12	Nov. 12	7 dead larvae in vial	44 eggs hatched	10 eggs hatched	160
Nov. 3	Oct. 31- Nov. 3	18 dead larvae in vial	1 egg hatched eggs attacked by fungus	no hatch	175

At the same time, a series of eggs was stored in vials of water and placed in the deep freeze. These eggs were also examined on March 18, 1958. No hatching had occurred. All the eggs were in a desiccated condition.

The writer recorded the soil temperature at 6" depth in alfalfa sod throughout the summer and winter of 1958-59. The temperature ranged from a high of 75°F. in August to a low of 30°F. in January. The low in January most certainly resulted from the lack of snow cover. It would seem to the author, based on the scarcity of larvae in the spring of 1959, that prolonged freezing also results in the desiccation of eggs in the soil.

Egg - S. flavescens

The duration of egg development of fall laid eggs of S. flavescens was investigated under laboratory conditions. While the tests were being run, the laboratory temperatures ranged from 64°-82°F. The maximum, minimum, and mean temperatures are recorded in Table 6. Under these conditions, the duration of the egg phase was found to vary from 11 to 15 days as shown in Graphs XI, XII, and XIII.

At the same time, comparative tests were carried on using fall deposited eggs of S. hispidula. Eggs of S. hispidula tested under the same conditions hatched in 9-12 days. Graphs XII and XIII show that peak hatching of S. flavescens eggs occurred approximately 24 hours following peak hatching of S. hispidula eggs.

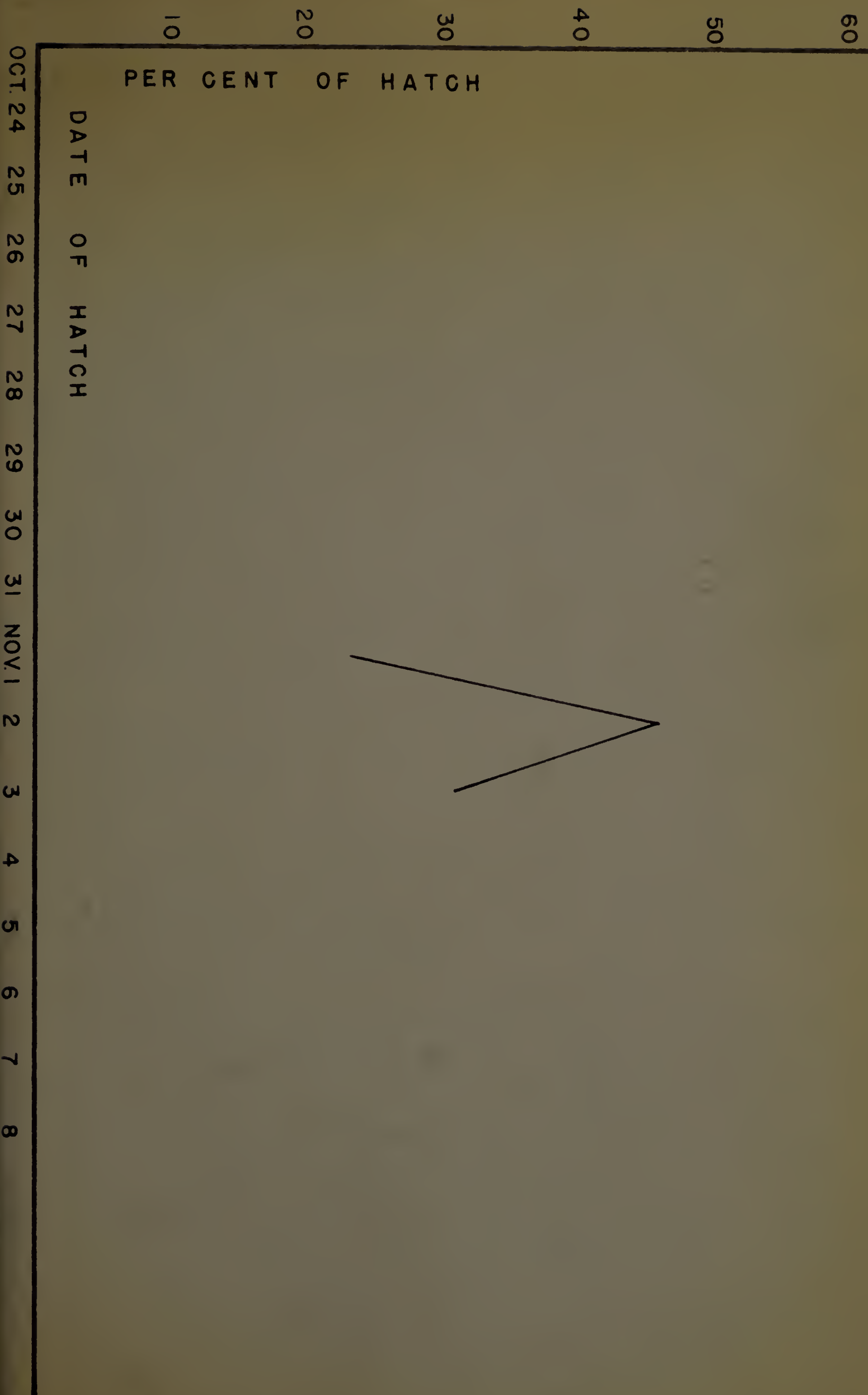
Table 6 Maximum, minimum, and mean temperatures recorded in the laborstory during experiments with fell deposited eggs.

Date 1959	Maximum	Minimum	Mean
Oct. 9	68	64	62
10	74	68	71
11	74	73	73.5
12	76	72	74
13	76	72	74
14	76	71	73.5
15	71	67	69
16	80	67	73.5
17	80	79	79.5
18	82	80	81
19	82	76	79
20	75	75	75
21	75	73	74
22	79	75	77
23	76	77	77.5
24	78	78	78
25	79	79	79
26	81	77	79
27	82	81	81.5
28	81	79	80
29	79	77	78
30	77	72	74.5
31	81	77	79

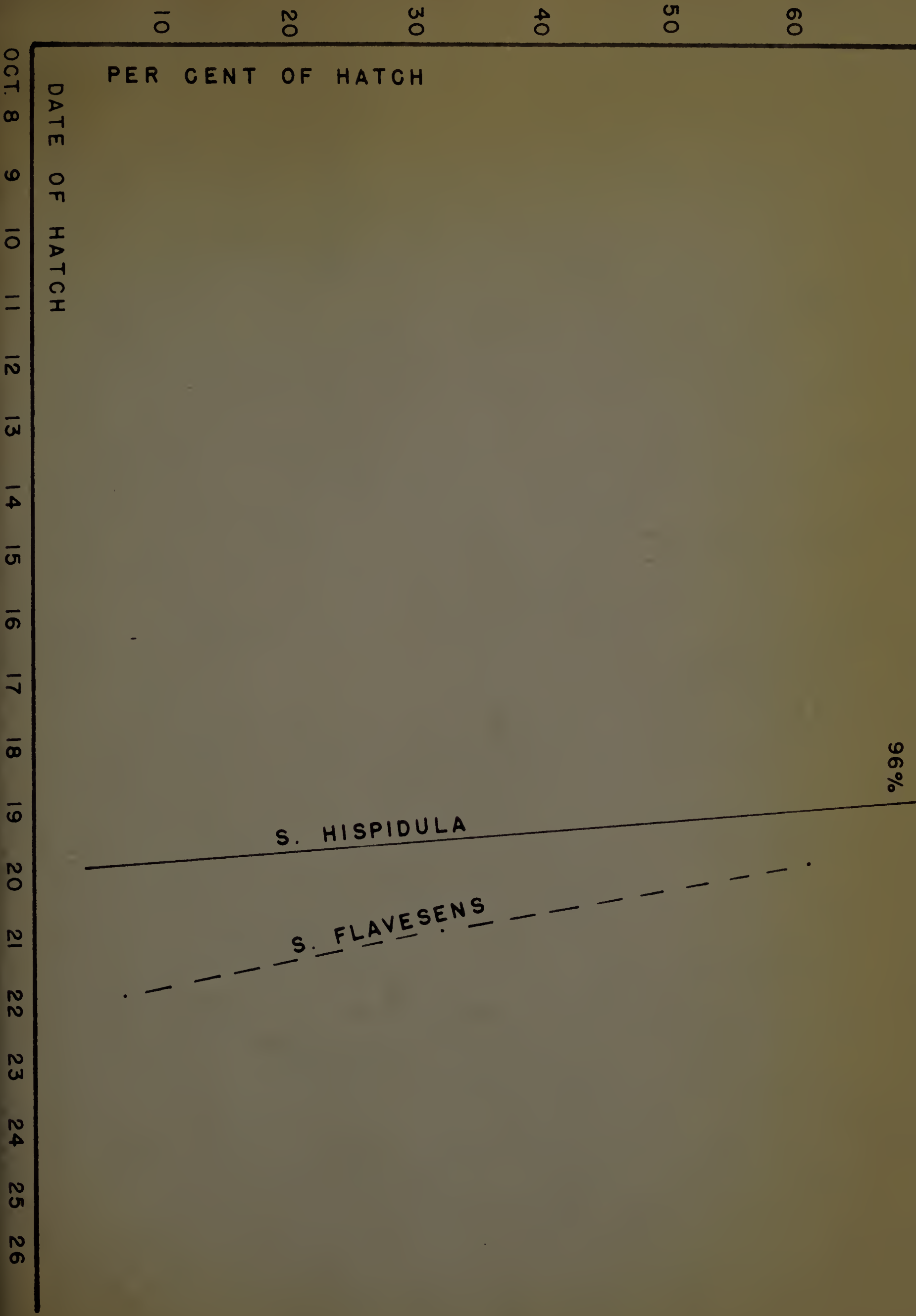
Table 6 (continued)

