A STUDY OF *XANTHIUM* INSECTS TO BE USED IN THE BIOLOGICAL CONTROL OF COCKLEBURS IN AUSTRALIA

by

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B. S., Kansas State Agricultural College, 1929

A THESIS

submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

KANSAS STATE AGRICULTURAL COLLEGE

1930

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INTRODUCTION

In April, 1929, an arrangement was made with the Australian government by which preliminary studies could be conducted with insects attacking *Xanthium* from June 1, 1929, until October 1, 1929. Since then, the time allotted to the investigations has been extended until July 1, 1930. The purpose of the problem was to make a study of the insects attacking *Xanthium* with the hope of finding one or more species which could be safely introduced into Australia and used for the biological control of the cocklebur.

The cocklebur is a worse pest in Australia than it is in the United States. Since it is an introduced weed in that country, it has few or no natural factors as are found in Kansas to check its growth and distribution. Climatic conditions in Kansas are very similar to those in Australia, hence, the weed and insect problems would be similar. The principal reason why the weed is disliked in Australia is that the plants grow to such enormous size in the sheep pastures. Wool production is a very important industry there and the burs are a dreaded menace to it. The low values of land in Australia prohibit the practice of profitable control of widespread weeds by mechanical or chemical means; therefore, a cheaper method is needed.

The Australian government has had remarkable success in the biological control of one of their bad weeds, the prickly pear. They have now started investigations for biological control of additional weeds, *Xanthium* being one of the more important ones.

REVIEW OF LITERATURE

Literature on Biological Control

Biological studies involving the use of insects for the control of noxious weeds are comparatively new to entomological science. A review of the literature on the problem of weed control shows that some very intensive and successful practices have been employed in the control of the

Lantana weed in the Hawaiian Islands, Fiji Islands, and Australia; the prickly pear in Australia; and gorse in New Zealand.

Perkins and Swezey (24) gave an account of the control of Lantana camara in the Hawaiian Islands. Perkins stated that a few insects of Lantana were present in 1902 and one scale insect (Othezia insignis) which was rather effective in its attack on the plant, was being spread by the ranchers before that date. He stated that Lantana was introduced into Hawaii by a botanist and the seeds were spread by a turtle dove which was fond of the seeds.

It was pointed out by Perkins (24) that the control of weeds by insects was "a cause for great anxiety for those undertaking it", and that "there must of necessity be some risks". A man named Koebele was sent to Mexico in 1902 for the purpose of studying insects of Lantana and shipping them to Hawaii. This undertaking was beset with many difficulties, such as the high mortality of insects in transit, besides the hardships the men endured while in Mexico.

Imms (16) summarized the work of Lantana control and mentioned a number of the more important insects that have been introduced into Hawaii for the control of that pest. The insects which he named included:

1. A Tortricid moth (Crocidosema lantana) whose larvae feed on the flowers and fruit.

2. A seed fly larva (*Agromyza lantanae*) which feeds in the berries.

3. A Tingid bug (*Teleonema lantanae*) which feeds on the leaves.

4. A trypaenid gall fly (*Eutreta xanthocaeta*).

5. A plume moth larva (*Platyptilia*).

6. A tineid leaf miner (*Crematobombycia lantanella*).

Knowles (18) told of the Lantana seed fly (*Agromyza lantanae*) which was introduced into the Fiji Islands. It was introduced from Hawaii in 1911 and in 1917 it continued to check the weed.

The Lantana weed has become a pest in Australia. Froggatt (11) expressed the fact that although the Lantana seed fly had controlled the weed in Hawaii he did not consider it advisable to introduce it into New South Wales because it might attack some common plants in Australia. Later he mentioned the fact that the seed fly had never been associated injuriously with any other plant. He reported the flies present in New South Wales in 1919 although no one knew how they arrived there. Tryon (31) stated that the fly had been introduced into Queensland from Honolulu and was well established in some localities.

