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A STUDY OF THE BULB MITE.

By Philip Garman.

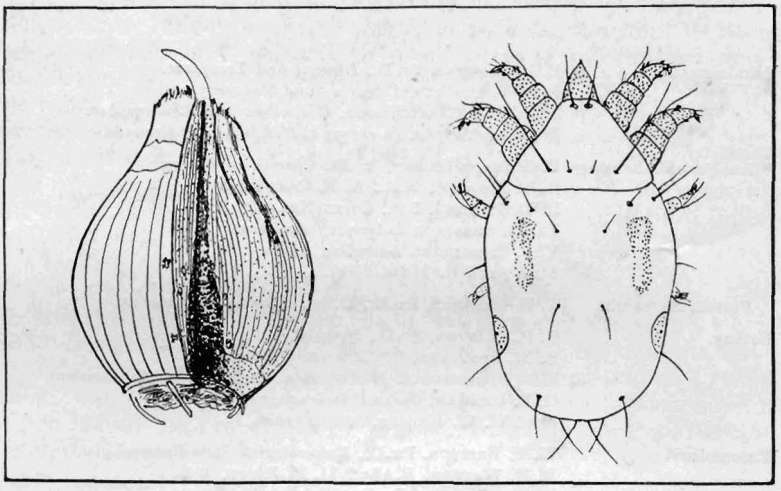

Figure 1. *Section of infested bulb, and a mite greatly enlarged.*

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A Study of the Bulb Mite.

(*Rhizoglyphus hyacinthi Banks.*)

By Philip Garman, Ph.D.

Inspection of over a million bulbs in Connecticut during 1919 brought to light the significant fact that nearly all shipments contained the bulb mite *R. hyacinthi* Banks. In many shipments only a few infested bulbs were found, but in others as high as fifteen to twenty per cent. were apparently destroyed. Shipments were, however, frequently delayed in transit according to reports, a state of affairs doubtless responsible for the poor condition of many bulbs when they arrived at their destination. Rotten bulbs, too, are not always the result of mite infestation alone, there being several other causes of rot and disease—but the almost universal presence of the mites in decayed bulbs has led to the present study of the life history, habits and control of the pest.

Woods[1] claims that the Bermuda lily disease, caused in part by mite infestation, results in a yearly loss of 20 to 60 per cent. of the entire crop where the plants are forced. Destruction of bulbs has also been noted by many other American and European workers.

The injurious effects of the species in Connecticut were first described in the report of the State Entomologist for 1915[2], when 3000 Easter lilies were destroyed. Since then, no specific case in which extensive damage was done, has been reported to this office, but there is doubtless a small per cent. of loss each year which should be prevented by proper inspection, care and treatment of the mite-infested bulbs.

Distribution of the Species.

The bulb mite has been reported in foreign shipments to various states and to Canada. Shipments of bulbs to Connecticut come mostly from France, Belgium and Holland, but what is apparently the same species was found in one shipment received from Japan. It has also been reported in shipments of bulbs from the Bermuda Islands and thus seems to have a fairly wide distribution.

The Name of the Bulb Mite.

Banks[3] in 1906, listed under the name of *Rhizoglyphus hyacinthi* Boisduval a species of mite which he found in bulbs. Since that

[1] U. S. Dept. Agr. Div. Veg. Phy. & Path. Bul. 14: 1897.
[2] Conn. Agr. Exp. Sta. Rep. 190: 1915.
[3] Banks, N., Revision of the Tyroglyphidae, U.S.D.A. Bur.Ent.Tech. Ser.13: 21: 1906.

time Americans have religiously followed the name *hyacinthi* in preference to the name *echinopus* of European authors. Michael[1], however, places *hyacinthi* as a synonym of *echinopus*, with the remark that *hyacinthi* of Boisduval is a *nomum nudum* being listed without description. Michael is correct in this statement, since the original description given by Boisduval is very meager and is not sufficient for purposes of identification. However, the description of *echinopus* given by Fumouze and Robin[2] shows that the latter may also have considered a different species; for the species in hand differs from it (and also Michael's description) in important particulars.

The most striking of these characters are the chitinous thickenings on the fourth pair of legs, which occur both in normal and heteromorphic males. Michael states that the only species bearing this character is *R. crassipes* Haller, which was originally described as an American species[3], but *crassipes* differs (in other particulars), from our species, and we are forced to conclude that either the chitinous thickenings have been overlooked or the species may be different from all described species. Inasmuch as Michael (l. c., p. 83) says emphatically that "there are not any suckers on the leg of the male of any species except *R. crassipes* Haller" we are able to conclude that he must have examined the species which he described, for this particular character. Examination of material from the U. S. National Museum shows chitinous thickenings on the fourth pair of legs in *R. hyacinthi* and *R. rhizophagus*. The rather frequent presence of the dimorphic male excludes the species in hand from *rhizophagus* and refers it to *hyacinthi*. As already intimated, a search through Boisduval's works has revealed no adequate description of this species and either his name *hyacinthi* must be disregarded or the authority changed from Boisduval to Banks. The latter course is to be preferred and the name *Rhizoglyphus hyacinthi* Banks instead of *Rhizoglyphus hyacinthi* Boisduval should be used, since Boisduval's name cannot be connected with any known species.

For convenience the description given by Boisduval is quoted herewith. Bank's description of the species is found in Bur. Ent. Tech. Ser. Bul. 13, p. 21, 1906 (pl. V fig. 49).

DESCRIPTION BY BOISDUVAL.

Entomologie Horticole p. 86: 1867.

"Nous ne trouvons mentionnè nulle part l'acarus de la Jacinthe, nous ne savons pa s'il n'a pas deja ete observé par quelque naturaliste. Nous lui donnons le nom provisoire d'acarus des Jacinthes *Acarus hyacinthi.*"

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[1] Michael, A. D., British Tyroglyphidae II: p. 85: 1903.
[2] Jour. Anat. Phys , V: 287: 1868.
[3] Haller, Archiv Naturgeschichte, 50: 218: 1884.

General Description.

Egg (Fig. 2, No. 6),—The egg is ellipsoidal, white and semitransparent; .12 by .07 mm. in size.

Larva (Fig. 2, No. 2),—Small, white, somewhat ovoid in shape; genital suckers absent. Cephalo-thorax with two long setae on the frontal margin above, and two near the caudo-lateral angle; no minute bristles between the latter as in the adult; venter of the thorax with a clavate sense organ (Fig. 2, No. 3) between the bases of the first and second coxae on each side and small setae mesad of these; front tarsi with strong spines as in the adult, but the clavate hair much longer than the spine immediately beyond it; tip of the tarsus with three slender setae; front tibiae with the usual long setae on the dorsum, the patella (3rd segment from end beginning with tarsus) each with two shorter setae on the dorsum as in the adult. Abdomen with one pair of legs, the tarsi of each of which bears a long heavy spine and longer seta on the dorsal surface and three spines on the ventral; tarsal claw very stout; tibiae each bearing a single long seta on the dorsal surface; lateral margins of the abdomen with four setae on each side and a pair near the anal opening.