Nov. 1	81	79	80
2	79	76	77.5
3	77	76	76.5
4	81	78	79.5
5	79	77	78

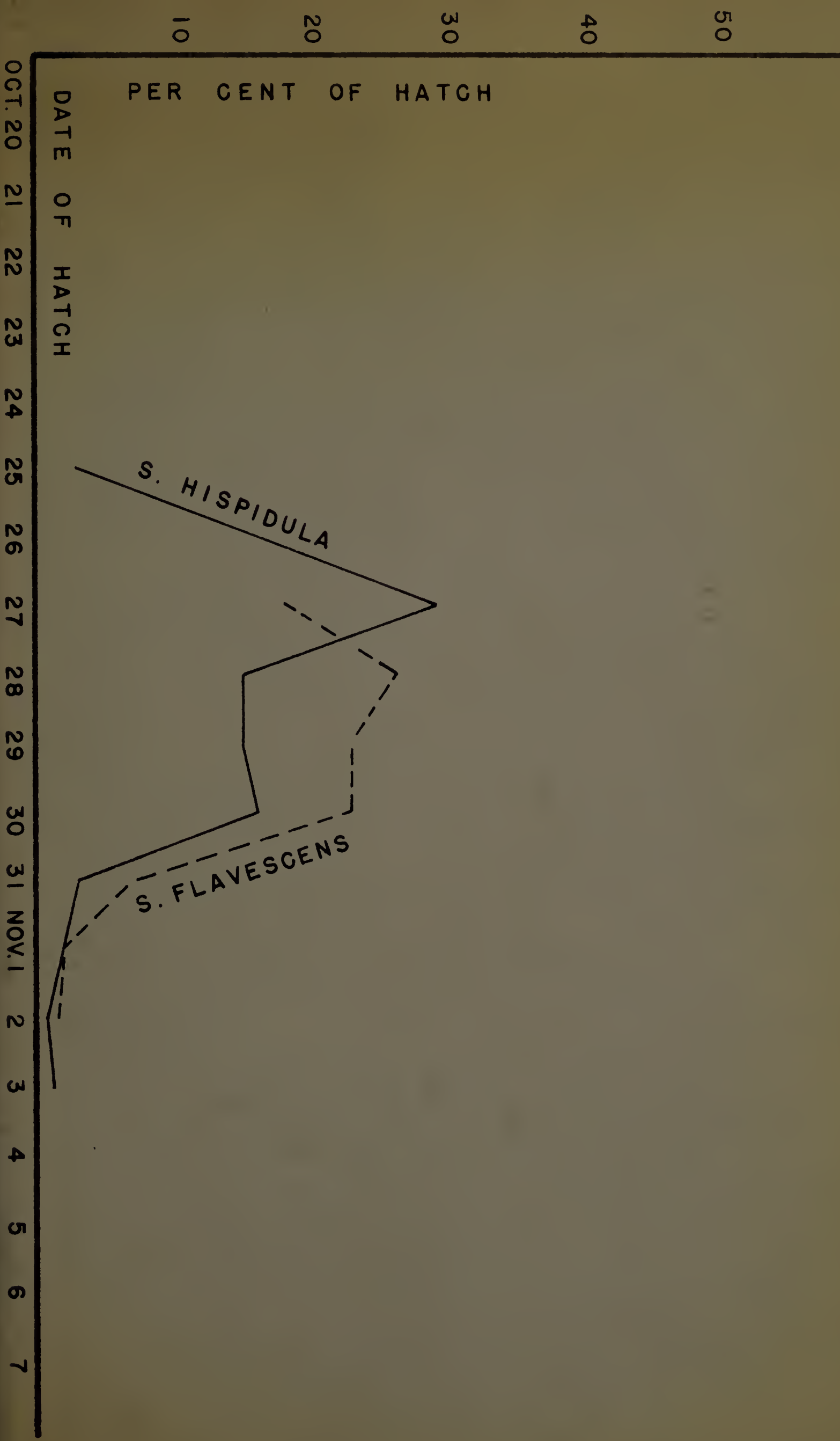
GRAPH XI. HATCHING DATA ON FALL DEPOSITED EGGS OF SITONA FLAVESCENS LAID
OCT. 21 - 24, 1958.



GRAPH XII. COMPARISON OF TIME OF PEAK HATCH OF S. HISPIDULA AND S. FLAVESENS



GRAPH XIII. COMPARISON OF TIME OF HATCH OF EGGS OF *S. HISPIDULA* AND *S. FLAVESSENS*
DEPOSITED OCT. 16-20, 1958



Hatching

With the aid of a binocular microscope, the author was able to observe the egg hatching processes of both species of Sitona in the laboratory. No differences were noted in the methods used by the two species of larvae to free themselves from the egg.

The larvae obtain their freedom by using their mandibles to break off tiny pieces of the shell at one end of the egg. As progress is made, the larvae make several attempts to crawl through the opening. If unsuccessful, they continue breaking off pieces until the hole is sufficiently large. In emerging, they contort their bodies much in the same fashion as the movements of the "inch" worm. Fifteen to twenty minutes was required by the observed larvae to complete the process of hatching.

Some of the larvae apparently misjudged the size of the hole and were unable to get more than halfway out. They died in this position. In one instance, a larvae attempted to emerge backwards. However, it was unable to get its head capsule through the opening and eventually died.

Larva

All attempts to rear larvae of either species of Sitona from the egg through to adult were unsuccessful. First instar larvae when placed in crushed bacterial nodules only remained alive for a few days and then died of unknown causes. First instar larvae of both species were placed in holes adjacent to the roots of

innoculated alfalfa and clover seedlings in pots in the laboratory but they failed to develop under these conditions.

The writer was able to bring nearly mature larvae into the laboratory, place them in pots of alfalfa and clover and obtain adults. It was found that Sitona larvae which were feeding on a specific legume in the field failed to develop to the adult stage if placed in a pot containing a different legume. Thus, it was determined that Sitona larvae feeding on alfalfa in the field failed to develop when placed in pots of white clover whereas they successfully completed their development when placed in pots of alfalfa.