Alexander (2), Dodd (8, 9), Rivett (26), and Froggatt (12) gave a very complete history of the efforts of the

Australian government in its attempt to control the different species of *Opuntia* in that country. Prickly pears were introduced into Australia in 1788, according to Dodd. He stated that due to the low values of land in the greater part of Australia the control of weeds by mechanical or chemical means was too expensive a practice. Investigations were made in an effort to find a cheap and effective method of control. Froggatt (12) mentioned a world tour by Tryon and Johnston in 1912 for the purpose of studying prickly pears in other parts of the world in order to investigate the natural enemies of the plant. The plants had spread over large areas after their introduction into Australia and Dodd (8) stated that the most satisfactory method of control seemed to be by biological means.

Work on the native insects of prickly pear started in the United States, Mexico, and South America. The scope of their work as given by Dodd (9) included:

1. Studies of all prickly pear insects in their native countries.

2. The breeding of those insects free from parasites and predators.

3. The testing of the insects against crops and other plants.

4. Sending of selected kinds to Australia.

5. The breeding and acclimatizing under the local conditions in Australia.

6. Establishing of insects in the open country in various localities on pest pears.

According to Dodd (8) the insects received were sent from southern United States, Mexico, and South America. A breeding station is maintained at Uvalde, Texas, for this purpose.

The four most important forms according to Dodd were: (1) Cochineal insects, (2) a tunneling caterpillar (*Cactoblastis cactorum*), (3) a Hemipteron (*Chelinidea tabulata*), and (4) the red spider of prickly pear.

He also stated that the combined attack made by these insects has been very destructive to the prickly pear in that country. In some regions where those weed pests were very abundant prior to the introductions no prickly pears can be found at this time.

Davies (7) gave an account of the control of a leguminous weed, gorse (*Ulex europaeus*), in New Zealand by the gorse weevil (*Apion ulicis*). A survey was made in the British Isles and high pod infestations were found. Tests were made in order to find if oviposition occurred in plants of economic value. It was found that only leguminous plants need be considered and of these oviposition occurred only in pods of gorse. The weevils are now well established in New

Zealand.

Imms (16) emphasized four principles of biological control of weeds by insects which were briefly as follows: (1) Alien insect pests of crop plants are very destructive if allowed into a country without their native parasite; therefore the principle can work against weeds. (2) No insects should be used which are not specific feeders on a limited number of plants and not liable to change to plants of economic value. (3) Foresight should be used in introducing. Seed feeders, fruit feeders, and stem borers are likely to be more specific. (4) The insects need to be tested a great deal in their native home and also after they have been introduced into the new country.

No attempts have been made in the past on the biological control of Xanthium except as mentioned by Tillyard (30).

It is the opinion of Tillyard that biological control will not be effective with any other than introduced weeds. Introductions occur in many ways, mostly by accident.

Literature on Xanthium Insects

The amount of literature on Xanthium insects is limited due to the fact that those insects are not considered important by most workers.

(1) The cocklebur billbug (Rhodobaenus tredecumpunctatus) was first described by Illeger in 1791. Riley (25)

mentioned the occurrence of the insect on *Xanthium* in 1870. Blatchley and Leng (4) stated that it is common in Indiana and that it occurs over the United States. They stated that it breeds in the stems of cocklebur, joe-pye weed, leaf-cup, sunflower, thistle, greater ragweed, and rosin weed and it hibernates in the adult stage.

Blatchley and Leng stated that several varieties of this species have been described on the basis of color alone. *Rhodobaenus tredecumpunctatus pulchellis* has the spots at the end of the elytra coalesced. They stated that it was scarcely worthy of a variety name. *R. tredecumpunctatus quinquepunctatus* has the elytra wholly black except a narrow reddish strip along each side. The thorax also has a large portion blackened. They said that it occurs in southern United States.

Chittendon (5) stated that it has long been known to breed in the stems of *Dahlia* and there was evidence that it could breed in beetstalks. A full description of the larvae was given by Chittendon (5) and he gave the distribution as the United States, Mexico, Central America, and Colombia, South America.

There have been as many as nine synonyms of this insect mentioned by various writers, but the one mentioned by Blatchley and Leng (4) is the accepted one.