Size shortly after emergence from the egg, .15-.2 by .1 mm., full grown, .25 by .15 mm.

Protonymph (Fig. 2, No.1),—Similar to the larva in size and shape but larger and provided with four pairs of legs instead of three; rostrum as in adult; cephalo-thorax as in adult; with two long setae on the frontal margin of the dorsum and two near the caudo-lateral angle; no minute setae between the latter; the front tarsi have, in common with the adult, a minute clavate hair at the base and to one side of the large clavate hair; and between the larger clavate hair and the spine (immediately beyond) is a smaller spine about one-fifth the length of the latter; tip of front tarsi with three slender setae each. The fouth pair of legs has only one seta at the tip of the tarsus and there is no dorsal spine on that segment; however, there is a strong lateral spine and a ventral spine. Judging from the spines and setae on the tarsi of leg three in the larva and the protonymph, the fourth pair of legs of the protonymph must grow in behind the third pair of the larva.

This stage is most easily distinguished from the tritonymph, which it resembles more closely than other stages, by the appearance of the genital suckers. In the protonymph only two make their appearance while in the tritonymph there are three or four (see Fig. 2, No. 5). There is also some difference in the tarsi of the fourth pair of legs, the latter possessing no dorsal spine in this stage.

Length full grown, about .4 mm., width about .2 mm.

Deutonymph or **hypopus** (Fig. 2, No. 11),—Oval in shape, dorsum convex; venter flat; color brown, the body heavily reinforced throughout with chitin. Rostrum apparently reduced to a small cylindrical projection entirely covered by the cephalo-thorax; distal end of rostrum with two long setae, and a smaller one at the base of each. Mouth parts wanting; cephalo-thorax with two long setae on the front margin placed closely together, and about the same length as the long setae of the rostrum; legs for the most part without the heavy spines of the adult, the latter replaced in most cases by setae; tarsal claws long, curved rather sharply; tarsi of first pair of legs with four slender setae at tip and two near middle of ventral surface. There is also a heavy spine on the ventral surface; a large clavate hair nearly half as long as the segment, and a smaller clavate hair and small seta on caudal surface near the larger one. In front of the larger clavate hair there is also a long seta; front tibia with a long seta on dorsum and a single spine on each side; patella with a single seta at tip instead of two, as in all other stages. Abdomen with conspicuous expulsory vesicles on either side; margin composed of thick heavy chitin, which shows prominent striations under magnification; venter with conspicuous suckers as in Fig. 2, No. 11, one on each side of the

anal opening, two caudad of this, then a row of four, and finally two more Surrounding the eight caudal suckers is a squarish ring which is thickened at each of its four corners, making it appear as if four additional suckers were present; conspicuous lines of chitin on the venter, extending cephalo-mesad from the anal opening and each coxa of legs III and IV; third and fourth pair of legs short and usually hidden by the overhanging body wall when viewed from above; tarsi with four setae and two heavy spines at tip; tibiae with a long seta near tip, on dorsum; margin of abdomen with four, minute marginal setae.

Length, .2-.3 mm. Width .13-.18 mm.

Tritonymph (Fig. 2, No. 9),—Color white, translucent or semiopaque, legs brown or tinged with pink.

Rostrum and cephalo-thorax agreeing in nearly all particulars with the adult female. Abdomen as in the adult as regards setae; but the genitalia undeveloped; the genital suckers consist of four indistinct suckers closely approximated (Fig. 2, No. 9).

Length .5-.6 mm, width .3-.3.5 mm.

Adult (Fig. 3, Nos. 12-15; Fig. 2, Nos. 4, 5, 7 and 8),—Color white, body somewhat transparent; legs epimera and rostrum brown, sometimes with a pinkish hue.

Rostrum with large mandibles, which are chelate, maxillary palpi with two distinct segments closely joined to the rostrum and a very small projection at the tip, which may represent a third segment. Each of the longer segments with a minute seta, and a longer seta on each maxilla; cephalo-thorax narrowed rapidly in front, the sides gently curved, the front margin with two long setae extending beyond the rostrum and placed closely together; near the caudo-lateral angles of the dorsum are also two long setae between which are two usually minute hairs; venter of cephalo-thorax with conspicuous epimera, the front epimera being united on the mesal line; between the first and second epimera on each side there is usually a small seta; first two pairs of legs thicker than the last two, 5-segmented, the tarsi of the first pair provided with spines and setae as follows: a large clavate sense organ, near the proxima lmargin on the dorsum, and a large heavy spine just distad of this; a much smaller clavate hair at one side of the larger sense organ, about half its length; between the larger clavate sense organ first mentioned and the spine distad of it is a smaller spine about one-third its length; at the tip of the tarsus above there is also a large spine with three setae surrounding it, one of which is much smaller than the rest; ventrad of the tarsal claw there are usually three or four heavy spines, grouped together and another proximad of these; there is a long seta near the proximal spine and a very inconspicuous one on the opposite surface of the tarsus; tarsal claw not sharply curved; tibia with a long seta on the dorsum near the distal end which is often as long or longer than the tarsal segment; there is a single stout spine on the caudal and ventral surface of this segment; the patella has two closely placed setae near the distal margin of the dorsum and the femur has a single long seta on the ventral surface; the second tarsus is essentially the same as the first, except that the smaller clavate hair or sense organ, and the small spine (between the larger hair and the spine immediately distad) are wanting; one seta is also lacking from the tip; the third and fourth pairs of legs lack the clavate sense organs and are different in the two sexes. In the female and normal male the third pair of legs are similar; there is a long thick spine at the tip of the tarsus, above and below which is a long slender seta; on the caudal surface of this segment there is also one seta and there is a spine on the opposite surface; the ventral surface has a spine shortly distad of the middle and a group of about four ventrad of the tarsal claw; the latter is sharply hooked. The third pair of legs of the dimorphic male are much thicker than the third pair of the female or normal male. There are four long setae at the tip, and the tarsal claw seems to be fused with the

tarsal segment (Fig. 2, No. 10); the fourth pair of legs differ in the two sexes but are the same in dimorphic and normal males. In the female there is a distal spine on the tarsal segment just above the claw and one lateral (caudal surface) and one ventral spine in addition, besides a group of three just beneath the claw. There are usually three setae, one above and another below the distal spine and one lateral seta; in the male the distal dorsal spine is wanting, being replaced by a chitinous thickening sometimes called a sucker; proximad of this is still another thickening and between the two a single seta; the segment possesses the usual number of spines below the claw on lateral and ventral surfaces (Fig. 2, No. 7).