While examining square foot samples of legume soil, the writer determined that the majority of the larvae are found within 6 inches of the surface. Preparatory to pupation, they migrate to the top 2 inches of soil.

It was observed by the author that mature larvae, when found in the soil, are usually in an earthen cell wherein they pupate. When these larvae are transferred to soil in the laboratory, they reconstruct this earthen cell.

Pupae

The pupae of both species of Sitona observed in this study complete their development in an earthen cell. This cell is oval in outline and approximately 5 by 3 mm.

In this earthen cell, the pupae are relatively quiescent. The only portion of the body which is capable of movement at this stage is the abdomen. When disturbed, the abdomen is rotated in a circular motion.

The length of the pupal period was determined by the writer by bringing mature larvae into the laboratory and placing them in petri dishes partially filled with soil. The duration of the pupal period for both species in the laboratory ranged from five to nine days, there appearing to be no difference in the length of time required for each. However, weekly surveys have indicated that the pupal stage is more extended in the field, being approximately 30-40 days duration. The length of this stage in the field probably depends to a great extent on the temperature and moisture conditions.

Adult - Sitona hispidula

The habits of the adults of both species were observed during both the 1957 and 1958 seasons. Problems involving seasonal abundance, host preferences, parasitism, occurrence of dimorphic forms and reproduction were investigated.

While both species may overwinter in the adult form hidden beneath rubbish and leaves or just beneath the surface of the ground, only an occasional S. flavescens adult survives the winter. During the 1959-1960 winter season, apparently all the adults of both species succumbed due to lack of adequate snow cover and exceptionally low temperatures which froze the ground to a depth of 6 inches.

Adults appear to be rather timid and on being disturbed, drop to the ground where they sham death. They may lay on their backs for several minutes without moving.

An attempt was made to determine if time of day affected the feeding behavior of adults of S. hispidula. Four fields were examined at four different times by making 100 sweeps with a 15" beating net on August 21, 1958. Based on the data presented in Table 7, it appears that major feeding activity takes place in the evening. Adults apparently spend the hottest part of the day around the base of the plants, largely inactive.

Bigger (1934) indicated that the adults are most active at temperatures ranging from 50-70°F. From the data presented in Table 7, it would appear that as the temperature decreased with nightfall, the activity of the adults increased.

Occurrence of dimorphic forms

Jackson (1921, 1922, 1928) reported on the occurrence of two forms of S. hispidula in England, one with fully developed metathoracic wings and the other with small vestigial wings. She noted that the distribution of the two forms appeared to have no relation to latitude or altitude and that the brachypterous form was abundant in localities where it occurred.

Since S. hispidula is apparently a recent importation and probably came from England or Europe, the author felt it would be of some interest to determine if both forms occurred in Massachusetts. Some 638 adults were examined for the presence of the brachypterous wing type. All specimens examined had fully developed wings.

One-hundred and nineteen adults of S. flavescens were examined for the same phenomenon. No brachypterous forms were found.

Table 7 Effect of time of day on feeding behavior of S. hispidula adults.

<u>Time</u>	<u>Temperature F</u>	<u>Relative humidity</u>	<u>Field type</u>	<u># of adults per 100 sweeps</u>
9:30 AM	74°	77%	alfalfa	0
	74°	77%	alfalfa	1
	80°	69%	alfalfa	1
	80°	66%	red clover	8
1:30 PM	83°	55%	alfalfa	0
	86°	56%	alfalfa	0
	86°	56%	alfalfa	0
	86°	56%	red clover	0
4:00 PM	84°	56%	alfalfa	0
	85°	56%	alfalfa	0
	85°	57%	alfalfa	2
	85°	57%	red clover	3
6:30 PM	80°	75%	alfalfa	10
	80°	73%	alfalfa	1
	80°	71%	alfalfa	15
	79°	70%	red clover	12

Seasonal Proportion of Sexes

There is no record in the literature of any effort being made to determine the seasonal proportion of sexes. With this in mind, the author examined 515 adults collected during the 1958 season and preserved in alcohol. Of these, 266 were females and 249 were males. The data provided in Table 8 would seem to indicate that there was a slight predominance of females throughout the season. This greater predominance of females requires that males copulate with more than one female. Observations in the laboratory have borne this out.

Table 8 Relative abundance of males to females throughout the 1958 season collected in Amherst, Massachusetts.

Date	June	July	August	September	October	November
♂	9	75	25	24	113	3
♀	16	79	15	32	121	3

Adult - General

Emergence of Adults

Observations were made during the period of the study to determine when adults of both species of Sitona emerged from their pupal stage. Table 9 indicates that majority of adults of both species emerge during the same period, June and July.

Table 9 Dates of adult emergence of both species of Sitona over a three year's period.

Year	<u>Sitona flavescens</u>		<u>Sitona hispidula</u>	
1957	June 10	Lab.	June 10	Lab.
	June 14	Lab.	June 14	Lab.
	June 19	Lab.	June 19	Lab.
	June 25	Lab.	June 25	Lab.
	June 26	Lab.	June 26	Lab.
	June 28	Lab.	June 28	Lab.
	July 2	Lab.		
1958	July 1	Field	June 17	Lab.
	July 8	Lab.	June 18	Lab.
	July 11	Field	July 1	Field
	July 18	Field	July 8	Field
	July 30	Field	July 11	Field
	August 4	Field	July 13	Lab.
			July 14	Field
		July 15	Field	

Table 9 (continued)

Year	<u>Sitona flavescens</u>	<u>Sitona hispidula</u>
1958 (cont.)		July 18 Field
		July 19 Field
		July 20 Field
		July 21 Field
		July 22 Field
		July 30 Field
		Sept. 5 Field
1959	June 4 Lab.	no emergence data
	June 8 Lab.	
	June 10 Lab.	
	June 13 Lab.	

Host Preference of Adults

Data was collected during both 1957 and 1958 in an effort to determine host feeding preferences of adult Sitonas in Massachusetts. Based on the data provided in Tables 10, 11, 12, and 13, the following may be surmised. S. hispidula adults appear to favor those fields containing a mixture of clover, alfalfa and grass as opposed to red clover or alfalfa alone or an alfalfa-grass mixture. S. flavescens adults show a decided preference for fields largely composed of red clover. The other types of fields examined contained an almost non-existent population of this species. This premise was further borne out by sampling in Worcester County in July of 1958 where 39 S. flavescens adults per 100 sweeps were found in a field of red clover, as opposed to 1 per 100 sweeps at the most in seven fields of alfalfa. However, fall sampling in the vicinity of Amherst has shown S. flavescens to be prevalent in fields of Dutch white clover.

The data in Tables 10 and 11 would seem to indicate a complete absence of both species during the summer months. However, this was not the case as adults were found around the bases of the plants. Apparently, a combination of low overwintering populations and high summer temperatures account for this gap.

Table 10 Abundance of *Sitona hispidula* adults taken in 50 net* sweeps at weekly intervals during the 1957 season, comparing the relative population densities in four types of forage crops.

PIND TYPE	May				June				July				August				
	15	22	29		5	12	19	27	3	9	16	23	31	6	13	21	28
Alfalfa	0	0	0		0	**	0	0	0	0	**	0	0	0	0	0	0
Alfalfa-grass	0	0	0		0	0	0	0	**	0	0	0	0	0	0	0	0
Mixed clover	0	0	0		0	**	0	0	0	0	0	**	0	0	0	0	0
Red clover	0	0	0		0	0	0	0	0	0	0	**	0	0	0	0	0
PIND TYPE	Sept.				Oct.				Nov.				Dec.				
	3	24			1	9	15	22	29	5	12	20	3				
Alfalfa	4	1			1	**	3	0	1	1	1	0	0	0	0	0	0
Alfalfa-grass	9	0			1	7	2	0	0	6	0	0	0	0	0	0	0
Mixed clover	4	1			1	22	5	0	**	1	0	0	0	0	0	0	0
Red clover	9	0			**	0	0	0	0	1	0	0	0	0	0	0	0

* 12" dia. beating net
 ** date of cutting

Table 11 Abundance of *Sitona flavescens* adults taken in 50 net* sweeps at weekly intervals during the 1957 season, comparing the relative population densities in four types of forage crops.