(2) *Baris callida* Casey.

Blatchley and Leng (3) stated that this insect was taken in New York and New Jersey and the larvae, pupae, and adults were taken in *Xanthium.* Pierce, in Texas, found that the larvae bore to the roots and pupate.

(3) *Ataxia hubbardi* Fisher

A full description of this new species is given by Fisher (10). He mentioned that it had been confused with *Ataxia crypta* Say and was found in collections by him along with *A. crypta*. The localities given by Fisher were Texas, Oklahoma, Kansas, and Nebraska. It was collected in the stems of *Xanthium*, *Helianthus*, and *Ambrosia*.

(4) *Euaresta aequalis* Loew.

Aldrich (1) listed this insect under the family Trypetidae and gave the first description as having been made by Loew.

Marlatt (22) called it the *Xanthium trypeta*. He reared the adults from cockleburs which he had collected at Washington, D. C., in 1899. He found the flies in the cage on September 1, but the exact date of emergence was not known. In no case did he find more than one larva in a bur. He described the larvae and adults.

Literature on Cocklebururs

Literature on cockleburs is very extensive but very little of it applies to this problem. The best American publication that was found on the taxonomy of cockleburs was used which is a monograph by Millspaugh and Sherff (23).

Some germination work has been done but it was not considered applicable to this problem.

Maiden (21) stated that the Bathurst bur (X. strumarium) was found in Queensland in 1863 and had probably been introduced in earth ballast from Argentina. Wyman (34) mentioned about an estate in Queensland that was overrun by the Noogoora bur in 1872. The seeds evidently had been introduced with importations of cotton seed.

Little (19) stated that Xanthium was the worst weed in many parts of Australia and among the first five noxious weeds in practically all parts of the country.

MATERIAL AND METHODS

The present studies were begun in June, 1929, and are to be continued until July 1, 1930. Fundamental botanical studies of Xanthium that seemed necessary to the investigation of the problem were made at the start and continued as the work advanced. A survey was made to determine the species of Xanthium occurring in the vicinity of Manhattan.

Frequent visits were made to these areas as the season progressed to determine the insects present. Longer trips were made throughout the period and in order to make roadside stops it was found convenient to use an automobile. The points of consideration of the insects were the time each species was most abundant, habits and life history of each, and the parts of the plants the insects were attacking. Laboratory work was conducted with cockleburs planted for experimental purposes at the field insectary of the Department of Entomology.

Insects were collected in the fields from the roots, stems, leaves, flowers, and burs of cocklebur plants. In some cases immature forms of insects were collected which could not be identified. In such instances they were reared to the adult stage in cages. The investigations concerning insects not likely to attack plants of economic value were continued while studies of those found to be feeders upon valuable plants were discontinued. A record was kept of each place where collections were made in order to determine the phenologic and edaphic factors which might have influenced the abundance and distribution of the insects.

Since it seemed most desirable to find an insect which would infest the seed, considerable stress was placed on this phase of the work. Burs of the 1928 crop had been collected in the spring of 1929 and examined in order to ascertain if any insects were attacking the seeds. Some maggots were found infesting the seeds and the adults which emerged from them in August, 1929, were identified as *Euaresta aequalis*. A survey trip was made in August, 1929, over an area comprising 19 counties to determine the distribution of the fly.

Burs were collected after the first frost for infestation counts of the larvae and were continued throughout the winter. The burs were cut open so that both seed capsules were exposed to view. This was accomplished by splitting the burs parallel to the long axis of the bur and parallel to a line between the two beaks. The side walls of the two seed capsules were cut away, exposing both seeds by the same cut. A complete record was kept of the condition of each bur examined, including the exact character of each seed capsule. The condition of the lower seed, which normally germinates the first year after ripening, was recorded separately from the upper, or delayed germinating seed. The seeds which appeared viable were recorded as normal (N) while the dead ones resulting from causes other than insect injury were recorded as dead (D). Those causes were principally abortion or lack of pollination. However, if the seeds were infested with larvae of *Euaresta aequalis* they were recorded as infested (I). If the larvae were dead the "I" was followed by a small letter "d". Infestation initials were made with red pencil in order to make the summarization more easily accomplished. All of the larvae were kept for rearing purposes. Each month the records were summarized and compiled in tabular form.