In the female the lateral surfaces of the abdomen are provided with about five setae on each side; the ventral surface with three minute setae on each side of the genital opening and one between the third and fourth coxae, a small one in front of and to one side of the third coxae and a long one on each side of the anal opening; the genital opening forms an inverted V-shaped figure with two genital suckers on each side (Fig. 3, No. 14); the dorsum has five setae on each side, of which the caudal pair are the longest.

In the male there are the usual five setae on lateral and caudo-lateral surfaces of the abdomen and one minute seta between the third and fourth pairs of legs on ventral surface, and a smaller one in front of and to one side of the third coxae; genital opening as in Fig. 3, No. 12 with two genital suckers on each side. Caudad of the genital opening are found two larger disc-like suckers, with a minute seta, caudad and cephalad, and usually a row of four longer ones caudad of the suckers; setae of the dorsum as in female.

Variations—There seems to be some variation both in the length of the setae of the legs and body and also in the thickness of the tarsal segments. Of seventeen individuals, however, measured with micrometer the ratio of width to length of tarsus IV ranged from 1-1.6 to 1-2.5, both sexes being examined. There is also a great variation in the depth of the depressions on the dorsum of the adult, they being almost obliterated in some individuals.

Length, female .47-.95 mm; male .5-.6 mm. Width, female .3-.4 mm; male .25-.3 mm.

Host Plants Infested and the Injury Resulting from the Infestation.

Narcissus (Plate I, b; II, a; III, b), hyacinth, tulip, crocus and Easter lily bulbs, are infested by the bulb mite. In the laboratory it has been reared on onions and potatoes, and is probably capable of subsisting on almost any tuber or bulb. Its common occurrence in narcissus and lily bulbs may be due to the fact that these bulbs offer least resistance to attack since the scales are loose and the mites find it easy to penetrate to the interior. Tulips are least injured, owing to their outer skin and tight-fitting scales which have no place for the mites to enter. Hyacinths seem to be less easy to penetrate than narcissus, while onions, artificially infested with mites, were not injured unless they were partly rotten or bruised in the beginning.

That the mites are able to feed on healthy tissue seems evident both from numerous references to this particular ability by various writers and from the experience of those connected with this office in the case of the Bermuda lilies already mentioned. A small

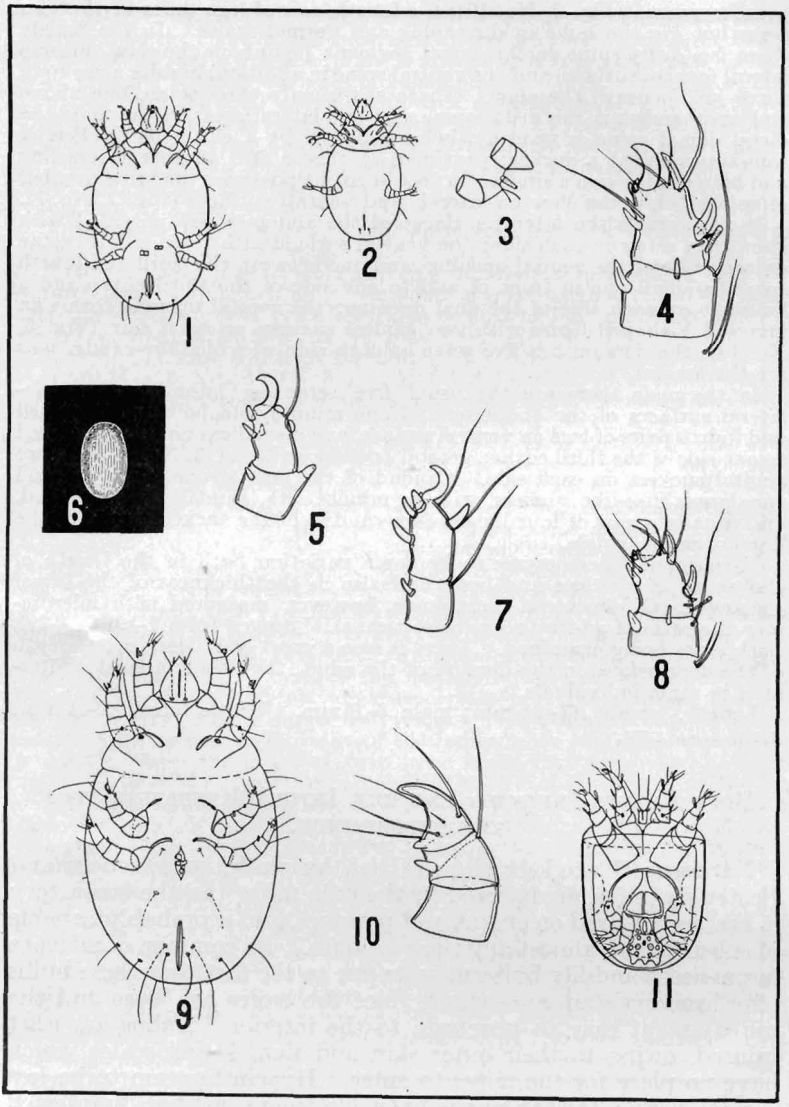


Figure 2. The bulb mite (*Rhizoglyphus hyacinthi* Banks). 1. Protonymph, enlarged about 80 times. 2. Larva, enlarged about 80 times. 3. Larva, sense organ of the ventral surface of the cephalothorax. 4. Front tibia and tarsus of the female. 5. Fourth tibia and tarsus of male. 6. Egg, enlarged about 80 times. 7. Fourth tibia and tarsus of the female. 8. Front tibia and tarsus of the female. 9. Tritonymph, enlarged about 80 times. 10. Fourth tibia and tarsus of dimorphic male. 11. Deutonymph or hypopus, enlarged about 80 times.