PFLD TYPE	May			June				July			August					
	15	22	29	5	12	19	27	3	9	16	23	31	6	13	21	28
Alfalfa	0	0	0	0	**	0	0	0	0	**	0	0	0	0	0	0
Alfalfa-grass	0	0	0	0	0	0	0	**	0	0	1	0	0	0	0	0
Mixed clover	0	0	0	0	**	0	0	0	0	0	**	**	0	0	0	0
Red clover	0	0	0	0	0	0	0	0	0	0	**	**	0	0	0	0
PFLD TYPE	September			October				November			December					
	3	24		1	9	15	22	29	5	12	20	3				
Alfalfa	0	0	0	0	**	0	0	0	0	0	0	0	0	0	0	0
Alfalfa-grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed clover	0	0	0	0	5	3	0	**	0	0	0	0	0	0	0	0
Red clover	0	0	0	**	0	0	0	0	0	0	0	0	0	0	0	0

* 12' dia. beating net
 ** date of cutting

Table 12 (a) Abundance of *Sitona hispidula* adults taken in 100 net* sweeps at approximately weekly intervals during the 1958 season, comparing the relative population densities in four types of forage.

FIELD TYPE	May				June				July				August				
	2	9	22	29	4	16	24		1	8	14	22	29	4	12	19	26
Alfalfa-clover-																	
grass	12	35	10	9	20	1	**	0	0	0	3	6	4	**	0	0	1
Alfalfa-grass	5	0	0	5	**	0	0	2	3	0	**	0	0	0	0	0	2
Red clover	2	15	2	0	3	**	0	0	1	0	1	4	15	**	0	0	2
Alfalfa	4	0	0	4	**	0	0	0	0	0	0	4	1	0	1	2	2

* 15" dia. beating net
 ** date of cutting

Table 12 (b)

FIELD TYPE	September				October			
	2	9	15	22	29	6	14	20
Alfalfa-clover-								
grass	0	0	0	2	2	0	**	0
Alfalfa-grass	0	1	**	0	0	0	0	0
Red clover	1	0	4	5	**	0	0	0
Alfalfa	0	0	1	1	0	1	**	0

** date of cutting

Table 13 (a) Abundance of *Stenomacrus flavescens* adults taken in 100 net* sweeps at approximately weekly intervals during the 1958 season, comparing the relative population densities in four types of forage.

FIELD TYPE	May				June				July				August				
	2	9	22	29	4	16	24		1	8	14	22	29	4	12	19	26
Alfalfa-clover-	0	0	0	0	0	0	**	0	0	0	0	0	2	2	**	0	0
grass	0	0	0	0	0	**	0	**	0	0	0	0	0	0	0	0	0
Alfalfa-grass	0	0	0	0	0	0	0	0	0	0	**	0	0	0	0	0	0
Red clover	0	0	0	0	0	**	0	0	1	4	0	0	21	19	**	0	2
Alfalfa	0	0	0	0	0	0	0	2	0	0	0	0	4	0	0	0	0

Table 13 (b)

FIELD TYPE	September				October		
	2	9	15	22	6	14	20
Alfalfa-clover-	0	0	0	0	0	**	0
grass	0	0	0	0	0	0	0
Alfalfa-grass	0	0	**	0	0	0	0
Red clover	0	0	2	3	0	0	0
Alfalfa	0	0	0	0	0	**	0

** Date of cutting

* 15" dia. beating net
** date of cutting

Seasonal Abundance of Adult Sitona sp.

Periodic surveys, at roughly weekly intervals, were carried on during the 1957 and 1958 seasons. Adults were collected by sweeping with a 12" net in 1957 and a 15" net in 1958 and 1959. Surveys were also carried on in the spring of 1959 but no adults of either species of Sitona were collected in Hampshire County. Fifty sweeps were taken in each field in 1957 and 100 sweeps were taken in each field in 1958 and 1959. The specimens thus obtained were immediately transferred to ethyl acetate killing jars and then removed to the laboratory for further study.

Despite the difference in the number of sweeps taken between 1957 and 1958, it is apparent from the data presented in tables 14, 15, 16, and 17 that both species of Sitona were more abundant in 1958. The population density of adults in 1957 is so slight that no valid conclusions can be drawn from it other than that the adults are active in the fall apparently in preparation for migration to winter quarters. The most obvious point shown by Tables 14 and 16 is that the adult population of Sitona hispidula was much reduced in the fall of 1958. It is even more striking when one considers that the number of sweeps taken in each field in 1958 was double that taken in 1957.

It is obvious from this data that Sitona hispidula is the dominant species in Hampshire County. State wide surveys during the fall of 1957 and the spring of 1958 support this statement. (Table 18)

Jackson (1922) stated that the old S. hispidula adults die in June and July in England, and that new generation adults begin to

appear in August. Based on the data presented in Table 16, it is apparent that under Massachusetts conditions old adults die in late May and early June. Data previously presented has shown that June and July are the periods of larval and pupal activity. The new generation adults begin to appear in late July. This statement is supported by the increase in the adult population in late July as shown in Table 16.

Tables 15, 17, and 18 indicate that Sitona flavescens was relatively rare during the 1957 and 1958 seasons. That it must have been comparatively rare in 1952 is indicated by the failure of Shaw et al (1953) to mention it in their report of a survey of the forage crop pests in Massachusetts.

Based on the data presented, it would appear that overwintering adults of S. flavescens are uncommon. This assumption has been borne out through collections by other means, i.e. square foot samples, Berlese funnel samples and general observation.

The data previously presented and the emergence data in Table 9 indicate that the new generation adults of both species appear in the field in early July and continue emerging until early August.

Although the data presented fails to show it, S. flavescens are occasionally abundant in some fields in the fall. While collecting specimens for laboratory experiments in the fall of 1958, the writer found S. flavescens to be quite common in an alsike clover field near Amherst although not nearly as abundant as S. hispidule.

Table 14 Abundance of *Sitona hispidula* adults taken in Net* sweeps at approximately weekly intervals during the 1957 season comparing the relative population densities in nine fields of forage in the vicinity of Amherst, Massachusetts.

FIELDS	April		May		June			July		August							
	24	15	22	29	5	12	19	27	3	9	16	23	31	6	13	21	28
Rte. 63 - Alfalfa	0	4	0	0	0	**	0	0	1	**	0	0	1	0	0	0	0
Mill Valley Rd. Alfalfa - Grass	1	0	0	0	0	0	0	0	**	0	0	0	0	0	0	0	0
S. Maple St. Mixed Clover	0	0	0	0	0	**	0	0	0	0	0	**	0	0	0	0	0
S. Maple Red Clover								**									
Bay Rd. Alfalfa	1	3	0	0	0	0	0	0	0	0	0	0	**	0	0	0	0
Clusters - Alfalfa	1	0	0	0	0	**	0	0	0	0	0	0	**	0	0	0	0
McWitt Alfalfa	2	0	0	0	0	**	0	0	0	0	**	0	0	0	0	0	0
McWitt - Alfalfa - Grass	0	0	0	0	0	**	0	0	0	0	0	0	0	0	0	0	0
Stockbridge Rd. Alfalfa	0	3	**	0	0	0	0	0	0	0	0	0	0	0	0	**	0

FIELDS	Sept.		October			November			December		
	3	24	1	9	15	22	29	5	12	20	3
Rte. 63 Alfalfa	4	0	1	21	0	0	1	1	1	0	0
Mill Valley Rd. Alfalfa Grass	9	0	1	7	2	0	0	6	0	0	0
S. Maple St. Mixed Clover	4	1	1	22	5	0	**	1	0	0	0
S. Maple Red Clover	9	0	**	0	0	0	0	1	0	0	0
Bay Rd. Alfalfa	14	1	0	**	0	1	0	0	1	0	0
Clusters Alfalfa	32	0	1	1	1	1	0	0	0	0	0
McWitt Alfalfa	4	1	1	**	3	0	1	1	1	0	0
McWitt Alfalfa - Grass	0	0	1	**	0	0	0	2	0	0	0
Stockbridge Rd. Alfalfa	1	0	0	**	0	0	0	0	3	0	0

* 12" dia. beating net
** date of cutting

Table 15 Abundance of *Sitona flavescens* adults taken in 50 net* sweeps at approximately weekly intervals during the 1957 season, comparing the relative population densities in nine fields of forage in the vicinity of Amherst, Massachusetts.