Cocklebur billbugs (Rhodobaenus tredecumpunctatus Ill.) were collected as adults in June, 1929. One beetle for each plant was put in a cage and accompanying this was an adjacent cage which contained uninfested plants of the same age. The plants in the latter cage served as a control in order to compare the injured plants with the uninfested ones.

The larvae were collected from plants in the field and reared to the adult stage in order to determine the lengths of the larval and pupal stages. Sections of fresh cocklebur stems were furnished twice each week for the larvae to feed in until pupation occurred. Collection records were made of the beetles representing the two common types of color patterns and the host selection of each.

Rearing work was begun on the larvae of a Cerambycid beetle (Ataxia hubbardi Fisher) which bore in the stems of cocklebur plants. A peculiar habit of the larvae was discovered when they were found to prune off the stems and hibernate in the roots. This made subsequent collecting during during the fall and winter easy to accomplish. The collected roots containing the larvae have been buried in soil under a cage in order to obtain the adults when they emerge.

Very little equipment was necessary for the work on this problem. Shell vials and larger glass containers were used for hand rearing in the insectary while screen wire cages were used for outdoor rearing. The dry burs were very tough and required the use of a strong pocket knife for splitting them. A small spade, trowel, collecting net, and vials were necessary for field work.

General observations were made in the fields and examinations were conducted wherever and whenever the plants showed any symptoms of insect attack. The insects making the infestation were taken to the insectary for further study.

The data and observations obtained through the application of these above methods are discussed under the "Presentation of Data".

DISCUSSION AND PRESENTATION OF DATA

The survey conducted during the early part of June, 1929, revealed two areas near Manhattan where observations and collections could be made during the summer and fall. One of these areas was a neglected orchard approximately three miles west of Manhattan while the other was near the south bank of the Kansas River four miles southwest of Manhattan. These places furnished an abundant supply of both insects and plants which were easily accessible when material was needed for study.

The botanical studies of *Xanthium* in the literature were rather difficult because of the disagreement among botanists regarding the classification of the species within the genus. Burs to be identified were sent to Sherff, who has monographed the genus *Xanthium*. The two species of *Xanthium* studied were identified by him as *X. pennsylvanicum* and *X. chinense*. Since the species within the genus *Xanthium* are closely related the insects apparently attack all members of the genus alike; therefore, little concern was felt about the exact classification of the plants.

Insects

(1) When the study was undertaken one of the first insects encountered was the cocklebur billbug (*Rhodobaenus tredecumpunctatus* Ill.). This insect was found very commonly on cocklebur and sunflower during June, 1929. The adults were observed mating from June 5 until about July 15. The first oviposition was noticed on June 10, and egg-laying was common from that date until July 1.

No data were obtained on the length of egg stage. The eggs were laid in the stems of the plants and no studies were conducted in an effort to determine the exact length of the egg stage. Larvae which appeared to be half grown were collected July 12 and other larvae varying in size were collected from that time until the latter part of the month when most of them had pupated. The first pupae were found on July 24. The length of the pupal stage was determined for five specimens. The length of the pupal stage for four of them was 11 days while the fifth specimen emerged in eight days after pupation. The greatest number of adults of the 1929 brood appeared about August 10, and since egg-laying was most common on June 15, the time for development from egg to adult appeared to be approximately eight weeks. The adults probably hibernate but the writer failed to find any during the winter months. According to the data obtained, there appeared to be but one generation each year.

The adults injure the plants by making punctures in the stems and leaf petioles for the purpose of feeding and egg-laying. Two insects for each plant were put in a cage to determine the effects of the insects when confined to a limited number of plants. Within one week the plants were all killed. The plants were approximately five inches high at the time of infestation. One beetle for each plant was put in another cage and the feeding punctures and boring of the larvae caused the plants to die within three weeks. The plants were approximately 15 inches high at the time of infestation. Uninfested plants in similar situations continued to thrive normally. The larvae did no appreciable injury to large plants in the fields with stems having a diameter of one-half inch or more.