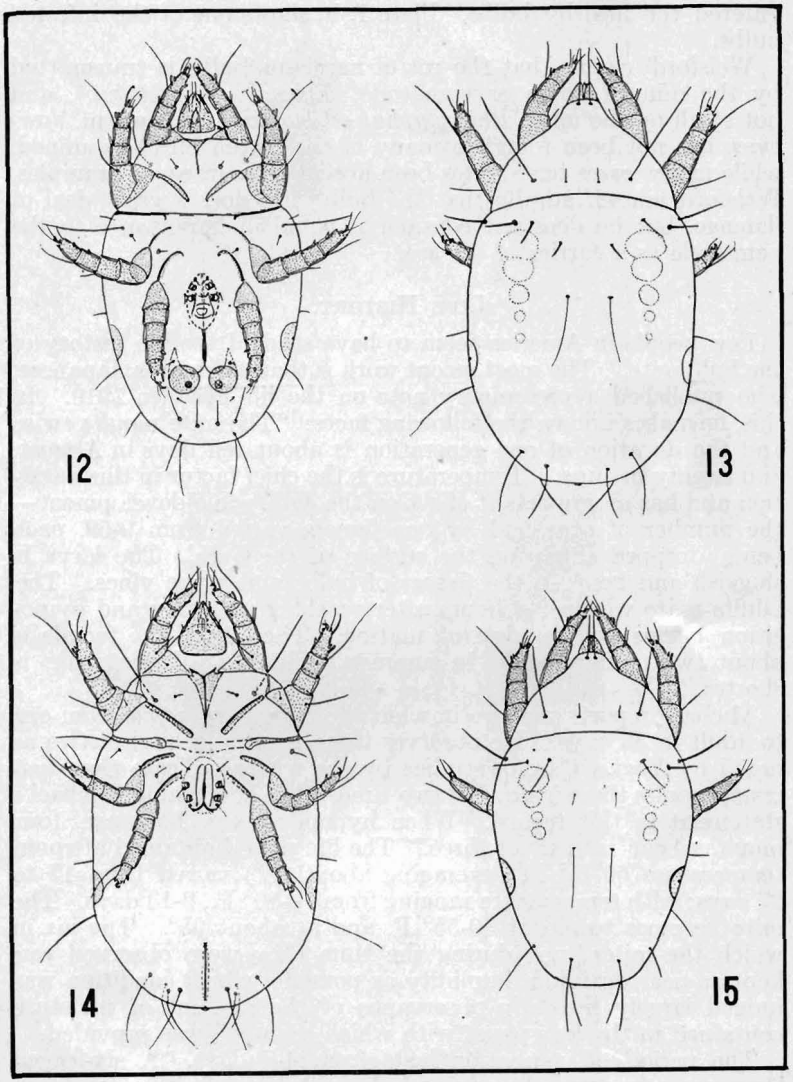


Figure 3. Adult bulb mite (*Rhizoglyphus hyacinthi* Banks), enlarged 80 times. 12. Male, ventral view. 13. Female, dorsal view. 14. Female, ventral view. 15. Male, dorsal view.

number of tests have been conducted by the writer in which mites entered and fed on growing narcissus bulbs. In these tests rotten bulbs containing mites were placed in pots of soil just below the healthy ones and the mites readily left the rotten and

entered the healthy bulbs. Plate I, b, shows one of the infested bulbs.

Welsford[1] claims that the rot of narcissus bulbs is transmitted by the minute worm or nematode, *Tylenchus devastatrix**, and not at all by the mite, *Rhizoglyphus echinopus*. This worm, however, has not been found in many of the rotten bulbs examined, while in few cases have mites been absent from diseased examples. Welsford himself admits that the bulb mite does a great deal of damage, but he does not consider it equal in importance to the nematode as a carrier of disease.

Life History.

Few people in America seem to have studied the life history of the bulb mite. The most recent work is that of Yagi[2], a Japanese, who published a preliminary note on the life cycle in 1919. In this, he makes known the following facts: "The mite moults twice and the duration of one generation is about ten days in August, and twenty in June. Temperature is the chief factor in this variation and has an important effect on the embryonic development—the number of eggs laid by one female varied from 9-59, each being dropped singly on the surface of the bulb. The larva is sluggish and bores in the tissues of bulbs and grape vines. The adults mate within 2-8 hours after reaching maturity and oviposition begins on the day of mating. The life of the female is about two to four weeks in summer while that of the male is shorter."

Michael[3] reports one case in which he reared *echinopus* from egg to adult in 33 days. He observes three moults instead of two as noted by Yagi. Careful studies by the writer indicate that *hyacinthi* moults three instead of two times, thus confirming Michael's statement in this regard. When hypopi appear, however, four moults accur instead of three. The life period obtained at room temperature 60-75° F. (averaging about 68°) varied from 17 to 27 days; with temperature ranging from 70-80° F., 9-13 days. The mite becomes torpid at 50-55° F. and at about 95°. The air in which the mites lived during the time they were observed was kept as near optimum humidity as possible, which condition was judged largely by daily observance of the amount of moisture contained in the lens paper with which each cell was provided.

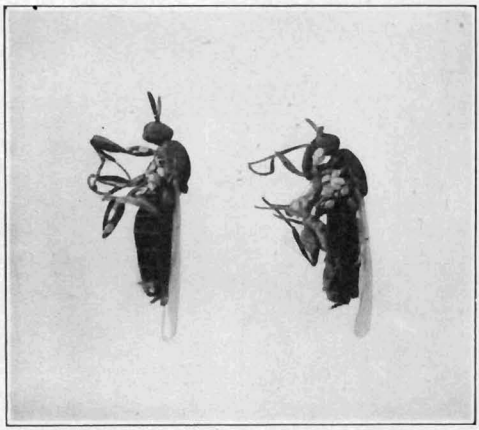
The period of incubation lasts from 4-7 days. A six-legged larva emerges from the egg and the mite lives in this condition 3 to 8 days. The last day or so of this period, sometimes two

* Now *T. dipsaci* Kühn.

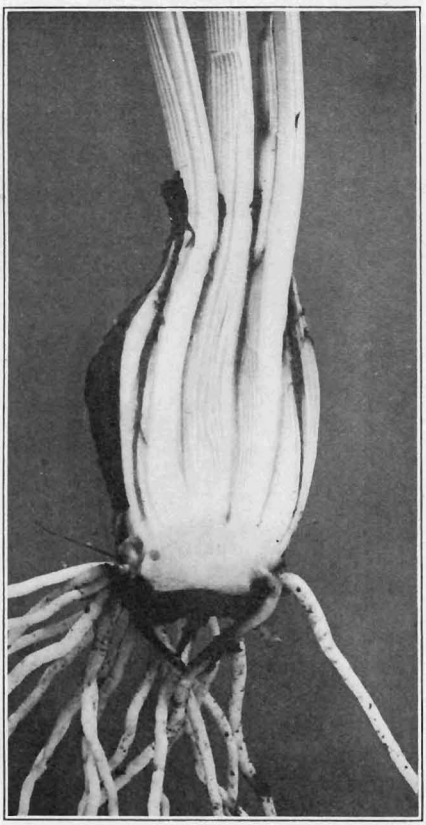
[1] Welsford, E. J. Investigation of bulb rot of narcissus. Ann. Appl. Biol. 82: 36-46: 1917.

[2] Yagi, N. Berichte Ohara Inst. Landwirtsch. Forschungen I: 349-360: 1918 Abstract in Rev. Appl. Ent., VII: 439-440: 1919.

[3] Michael, A. D. British Tyroglyphidae. Vol. II: 92-93: 1903.