FIELD	April		May		June			July			August							
	24	24	15	22	29	5	12	19	27	3	9	16	23	31	6	13	21	28
Rte. 63 Alfalfa	1	0	0	0	0	0	**	0	0	0	**	0	0	0	0	0	0	0
Mill Valley Rd. Alfalfa-Grass	0	0	0	0	0	0	0	0	0	**	0	1	0	0	0	0	0	0
S. Maple St. Mixed Clover	0	0	0	0	0	0	**	0	0	0	0	0	0	**	0	0	0	0
S. Maple St. Red Clover	0	0	0	0	0	0	0	0	**	0	0	0	0	0	0	0	0	0
Bay Rd. Alfalfa	0	0	0	0	0	0	0	0	1	0	0	0	1	**	0	0	0	0
Clusters-Alfalfa	0	0	0	0	0	0	**	0	0	0	0	1	0	**	0	0	0	0
McNiff Alfalfa	0	0	0	0	0	0	**	0	0	0	0	**	0	0	0	0	0	0
McNiff Alfalfa Grass	0	0	0	0	0	0	**	0	0	0	0	0	0	0	0	0	0	0
Stockbridge Rd. Alfalfa	0	0	0	**	0	0	0	0	1	1	1	**	0	1	1	0	0	0

FIELDS	Sept.		October			November			December		
	2	24	1	9	15	22	29	5	12	20	3
Rte. 63 Alfalfa	0	0	0	0	0	0	0	0	0	0	0
Mill Valley Rd. Alfalfa Grass	0	0	0	0	0	0	0	0	0	0	0
S. Maple St. Mixed Clover	0	0	0	5	3	0	0	0	0	0	0
S. Maple St. Red Clover	0	0	**	0	0	0	0	0	0	0	0
Bay Rd. Alfalfa	0	0	0	**	0	0	0	0	0	0	0
Clusters Alfalfa	0	0	0	0	0	0	0	0	0	0	0
McNiff Alfalfa	0	0	0	0	0	0	0	0	0	0	0
McNiff Alfalfa Grass	0	0	0	**	0	0	0	0	0	0	0
Stockbridge Rd. Alfalfa	0	0	0	**	0	0	0	0	0	0	0

* 12" dia. beating net
 ** date of cutting

Table 16 Abundance of *Stenomacrus hispidus* adults taken in 100 net sweeps at approximately weekly intervals during the 1950 season, comparing the relative population densities in six fields of forage in the vicinity of Amherst, Massachusetts.

FIELDS	May			June			July			August							
	2	9	22	29	4	16	24	1	8	14	22	29	4	12	19	26	
Moody Bridge Rd. Alfalfa Clover	2	9	22	29	4	16	24	1	8	14	22	29	4	12	19	26	
Grass	1	4	2	4	9	**	0	0	0	0	2	20	9	**	0	0	
S. Maple St. Alfalfa Clover Grass	12	35	10	9	20	1	**	0	0	0	3	6	9	**	0	1	
Mill Valley Rd. Alfalfa Grass	5	0	0	5	**	0	0	2	3	0	**	0	0	0	0	2	
S. Maple St. Red Clover	2	15	2	0	3	**	‡										
Moody Bridge Rd. Red Clover Alsike												4	4	15	**	0	2
Timothy	4	0	0	4	**	0	0	0	1	0	0	4	1	0	1	2	
McNiff Alfalfa																	

FIELDS	September			October				
	2	9	15	22	29	6	14	20
Moody Bridge Rd. Alfalfa Clover	0	0	0	4	**	0	0	0
Grass	0	0	0	2	2	0	**	0
S. Maple St. Alfalfa Clover Grass	0	1	**	0	0	0	0	0
Mill Valley Rd. Alfalfa Grass	1	0	4	6	**	0	0	0
Moody Bridge Rd. Red Clover Alsike	0	0	1	1	0	1	**	0
Timothy	0	0	1	1	0	1	**	0
McNiff Alfalfa								

* 15" dia. beating net
 ** date of cutting
 ‡ field plowed under

Table 17 Abundance of *Bibio flavescens* adults taken in 100 net* sweeps at approximately weekly intervals during the 1958 season, comparing the relative population densities in six fields of forage in the vicinity of Amherst, Massachusetts.

FIELDS	May			June			July			August					
	2	9	22	4	16	24	1	8	14	22	29	4	12	19	26
Moody Bridge Rd. Alfalfa Clover	0	0	0	0	**	0	0	0	0	0	9	0	**	0	1
Grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. Maple St. Alfalfa Clover Grass	0	0	0	0	0	**	0	0	0	0	2	0	**	0	0
Mill Valley Rd. Alfalfa Clover Grass	0	0	0	0	**	0	0	0	0	**	0	0	0	0	0
S. Maple St. Red Clover	0	0	0	0	0	**	#	0	0	0	0	0	0	0	0
Moody Bridge Rd. Red Clover Alsike	0	0	0	0	**	0	0	1	4	0	0	0	21	19	**
Timothy	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0
McNiff Alfalfa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FIELDS	September			October				
	2	9	15	22	29	6	14	20
Moody Bridge Rd. Alfalfa Clover	0	0	0	0	**	0	0	0
Grass	0	0	0	0	**	0	0	0
S. Maple St. Alfalfa Clover Grass	0	0	0	0	0	0	**	0
Mill Valley Rd. Alfalfa Clover	0	0	**	0	0	0	0	0
Grass	0	0	0	0	0	0	0	0
Moody Bridge Rd. Red Clover Alsike	0	0	2	3	**	0	0	0
Timothy	0	0	0	0	0	0	**	0
McNiff Alfalfa	0	0	0	0	0	**	0	0

* 15" dia. beating net

** date of cutting

field plowed under

Table 18 Comparison of population densities of adults of Sitona hispidula and Sitona flavescens taken by sweeping fields of forage in the various counties of Massachusetts.

Fall 1957 Counties	No. of Fields Visited	<u>Sitona hispidula</u>	<u>Sitona flavescens</u>
Essex	9	35	0
Middlesex	10	117	0
Norfolk	7	26	0
Bristol	11	3	0
Plymouth	9	0	0
Barnstable	8	3	1
Hampshire	8	14	0
Worcester	10	122	1
Hampden	12	14	0
Franklin	9	13	7
Berkshire	10	361	0

Spring 1957 Counties	No. of Fields Visited	<u>Sitona hispidula</u>	<u>Sitona flavescens</u>
Essex	7	65	0
Middlesex	9	53	0
Norfolk	6	21	0
Bristol	8	3	0
Plymouth	4	22	0
Barnstable	4	58	0
Hampshire	5	23	0
Worcester	8	68	56
Hampden	6	38	0
Franklin	10	16	0
Berkshire	5	6	0

Mating

Adults of S. hispidula were observed to mate both in the spring and fall. During 1958, copulation was observed in the spring from May 1-June 7 and in the fall from September 8 to November 24th.

Adults were found to be indiscriminate in their choice of copulatory partners. Several pairs were observed to maintain the mating position as long as 24 hours. Some pairs would mate once and then mate again with the same partner at a later date.

During mating the male clings to the back of the female with all three pairs of legs. The prothoracic legs of the male hold on at the junction of the thorax and abdomen of the female, the mesothoracic legs about midway down the abdomen and the metathoracic legs at the apex of the abdomen. Preperatory to mating, the male protrudes its penis, the apex of which is chitinized while the base is fleshy and bulbous. The chitinized tip is utilized to force up the final tergite of the female and then the penis is inserted in a quick movement.

The adults of S. flavescens were only observed to mate during the fall. In 1958, copulation took place during October.

Oviposition

Various authors have noted that females of S. hispidula lay eggs in both the fall and spring. (Wilderhuth, 1910; Bigger, 1934; Marshall and Wilbur, 1934). This observation has been found to hold true under Massachusetts conditions. During 1958, adult females of S. hispidula captured in the field and brought into the laboratory laid eggs from

April 19 through June 21 in the spring. In the fall, eggs were deposited in the laboratory from September 23 through December 25th.

Oviposition by adult females of S. flavescens was only observed during the fall of 1958. Females captured in the field throughout the fall and brought into the laboratory laid eggs from October 8 through November 22nd.

In the spring of 1958, comparison was made of the number of eggs laid by S. hispidula females confined with males as compared with females confined alone. Fifteen females were used in both cases but eight of the females confined alone died of fungus infection within a few days. Table 19 indicates that in captivity individual females confined with males tend to deposit greater numbers of eggs than females confined alone. The average number of eggs per female confined with males was 160 as compared to 123 eggs deposited by females confined alone. These facts would seem to indicate that recurrent mating is necessary for maximum production of eggs.

Bigger (1934) noted that the majority of eggs of S. hispidula were laid in the spring. He found that 26.4% were laid during the fall and 73.5% were laid in the spring. Markkula (1959, in Finland, observed that the number of eggs deposited by females during the spring egg laying period was 75 per cent of the total number deposited in both spring and fall. Based on observations made by the author throughout the 1958 season, it is apparent that S. hispidula females also oviposit to a much greater extent in the spring in Massachusetts. The average number of eggs per female deposited in the spring of 1958, based on the records of 23 females, was 149 eggs as opposed to 19 eggs per female in the fall. The latter figure

Table 19 Comparison of total numbers of eggs laid by females confined with males as opposed to females confined alone in the laboratory.

Mating pairs	Total # of eggs	Length of life in captivity in days
1	198	44
2	163	24
3	361	52
4	46	13
5	31	20
6	133	52
7	240	52
8	229	34
9	296	52
10	306	52
11	88	41
12	112	23
13	186	52
14	107	23
15	45	19
16	17	52

Single females*	Total # of eggs	Length of life in captivity in days
1	160	14
2	72	52
3	9	44
4	60	44
5	167	52
6	223	32
7	172	21

* The other eight females died within a few days from fungus disease.

is based on the records of 27 females. The smallest number of eggs laid by an individual female during the fall was 6 and the largest, 28.

Sitona flavescens females lay more eggs in the fall than do S. hispidula females. Three S. flavescens females deposited a total of 287 eggs during the period October 16 to 20, 1958, an average of 95.7 eggs per female.

Thus, based on the numbers of eggs laid, we may surmise that S. hispidula depends a great deal on overwintering adults to insure large populations the following year whereas S. flavescens depends for the most part on overwintering eggs and larvae to insure large populations the following year. This theory is further borne out by observations on the occurrence of overwintering adults. During the period the study was conducted, only a few overwintering adults of S. flavescens were found in the field whereas large numbers of overwintering S. hispidula adults were collected.

While the occurrence of well developed eggs in the ovaries of the female curculios does not definitely establish the time egg laying takes place, it does provide some indication of it. Some 304 Sitona hispidula females and 78 S. flavescens females collected during the 1958 season, were examined for the presence of eggs. Egg development was found to occur from April 19 through July 30 and September 22 through November 4 in the S. hispidula females examined. About three quarters of the S. hispidula females were found not to have any signs of egg development in their ovaries during the fall months. This fact provides further proof that the majority of egg deposition takes place in the spring.

While only two of the 78 females of S. flavescens, which were collected September 2, 1958, were found to have developing eggs in their ovaries, all females used in the egg-laying experiments began depositing eggs in early October. No females of this species were collected prior to July 1st so no data is available as to any possible spring egg development.

The occurrence of developing eggs in the ovaries of both species in addition to the records of egg deposition indicate that during the fall months both species deposit their eggs at about the same time.

Parasites of Sitona sp.

Reference has previously been made to the parasites and predators attacking Sitona hispidula and S. flavescens. During the course of this study many of the specimens of both species brought into the laboratory were attacked by various diseases and parasites. A small number of specimens were found in the field in a diseased condition.

Samples of diseased specimens were sent to Dr. Edward A. Steinhaus, Professor of Insect Pathology at the University of California. The identifications of diseased specimens later were made by the author based on identifications received from Dr. Steinhaus. Specimens of larval dipterous parasites were submitted for identification to Dr. R. W. Smith of The Entomology Research Institute for Biological Control at Belleville, Ontario, Canada.

During June 1957, large numbers of larvae and pupae were brought into the laboratory where they were found to be in a diseased condition. The disease was relatively rare among the larvae. However,

following pupation, up to 95% of the pupae were killed by this fungus.

During the two and one-half years the study was being made, several specimens of adults of both S. hispidula and S. flavescens were found to be attacked by Beauveria bassiana in the laboratory. Occasional specimens which had been attacked by the fungus were found during field sampling. Adults of S. hispidula attacked by this fungus are shown in Plate II.

In September of 1958, a few adult specimens of S. hispidula that had been attacked by a different fungus disease were found on the surface of the soil in an alfalfa field. The fungus was identified as a species of the genus Hirsutella. This fungus is probably the imperfect stage of a species of Cordyceps. Since no sexual fruiting heads were found to form, positive identification was impossible. In the fall of 1958, fourteen adults of S. hispidula confined in a single petri dish exhibited symptoms of the same disease, i.e. long synnemata, white in color, growing from the bodies of the insects. The synnemata are clearly shown in Plate III growing from the bodies of adult specimens of both S. hispidula and S. flavescens. In the spring of 1959, adults of both species of Sitona were located in an alfalfa field exhibiting symptoms of this disease. This disease has not been previously reported as attacking S. flavescens.

While examining some newly emerged laboratory reared adults of both Sitona hispidula and S. flavescens in July 1958, the writer noted the presence of large numbers of nematodes crawling over their bodies and throughout the petri dish. Four days later, all the adults were dead and the nematodes were noted feeding inside the bodies. Diseased adults were placed in each of five petri dishes with field



Plate II. Adult specimens of *Sitona hispidula* attacked
by the fungus *Beauveria bassiana* (Bals.) Vuill.



Plate III. Adult specimens of S. hispidula and S. flavescens attacked by a fungus species of the genus Hirsutiella.

collected larvae and pupae on July 15. By August 5, all the larvae and pupae and the adults which emerged from pupal cases were dead. Nematodes were found feeding within the body cavities in all cases. Dr. Merlin Allen of the University of California identified them as belonging to the genus Diplogaster. Some of the species in this genus are considered to be semi-parasitic and he felt that the specimens he examined belonged to this group.

Examination of an alfalfa sod sample on April 21, 1959, which had been brought into the laboratory in early April, revealed the presence of one S. hispidula adult infested with nematodes.

Specimens of pupae and adults were examined to determine the point of entry of the nematodes. The nematodes enter the pupa primarily through the thin membrane beneath the wing pads and at the point of coxal attachment. Entry into adults is through the membrane at the base of the elytra, at the base of the coxae and between the sternal plates. The movement of the nematodes is apparently quite irritating to the weevils as they move their legs constantly.

As the nematodes establish themselves within the weevils, the bodies of the weevils become very soft. The entire soft tissues of the weevils are consumed. The majority of the nematodes were seen to leave the adults en masse either through the mouths of the weevils or from under the wing covers.