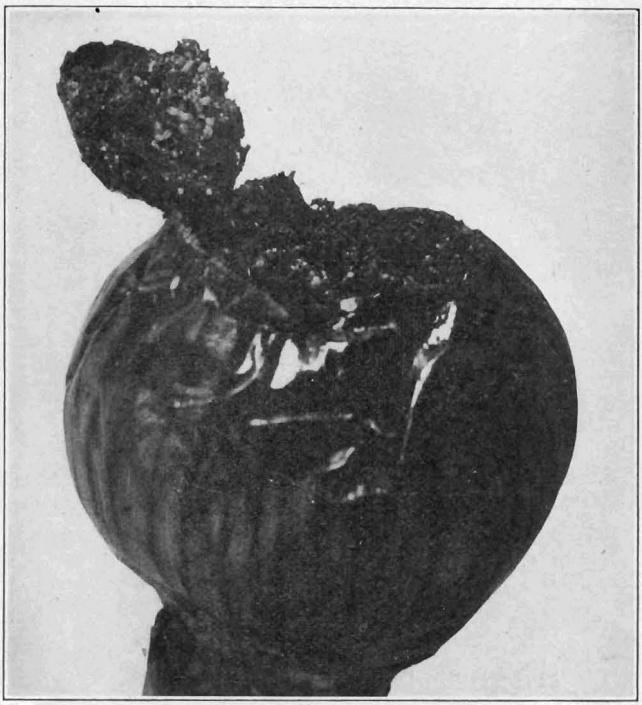


a. Flies, (*Scatopse pulicaria* Loew) with hypopi of the bulb mite clinging to them, enlarged 7 times.

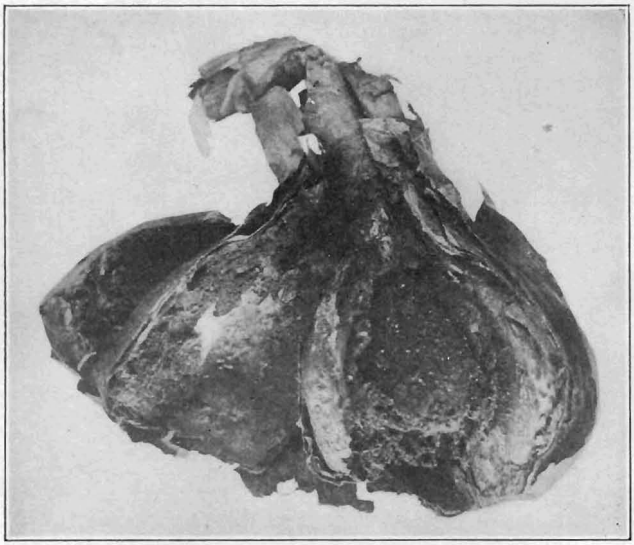


b. Mite infestation just beginning in a growing bulb. Its progress is indicated by the dark lines between the scales, natural size.

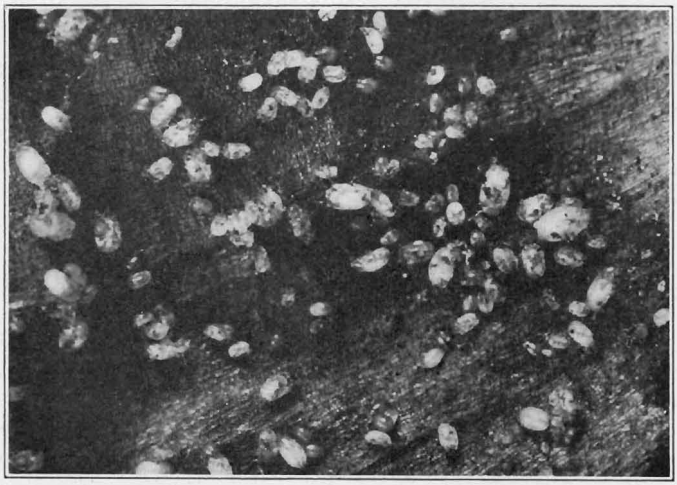
PLATE II.



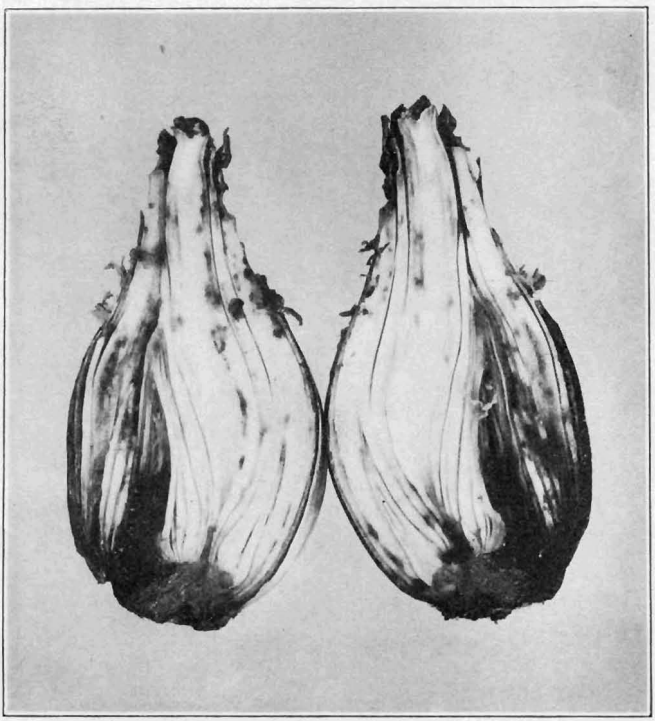
a. Rotten bulb with base removed showing mites, twice natural size.



b. Bulb completely destroyed and containing a great many mites, natural size.



a. Mites from a rotten bulb, enlarged 8 times.



b. Infestation just beginning in a healthy bulb, natural size.

days, is spent in a torpid or quiescent condition and at this time the larva swells so that the separating line between the thorax and abdomen is lost. On moulting the larva acquires two additional legs, making eight in all. The next period, which may be known as the protonymph* lasts two to four days, after which follows a second quiescent period of about two days and a second moult takes place. This time there is no increase in the number of legs or much change in form unless a hypopus or resting stage is produced. If normal in form the mite, now known as the tritonymph*, again goes into the quiescent state which lasts 1-2 days; and moults. The adult mite then emerges. If, however, the hypopial state appears after the second moult, the mite may rest for one or two weeks or more, afterwards moulting and giving rise to the tritonymph. The latter then moults and the adult mite emerges as before.

Adults mate a day or so after becoming mature and the eggs are soon laid, beginning with a few daily at first and later increasing in number up to six or eight. Two females observed laid ten eggs per day for four successive days, but this is rather unusual. The number of eggs laid has been found to vary considerably, some females laying more than one hundred, others laying only a few. One individual laid 130 eggs in all, while one other laid 81, and still another 59. The males usually die shortly after mating, but if kept separate have been observed at this laboratory to live for more than two months. Females also live from one to two months or more if properly fed and cared for.

The following shows the course of the life history:

Cycle in which hypopial stage is skipped.

Egg—larva—first nymph—third nymph—adult female.
Egg—larva—first nymph—third nymph—dimorphic male adult,
normal male adult.

Cycle with hypopial stage.

Egg—larva—first nymph—hypopus—third nymph—adult female.
Egg—larva—first nymph—hypopus—third nymph—dimorphic male adult,
normal male adult.

The Dimorphic or Heteromorphic Male.

The dimorphic male with enlarged third pair of legs (Fig. 2, No. 10) has been thought by some to be a distinct species, but it has been definitely proven by others to be merely a form of more or less infrequent occurrence. In one lot of mites examined 36 males were seen without encountering a single dimorphic form. In other lots the males with and without enlarged legs appeared in about equal numbers. The dimorphic males breed freely and the offspring consists of both females and normal and heteromorphic

* The hypopus is regarded as the deutonymph, and is frequently interpolated between protonymph and tritonymph.

males. One specimen was seen with an enlarged third leg on one side and a leg of normal size on the other. The exact function of the dimorphic male is not clearly understood, nor do we understand the causes which bring about such remarkable differences in this sex.

The Hypopus.

Rather complete studies of the hypopus of *echinopus* have been made by Michael and other European authorities, and it is now regarded as a normal period in the life history of the mite. Briefly explained, it is a form similar to some of its ancestors which is produced from time to time from no apparent reason other than a strong tendency to revert to type and "is a provision of nature for the distribution of the species occurring irrespective of adverse conditions[1]". Notwithstanding, the fact remains that is often impossible to distinguish between favorable and unfavorable conditions and it seems certain that conditions promoting their development are not always at hand. The following notes relate to the development of the hypopus.

First of all it has appeared that hypopi are much more numerous in jars where the bulbs are rotted enough to leave them in a wet, sticky condition. Hypopi are produced in dry as well as moist cells, but more rapidly and frequently more abundantly in the moist cells. This was demonstrated by use of a moisture gradient consisting of four hanging drop slides with small cells, clamped to a larger piece of glass and with a sheet of lens paper between; one end of the gradient being placed in moist sand, and each cell provided with a single pair of mites and the necessary food. The following shows the results of three tests with the gradient described. Cell No. 1 in each case was in contact with moist sand, 2, 3 and 4 further away in the order mentioned. These tests were then repeated with similar results.

No. of cell.	No. of mites.	Per cent. of hypopi.	Food used.	Date Begun.	Examined.
1	111	27	Unfermented dry narcissus.	May 14	July 7
3	83	7	"	" "	" "
4	90	0	"	" "	" "
2	39	82	Fermented hyacinth.	" "	" "
3	14	50	"	" "	" "
4	105	0	"	" "	" "
1	213	25	Fresh narcissus.	July 24	Sept. 9
2	60	10	"	" "	" "
3	21	0	"	" "	" "
4	60	0	"	" "	" "

[1] Michael, A. D. The hypopus question, or the life-history of certain Acarina. Jour. Linn. Soc., Zool., XVII; 389; 1884.

On April first a small tightly corked bottle was provided with about an inch of moist sand and a number of slices of potato previously infested with the bulb mite. These mites did not multiply rapidly but reproduced fairly well and on June 8, 100 individuals were counted without encountering a single hypopus. Little or no fermentation took place in the bottle until after this date and most of the eggs were laid on the outside of the potato and were fairly dry. However, where the potatoes were in contact with the sand there was considerable moisture surrounding the developing mites. Only one hypopus was seen in the bottle until July 1. During the latter part of July mold obtained a foothold on the potato but the mites continued to breed, many of them being covered with a wet sticky film. However, even under such conditions less than one per cent. of hypopi developed—as was seen by examination on September 9. In order to test the natural ability of the strain on potato to produce hypopi, mites were transferred to glass cells with narcissus or hyacinth at several different periods during the course of the experiment. Hypopi were produced abundantly in practically every case the percentage varying from 10 to 80%. In this bottle and five other similar ones made from it hypopi did not begin to appear in numbers until about October 25, making a period of some six months when they did not develop. It is difficult to explain the appearance of the hypopus in small cell transfers, but it seems as if some necessary change in conditions must have taken place.

Hypopi developed in light and dark, when fed on decayed and sound food, in moist and dry cells and apparently when warm and cold. They also developed about equally well when the food was covered with small amounts of sugar, alcohol (2%) and acetic acid (1%).

Michael used many experiments to try to induce certain species of Tyroglyphids to develop without producing hypopi, but failed; and he concluded that hypopus is a normal stage in their development. Notwithstanding, in the case of mites like the bulb mite in which all individuals do not pass through the hypopus stage, it seems hazardous to ascribe such a phenomenon entirely to the inherent atavistic tendency or natural habit of the individuals. It is well known that in a somewhat similar life cycle found in aphids, reversion to the sexual forms which are more commonly skipped are induced largely by changes of weather and food. Some species of aphids, moreover, may be reared continuously without reversion, when proper conditions of moisture, temperture, etc., are maintained, and it seems as if something similar must be true of the mites under investigation, caused by factors which we have not yet learned to recognize.

The length of the hypopus stage under favorable conditions is usually about one to two weeks.

Migration of the Species.

The hypopus is much more active than the remaining stages in the life cycle of the mite, and has a tendency to wander from place to place. It will also attach itself to any moving object. At the time when hypopi become numerous, the bulbs are commonly well rotted and infested by numerous small fly larvae, one of which (*Scatopse pulicaria* Loew) (Plate I, a) was found in large numbers. The flies of this species were frequently found to be literally covered with hypopi attached by means of their ventral suckers. Other hypopi were seen riding peacefully on the backs of predaceous mites, and still others have been found attached to lepidopterous larvae. The mite is thus afforded an admirable means of transportation, of which it is capable of taking full advantage because of its structure and habits.

The tables below show the length of the various stages as determined at this laboratory.

Tabular Life History of the Bulb Mite

LENGTH OF EGG STAGE.

Length of stage days.	Number observed.	Dates.
		1919.
	Temperature 60°-75° F.	
7	8	Sept. 29-Oct. 6.
6½	3	Oct. 10-Oct. 17.
7	4	Oct. 10-Oct. 17.
6½	4	Oct. 10-Oct. 17.
		1920.
	Temperature 70°-80° F.	
4	2	July 15-July 19.
3	2	July 16-July 19.
4	3	July 16-July 20.
4	8	July 16-July 20.

LENGTH OF LARVAL STAGE.

Length of stage days.	Number observed.	Dates.
		1919.
	Temperature 60°-75° F.	
8	1	Oct. 3-Oct. 10.
6	1	Oct. 6-Oct. 11.
7	2	Oct. 6-Oct. 12.
6	2	Oct. 17-Oct. 21.
6	1	Oct. 17-Oct. 22.
6	2	Oct. 17-Oct. 22.
6½	2	Oct. 16-Oct. 21.
		1920.
	Temperature 70°-80° F.	
2	2	July 19-July 21.
3	8	July 20-July 23.
3	2	July 18-July 21.
4	1	July 19-July 23.
5	3	July 19-July 24.

LENGTH OF FIRST NYMPHAL STAGE (PROTONYMPH).