Turner (1957) stated that there were no known native parasites of Sitona hispidula in the United States as far as could be ascertained. In Ontario, Thompson (1954) found a dipterous larvae in the body cavity of an adult of S. hispidula taken in 1928. This parasite

was identified as the Tachinid, Hyalomyodes triangulifera Loew, a common parasite of Coleoptera in eastern Canada.

While several hundred specimens of S. hispidula had been confined in the laboratory for periods up to three months, no parasites were found in any of the cages over a two year period. However, on November 15, 1958, the author found a dead dipterous larva in a petri dish containing about 15 adults of S. hispidula, most of which were dead. Subsequent examination of 580 specimens, collected during 1959 and 1958 and preserved in 70% alcohol, revealed the presence of three more dipterous larvae in the abdominal cavities of the adults. The latter three were found to be second stage larvae of the Tachinid parasite Hyalomyodes triangulifera Loew. The other specimen was found to be a third stage larva which Dr. Smith felt might be of the same species but which did not exactly fit Thompson's description.

No parasites were found in cages containing specimens of S. flavescens during the period of study. Examination of 119 adults preserved in alcohol did not reveal the presence of any parasitic larvae.

CONTROL STUDIES

The use of granular insecticides in control species of Sitona is a relatively recent development. Hansen and Dorsey (1957) found that granular dieldrin and heptachlor at the rate of 0.5 lb. actual per acre applied in late April provided between 95 and 98% control of adults of S. hispidula in West Virginia. In Virginia, Turner (1957) reported that heptachlor, dieldrin and chlordane applied at rates of 2.5, 2 and 5 pounds per acre respectively provided excellent reduction of root injury caused by S. hispidula larvae. He noted that heptachlor was equally effective when applied in the spring and fall whereas dieldrin and chlordane were effective only if applied in the fall. Lau (1958) in New Jersey obtained the most consistent control of larval sitonids with granular heptachlor and dieldrin applied in the fall. He found a fairly strong direct correlation between the numbers of sitonid larvae and feeding scars in his studies with red clover.

On May 9, 1958, the writer applied $2\frac{1}{2}$ granular heptachlor on four plots of alfalfa, previously described, at the rates of $1\frac{1}{2}$ and 3 pounds actual per acre. The plots were examined on June 24, 1958 and 3 square foot samples were taken from each plot. The average number of immature sitonids collected is recorded in Table 20. No control was obtained. The alfalfa, at the time of application was approximately 10" high. The writer feels that the majority of the granular material did not penetrate the foliage. That a good percentage of the material was retained in the foliage is borne out by the fact that 100% control of alfalfa weevil larvae was obtained.

A test was set up in August 1957 to determine the relative effectiveness of fall and spring applications of heptachlor on four

Table 20 Effects of the application of $2\frac{1}{2}\%$ granular heptachlor on alfalfa* plots for the control of the clover root curculios at the rates of $1\frac{1}{2}$ and 3 pounds of actual/acre.

Dosage	# of clover root curculios/sq. ft.
$1\frac{1}{2}$ lb. actual	80 larvae 6 pupae
3 lb. actual	112 larvae 9 pupae
Check	105 larvae 9 pupae
$1\frac{1}{2}$ lb. actual	184 larvae 10 pupae
3 lb. actual	115 larvae 4 pupae

* Alfalfa about 10" high when application made on May 9, 1958.

different legumes known to be infested with Sitona sp. The four legumes, alfalfa, ladino clover, red clover and birdsfoot trefoil, were replicated three times. Two and one-half percent granular heptachlor, mixed with beach sand was broadcast by hand following cutting in August 1957 and just previous to new growth in April 1958. As can be seen in Table 21, effective control of sitonid larvae was obtained only with the fall applications on ladino clover and birdsfoot trefoil. It is apparent from the data presented that one pound actual heptachlor per acre was sufficient to provide effective control of sitonid larvae on ladino clover and birdsfoot trefoil. There is some indication from the results obtained on these two legumes that fall applications are superior to spring applications.

Company representatives had reported that indications were that heptachlor was proving more effective the second year following application. In order to test this, the above plots were maintained under the regular cutting schedule. In addition, Thiodan was applied to similar plots in August 1958 at the rate of one pound actual per acre, in the same manner as heptachlor had been. The experiment was discontinued in the spring of 1959 for these reasons: (1) the majority of Sitona adults were winter killed with the result that there were no eggs laid in the spring, (2) the majority of the alfalfa, red clover and birdsfoot trefoil was also winter killed.

However, the writer took samples in ladino clover to determine the effects of the two materials on overwintering Sitona larvae. The plots were examined on May 12, 1959. Nine 1/3 square foot samples were taken from each plot. It is apparent from the results in Table 22 that a certain degree of control was attained. The results appear

Table 21 Effectiveness of fall and spring applications of 2½ granular heptachlor for the control of bitonid larvae on various legumes at the rate of 1 lb. actual per acre.

Date Plots Examined 1958	Legume	% of Immatures / Sq. Foot		Check	% Reduction Fall Appl.	% Reduction Spring Appl.
		August, 1957 Application	April, 1958 Application			
June 27	Alfalfa	102 larvae 41 pupae	73 larvae 60 pupae	81 larvae	0	0
June 30	Ladino clover	4 pupae	11 larvae 6 pupae	46 larvae 27 pupae	95%	77%
July 1	Red clover	36 larvae 42 pupae	10 larvae 6 pupae	20 larvae 23 pupae	0	0
July 2	Birdsfoot trefoil	8 larvae 9 pupae	20 larvae 13 pupae	59 larvae 43 pupae	84%	68%

Table 22 Comparison of the effectiveness of heptachlor and thiodan at the rate of 1 pound actual per acre applied at different times for the control of overwintering Sitona larvae.

Number of immature sitonids 1/3 square foot, 6" deep

<u>Samples</u>	<u>Check</u>	<u>Thiodan, Aug. 1958</u>	<u>heptachlor, Aug. 1957</u>	<u>heptachlor, April 1958</u>
1	2	3	2	1
2	4	0	3	0
3	0	5	7	0
4	12	3	1	0
5	8	0	0	2
6	6	2	0	0
7	13	3	0	2
8	2	0	1	6
9	13	0	3	8

to be erratic and the writer feels that insufficient numbers of larvae were present to obtain good data. However, if we considered that the 9 samples in each case were from a single plot, the results would indicate that Thiodan provided a 74% reduction of larvae; heptachlor applied in August 1957, a 72% reduction; and heptachlor applied in April 1958, a 69% reduction. If we compare these figures with the results obtained June 30, 1958 (Table 21), it would appear that heptachlor does not increase in efficiency the longer it remains in the soil but seems to decline slightly in residual effectiveness.

During the 1958 season some preliminary experiments were conducted to determine the relative merits of several insecticides, applied as sprays, against forage crop insects in general. These compounds were as follows: two formulations of Sevin (50% WP and 45 M), two American Cyanamid compounds (12,880 and 18,706) and Methoxychlor EC all at the rates of 1 lb. actual per acre.

All compounds were applied with a four gallon compressed air sprayer. Following treatment, fifty sweeps with a 15" beating net were taken in each plot. Check populations were taken from areas adjacent to treated areas. The effectiveness of these compounds against S. hispidula adults was especially noted. No adults of S. flavescens were taken in any of the plots. The data presented in Table 23 indicates that the scarcity of adults of S. hispidula makes any sound conclusions, as to the effectiveness of these compounds, difficult if not impossible although the two American Cyanamid compounds especially appeared to provide some control.

Table 23 Effectiveness of certain compounds, applied as sprays, for the control of adults of Sitona hispidula.

Compound	No. of insects in check at time of appl.	After	After	After	No. of insects in treated plots after 24 hours	After	After	After	After
		7 days	17 days	26 days		5 days	7 days	17 days	26 days
Methoxychlor** DC	0	3	5	1	0	-	0	3	2
Am. Cy. 18706*	1	6	-	-	0	0	0	-	-
Am. Cy. 12830**	0	0	5	1	0	-	0	0	0
Sevin 50 WP*	1	6	-	-	1	3	1	-	-
Sevin 45M**	0	3	5	1	0	-	0	2	0

** applications made July 10, 1958
* applications made Sept. 3, 1958

SUMMARY

In connection with this study, a thorough review was made of the literature. While a considerable number of papers have appeared relating to the clover root curculio, Sitona hispidula, almost no information was available concerning its occurrence, biology, or control under Massachusetts conditions. Neither was anything known concerning its close relative, S. flavescens within the State.

The foregoing study had as one of its major objectives the determination of the seasonal life history of Sitona hispidula under Massachusetts conditions. It was found that this insect has one generation a year. Overwintering occurs both in the egg and adult stage. Mating and oviposition take place both in the spring and fall. The larval and pupal stages are spent in the soil. Emergence of the new generation of adults begins about mid-June and extends through the end of July. The cycle from egg to adult appears to take about two months in the field. The earlier emerging females lay eggs in the fall while the later emerging adults oviposit the following spring. Fall laid eggs do not hatch until spring.

The life history of S. flavescens closely coincides with that of S. hispidula. The main differences are that egg deposition and mating apparently take place only in the fall. The larvae hatch in the fall and overwintering of the species occurs primarily in the egg and larval stages, although occasional adults survive the winter.

Field studies were conducted from March 1957 to June 1959. The surveys were of two types, soil sampling and sweeping. In soil sampling, square foot samples, six inches deep were examined at

approximately weekly intervals for the occurrence of larvae and pupae. Several fields containing legumes in various combinations were swept weekly throughout two and one-half seasons for the occurrence of adults. During 1957, 50 sweeps were taken in each field with a 12" net. During 1958, 100 sweeps were taken in each field with a 15" beating net. One swing of the net through an arc of 180 degrees was considered a full sweep.

A study was carried on to determine the distribution of these two species of Sitona in Massachusetts. While S. hispidula was found to occur commonly in every county, S. flavescens was only collected from five of the eleven counties in the State. Since the majority of collections were taken on alfalfa rather than red clover, the preferred host of S. flavescens, the author feels that this provides a reasonable explanation why this species was not taken in every county.

The character and extent of injury caused by both the adults and larvae of these two species was investigated. The injury to alfalfa and clover plants resulting from feeding by adults is slight except in unusual circumstances, i.e. severe drought or excessively dense populations. The major damage results from larval feeding. Two types of injury occur. One is the destruction of bacterial nodules thereby depleting the supply of available nitrogen. The second and perhaps more serious is the destruction of the tiny rootlets and the gouging and girdling of the tap root, thereby providing entrance for secondary disease pathogens.

The density of larval populations reflects the economic importance of these species of Sitona in Massachusetts. Populations in many of the fields under investigation far exceeded those reported by

all other states except New Jersey. Such high populations as 90-158 larvae per square foot which the author found in some alfalfa fields certainly must provide a partial explanation for the high incidence of winter killing of legumes and the decreased length of time that stands are able to maintain themselves in Massachusetts.

The effects of temperature and humidity on the hatching of the eggs of S. hispidula was investigated. It was found that although hatching would occur between 8-31°C., most hatching occurred between 19-27°C. Hatching did not occur below 75% R.H. and optimum hatching occurred at 100% R.H. Optimum hatching occurred at 24-27°C. in 11 days. As the temperature went up or down from these points, the duration of the egg stage was extended.

The duration of egg development of fall laid eggs of S. flavescens was investigated under laboratory conditions. The duration of the egg phase was found to vary from 11 to 15 days. In comparative tests with eggs of S. hispidula, it was found that peak hatching of S. hispidula eggs occurred approximately 24 hours preceding peak hatching of S. flavescens eggs.

Observations on the larvae and pupae were confined to attempts to rear them through to the adult stage. Such attempts resulted in failure with the larvae. The author was able to rear the pupae through to the adult stage in most instances.

Studies were carried on relative to the behavior of S. hispidula adults. It was found that the adults of S. hispidula were more active in the morning and evening and spent the hottest part of the day around the base of the plants. A slight preponderance of females was found to occur throughout the season for Sitona hispidula.

The occurrence of dimorphic forms of adults Sitona sp. was investigated. Over 600 specimens of S. hispidula were examined without finding any brachypterous forms. Over 100 specimens of S. flavescens were examined with the same results.

Mating habits of Sitona hispidula were noted. Copulation occurs both in the spring and fall. Males were found to mate indiscriminately. Several pairs were observed to maintain the copulatory position as long as 24 hours.

Oviposition behavior was investigated for both species of Sitona. It was found that the majority of eggs deposited by S. hispidula females are laid in the spring. S. flavescens females were only observed to oviposit in the fall at which time they oviposited much larger numbers of eggs per individual female than did S. hispidula females.

Data were collected for two seasons in an attempt to determine host preference of adult Sitonas. S. hispidula adults appear to favor those fields containing a mixture of clover, alfalfa, and grass, whereas S. flavescens show a decided preference for red clover.

Several parasitic forms were found to attack most stages of S. hispidula and S. flavescens. Both species were subject to attacks of a fungus, Beauvaria bassiana. Occasional specimens were found dead in the field with the characteristic synnemata of the fungus, Hirsutella sp., protruding from their bodies. Nematodes of the genus Diplogaster were found to attack all stages except the egg of both species of Sitona in the laboratory. Larvae of the Tachinid parasite, Hyalomyodes triangulifera Loew, were found parasitizing .005 per cent of the S. hispidula adults examined.

Control studies were carried on to test the effectiveness of certain chemicals for the control of both the larvae and adults of both species of Sitona. The results were inconclusive for the most part. Heptachlor and Thiodan applied as granulars did not provide satisfactory control of the immature stages with the exception of a fall application of heptachlor on ladino clover and birdsfoot trefoil.

CONCLUSIONS

Several conclusions can be reached based on the data presented in the foregoing study.

1. Under Massachusetts conditions, both Sitona hispidula and S. flavescens have one generation a year.
2. Sitona hispidula is distributed throughout Massachusetts. Sitona flavescens, although only represented in collections taken from scattered areas of the State, probably occurs throughout Massachusetts also.
3. The hosts of economic importance preferred by both species are alfalfa, red clover, Alsike clover, and white clover.
4. The density of larval populations is sufficiently high to cause grave concern to legume growers in Massachusetts.
5. As the relative humidity decreased the percentage of egg hatching of S. hispidula decreased in the laboratory. Below 75% R.H., no hatching occurred.
6. Egg hatching occurred over a wide range of temperatures, i.e., 8°C - 31°C.
7. As the temperature decreased, the duration of the egg stage of S. hispidula increased.
8. Eggs of S. hispidula stored in water at 8-11°C for four months remained viable.
9. No dimorphic forms of either species of Sitona were found in Massachusetts.
10. The adults of Sitona hispidula are parasitized by a Tachinid, Hyalomyodes triangulifera Loew, in Massachusetts.

11. Granular heptachlor and Thiodan at the rates used failed to provide satisfactory control of both species of Sitona in alfalfa and red clover in limited experiments but provided good control in ladine clover and birdsfoot trefoil.

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ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation and thanks to all those who provided assistance and guidance during the course of this study: to Dr. Frank R. Shaw, chairman of the thesis committee, for direction and helpful advice; to Dr. William Colby and Dr. Ellsworth Wheeler, members of the thesis committee, for many suggestions and helpful criticism; to Dr. Edward Steinhaus for the identification of diseased specimens; to Dr. R. W. Smith for the identification of parasites; to Robert Coffin for his excellent photographic work; to Dr. John Lilly, Head of the Department of Entomology and Plant Pathology, for his continual encouragement of myself and all other graduate students in the Department.

The author is deeply appreciative of the love and understanding of his wife who gave diligently of her time and effort so that this thesis might be completed.

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Date December 7, 1960