Length of stage days.	Number observed.	Dates.
		1919.
	Temperature 60°-75° F.	
3	1	Nov. 10-Nov. 13.
3	1	Nov. 12-Nov. 15.
4	1	Nov. 11-Nov. 15.
3	1	Nov. 8-Nov. 11.
4	1	Nov. 8-Nov. 12.
8	1	Nov. 16-Nov. 24.
5	1	Nov. 19-Nov. 24.
3	1	Nov. 20-Nov. 23.
2	1	Nov. 20-Nov. 22.
		1920.
	Temperature 70°-80° F.	
2	1	July 21-July 23.
2	1	July 21-July 23.
2	1	July 21-July 23.
1	2	July 21-July 22.
2	2	July 21-July 23.

LENGTH OF HYPOPUS STAGE (DEUTONYMPH).

Length of stage days.	Number observed.	Dates.
		1920.
	Temperature 65°-75° F.	
12	1	March 15-March 27.
7	1	March 29-April 5.
5	1	April 17-April 22.
7	1	April 10-April 17.
13	1	April 10-April 23.

LENGTH OF THIRD NYMPHAL STAGE (TRITONYMPH).

Length of stage days.	Number observed.	Dates.
		1919.
	Temperature 60°-75° F.	
4	1	Nov. 15-Nov. 19.
3	1	Nov. 11-Nov. 14.
4	1	Nov. 12-Nov. 16.
3	1	Nov. 24-Nov. 27.
3	1	Nov. 23-Nov. 26.
4	1	Nov. 22-Nov. 26.
		1920.
	Temperature 70°-80° F.	
3	1	July 23-July 26.
3	1	July 24-July 27.
2	1	July 25-July 27.
3	1	July 24-July 27.
2	1	July 23-July 25.
2	2	July 22-July 24.
2	1	July 23-July 25.

Variations obtained in length of life cycle 9-29 days (with hypopus absent from the cycle); with hypopus included 14-42 days.

Other Species of Mites and Predaceous Enemies.

Several predaceous mites (Parasitidae) and the Tyroglyphid, *Histiostoma rostro-serratus* have been found frequently, but the

Tests of Various Oils.

Insecticide used.	Strength of material used.	Length of exposure.	Number alive.	Number dead.	Per cent. killed	Dates. 1919.	Notes.
Fir tree oil*	1 pt.**—320 pts. water	2 min.	23	143	86.1	10/17	All stages included.
Scalecide	1 pt.—25 pts. water	2 min.	400	3	.7	10/17	" " "
"	1 pt.—15 pts. water	10 min.	500	0	0	11/20	" " "
Lemon oil	1 pt.—100 pts. water	½ hr.	149	1	.6		
" "	1 pt.—10 pts. water	½ hr.	10	0	0		Hypopi only.
" "	1 pt.—25 pts. water	2 hrs.	48	2	4.0	12/13	" "
Schnarr's Insecticide	1 pt.—100 pts. water	2 min.	100	0	0	10/17	
" "	1 pt.—50 pts. water	10 min.	200	2	.9	11/20	
Check (soaked in tap water)		10 min.	135	5	3.5	11/20	

Tests of Fumigants.

Carbon disulphide	1 oz.—100 cu. ft.	24 hrs.		50	11/17	Room temperature.
" "	1 oz.—100 cu. ft.	48 hrs.	4	106	96.0	11/20-22 " "
" "	1 oz.—100 cu. ft.	48 hrs.	36	11	23.4	11/20-22 Room temperature; hypopi only.

Tests of Heat, Nicotine, Formalin and Combinations Thereof.

Insecticide used.		Strength of Insecticide.	Length of exposure.	Number alive.	Number dead.	Per cent. killed	Dates 1919.	Notes.
Heat	70° C.		1 hr.	0	200	100	11/30	Mites put in stoppered bottles and heated in an oven with gas.
"	49° C.		1 hr.	98	2	2	12/2	
"	49° C.		1 hr.	8	2	20	12/2	All hypopi and mites on interior of bulb were dead at end of period.

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* This insecticide is now difficult to obtain on the market.

** Pt. equals part.

Hot water	50° C.		1 hr.	0	140	100	12/2	No hypopi seen.
" "	50° C.		10 min.	0	100	100	12/3	" " "
" "	50° C.		10 min.	8	2	20	12/3	Hypopi only.
" "	55° C.		10 min.	0	50	100	12/16	
" "	55° C.		10 min.	0	10	100	12/16	Hypopi only.
" "	60° C.		10 min.	0	200	100	12/5	Temperature fell from 60° at beginning to 52° at end of period.
" "	60° C.		20 min.	0	200	100		Hypopi and all mites on interior of bulb were killed.
40% Formalin	50° C.	1-20 (2%)	2 min.	16	38	70.3	12/23	Hypopi and normal mites observed alive.
40% "	50° C.	1-20 (2%)	10 min.	0	32	100	12/23	Hypopi only.
Nicotine sulphate	R*	1-800	2 min.	500	50	9.0	11/17	Some of mites on interior of bulb were dead.
Nicotine sulphate and soap	R	1-400 soap 2 lbs. 50 gals.	10 min.	64	11	14.6	11/20	
Nicotine sulphate and soap	R	" " "	24 hrs.	221	17	7.1	11/20 1920.	
Nicotine sulphate	51° C.	1-400	5 min.	0	110	100	1/17	Hypopi only.
" "	50° C.	1-400	10 min.	10	131	92.9	11/26	No hypopi. Many mites on interior of bulb killed.
Nicotine oleate	R	Moore's** formula	10 min.	2	14	87.5	1/14	Very few hypopi.
Nicotine oleate	50° C.	Moore's formula	5 min.	2	48	96	1/14	Hypopi only.
" "	50° C.	" "	5 min.	0	50	100	1/14	Normal mites only.
" "	50° C.	½ strength of above.	5 min.	0	21	100	1/15	Hypopi only.
" "	50° C.	Same as above.	5 min.	0	100	100	1/15	Normal mites.
Check (no treatment)				60	0	0	1/19	Hypopi only counted.

*R = room temperature. Tap water used at about 20° C.

**Nicotine oleate made by combining 10 parts kerosene with 1¼ parts commercial oleic acid, and then 2½ parts of 40% nicotine solution. 10 parts of water were added and the whole quantity then mixed with 480 parts of tap water. See Jour. Econ. Ent. XI: 342, 1918. The oleic acid from which nicotine oleate is prepared is difficult to obtain.

latter seems to flourish best in wet rotten bulbs and has not been observed to feed on healthy tissue. The small hypopus of this species is produced abundantly and frequently attaches itself to *Rhizoglyphus* or any insect which lives within the bulbs. *Histiostoma* is much smaller than *Rhizoglyphus* as is also the hypopus, compared with that of the bulb mite. When observed feeding the adult is much lighter in color and the caudal margins of the abdomen are less rounded. The predaceous species (Laelaptini) are very active brown mites slightly larger than the true bulb mite. In one box of bulbs containing about one-fourth bushel, these enemies became very numerous and were seen running about over the bulbs like ants. Doubtless they had destroyed many bulb mites. In another case a Mason jar containing many bulb mites was entirely cleared of *Rhizoglyphus* in about a month after the predaceous species was first noticed in the jar.

The small Cecidomyid fly *Lestodiplosis* sp.* was also found feeding upon the bulb mite. The larva is a small, pinkish maggot about one mm. in length, which crawls about among the mites and feeds on them.

Control Measures.

Morphological studies show that the mite has no tracheal system and cannot be killed, theoretically, by ordinary fumigants. Ewing[1] demonstrated that 4.1 oz. of potassium cyanide per 5470 cu. ft. or 1 oz. per 133 cu. ft. of air space was insufficient to kill the bulb mite. Fumigation at this laboratory with carbon disulphide in an air tight container, 1 oz. to 100 cu. ft. required 48 hours to obtain a good kill. Mites on the interior of the bulbs were not killed even with this length of exposure. Sorauer[2] recommends for use against the mite, *R. echinopus,* the use of a 48 hour carbon disulphide fumigation or immersion in tobacco extract. 40% nicotine sulphate 1-400 with the addition of soap killed only 7.1% in tests conducted here. Fir tree oil was considerably more efficient, killing 60-90% in some instances, while in bulbs soaked in water heated to 55° C. nearly 100% were killed. Woods[3] treated bulbs with mercuric chloride 1-1000 and 1-2000, formalin 1-1000 and 1-2000 without success. A good kill, however, was obtained by the writer with formalin heated to 50° C. (122° F.), the bulbs being left for a period of ten minutes. Nicotine sulphate 1-400 heated to 50° C. (122° F.) and nicotine oleate heated to 50° were also very successful acaricides.

In all cases careful observations were made on the hypopus because of its greater resistance, and the mites were examined daily for three days after treatment to be sure of results.

* Determined by Dr. E. P. Felt.

[1] Ewing, H. E. Oregon Agr. Exp. Sta. Bul. 121: 70: 1914.

[2] Sorauer P. Pflanzenkrankheiten III: 109: 1913.

[3] Woods, A. F. U. S. Dep. Agr., Div. Veg. Phy. & Path., Bul. 14: 1897.

For convenience, the different treatments and practices for control of the pest, will be enumerated.

UNSUCCESSFUL TREATMENTS.

1. Hydrocyanic acid gas (HCN) fumigation, the gas obtained by using potassium cyanide 1 oz. to 133 cu. feet of air space[1].
2. Carbon disulphide 1 oz.-100 cu. feet—24 hr. fumigation.
3. Formalin 1 part-1000 parts water and 1 part-2000 parts water—cold[2].
4. Nicotine sulphate 1 part-400 parts water plus soap 2 lbs.-50 gals.—cold.
5. Schnarr's insecticide 1 part-100 parts water.
6. Scalecide 1 part-15 parts water.
7. Mecuric chloride 1 part-1000 parts water and 1 part-2000 parts water[2].

PARTLY OR ENTIRELY SUCCESSFUL TREATMENTS.

1. Carbon disulphide 1 oz.-100 cu. feet—48 hour fumigation.
2. Nicotine sulphate 1-400 heated to 50° C. (122° F.)—bulbs immersed for 10 min. Also nicotine oleate at the same temperature.
3. Formalin (2%) heated to 50° C; bulbs immersed for 10 minutes.
4. Hot water 55° C. (131° F.)—bulbs immersed for 10 minutes.

PRACTICES OF VALUE IN GETTING RID OF THE MITE.

1. Selection of bulbs to be planted; all soft and rotten bulbs to be discarded.
2. Proper care and fertilization of the growing plants.
3. Cold storage 33-35° F. (any temperature below 50° F.) to prevent multiplication of the mites while stored.

TESTS OF TREATMENTS FOR NARCISSUS BULBS TO DETERMINE WHAT INJURY IF ANY RESULTS THEREFROM.

Insecticide Used	Temperature of Insecticide	Period of Treatment	Date of Treatment	Amount of Injury	Date of Examination	No. of bulbs per Treatment
Nicotine Sulphate 1-400 Soap (2 lbs.—50 gals.)	50° C.	10 min.	1920 Aug. 31	None	1920 Nov. 28	10
Nicotine Sulphate 1-400 Soap (2 lbs.—50 gals.)	50° C.	5 min.	Aug. 31	None	Nov. 28	10
Formalin 2%	50° C.	10 min.	Aug. 31	None	Nov. 28	10
Nicotine Sulphate 1–400	50° C.	10 min.	Aug. 31	None	Nov. 28	10
Nicotine Sulphate 1-400 Soap (2 lbs.—50 gals.)	45° C.	10 min.	Aug. 31	None	Nov. 28	9
Nicotine Sulphate 1-400 Soap (2 lbs.—50 gals.)	45° C.	5 min.	Aug. 31	None	Nov. 28	10
Check, no treatment	....	....	Aug. 31	None	Nov. 28	10

[1] Ewing, H. E. Oregon Agr. Exp. Sta., Bul. 121: 70: 1914.
[2] Woods, A. F. U. S. Dep. Agr., Div. Veg. Phys. and Path., Bul. 14: 1897.

A few tests were conducted with narcissus bulbs in order to be sure that no injury results from the more successful treatments. Ten narcissus bulbs were first heated to 59-65° C. in hot water and left for a period of one-half hour. Two bulbs were retained as checks. All treated bulbs were killed, but the checks remained healthy and grew. Shortly after, two narcissus bulbs were treated with hot water at a temperature of 50° C. for ten minutes. These bulbs had fresh roots about one inch in length. Two bulbs were retained as checks. All bulbs grew, but the untreated were seen to be in better condition at time of blooming and on removing from the pots, the original roots of the treated were found to be dead and a new lot in their place. The table above is a continuation of these tests and shows that a temperature of 50° C. is non-injurious to narcissus, if the bulbs are without fresh roots and the period of immersion is not great.

Paper white narcissus were used in these tests and none of the bulbs had any fresh roots. Some of the treated bulbs grew better and were more vigorous than the checks. All bulbs grew and the plants were approximately the same height at the conclusion of the test.

CONCLUSIONS.

1. The bulb mite is capable of injuring healthy growing bulbs.
2. It is spread from place to place chiefly by means of the hypopus, which clings to small flies emerging from the decayed bulbs.
3. The life cycle may be completed in less than a month (9-29 days), or may be extended to a month and a half if the hypopial stage develops or if adverse conditions prevail.
4. One of the most satisfactory means of killing the mites was found to be that of dipping the bulbs in nicotine sulphate 1-400 or nicotine oleate, heated to 50° C. Hot water (50° C.) also kills a good percentage.
5. The authority commonly given for the scientific name should be changed to Banks and the name should read *Rhizoglyphus hyacinthi* Banks.