An interesting host selection by the two common forms of the beetles was noticed. The insect was named *R. 13-punctatus* because of the fact that there are five distinct black spots on the prothorax and four on each elytron. A common variation of the color pattern is that the posterior spot on each elytron is large enough that the two coalesce, making one large black spot across the ends of the elytra. The form having the thirteen distinct spots was found on sunflower while the other form was found on cocklebur. The average sizes of the beetles taken on sunflower were slightly greater than those found on cocklebur. A record was kept of the host selection of each form and among 286 specimens collected, only four were found to be exceptions to this correlation.

Some of the larvae were parasitized by an Ichneumon fly but the insect was not identified.

It seems from the above discussion that this insect has the possibility of being a valuable insect for attacking young plants of cocklebur in Australia. It will require thorough testing, however, because it is known to attack a number of weeds of the Compositae family and Dahlia, which is a valuable ornamental plant in the United States. In case it is found to be unable to exist on any plants of economic value which grow in Australia, it can be sent there, where it would probably be a great check to the weed.

(2) A small, black snout beetle (*Baris callida* Casey) was also found attacking the stems and leaves. The larvae were found boring in the stems and feeding on the roots, but they did not seem to harm the plants to any noticeable extent. They pupated in the roots and the adults emerged in September. This insect was found hibernating in the adult stage in roots of cocklebur plants. The adults pruned off some of the young burs by feeding in the axils formed by the stems and burs.

A smaller species which probably belongs to the same genus was noticed, causing the same type of injury in all stages.

(3) A Lepidopterous gall forming larva was found in the stems during the month of July. The adults emerged from the galls during August. Two species of Ichneumon flies were found parasitizing the larvae.

The injury consisted in causing some of the stems to break at the point where the galls were formed. All infested stems did not break, however.

This insect seemed to be specific on *Xanthium*, since it was found on no other plants.

(4) A small snout beetle belonging to the genus *Apion* was reared from the larvae which were forming galls in the stems. The injury caused by the larvae seemed to be of

little consequence but the adults fed on young burs, causing them to drop.

(5) Larvae of a Cerambycid beetle (Ataxia hubbardi Fisher) were found boring in the stems during August and September. Some of the plants infested by this insect matured no seed and the number of matured seeds was reduced on many plants. The larvae bored to the roots when cool weather occurred. The stems were pruned off at the surface of the ground and the larvae hibernated in the roots, plugging the hole behind them with frass. They remained in the larval stage until May 5 which was the last date they were observed.

The habit of pruning made subsequent collection of the larvae during the fall and winter simple because the pruned plants fell, thus making the infested roots easily found. The roots containing larvae were collected at various times during the fall and winter. Due to an oversight, most of the larvae died because of the lack of a natural environment. Twenty of them were saved and were put in a cage for emergence. One adult was reared from larvae that had been put in the laboratory in a heated building. It emerged in March, and was found to be very similar to specimens of Ataxia crypta Say, in the Kansas State Agricultural College collection. A review of the literature disclosed the fact that Ataxia hubbardi is the species of Ataxia which attacks

Xanthium and that it is often confused with *A. crypta*, which is not known to feed on *Xanthium.* From the above fact, it was assumed that the insect was *A. hubbardi*.

Since this insect has not been reported to attack any other plants except ragweed (*Ambrosia*) there is a chance that it will not attack plants of economic value.

(6) Since the plants are spread by the burs a particular effort was made to secure an insect which would destroy the seeds. Burs of the 1928 crop were collected and brought to the laboratory for examination. Dipterous larvae were found in the seeds and were kept until the emergence date, which was August 5 for the first individual. The flies were identified by comparing them with specimens in the Kansas State Agricultural College collection and were found to belong to the family Trypetidae, species *Euaresta aequalis* Loew. A further proof of the identification was the fact that *Euaresta aequalis* was recorded in the literature as an insect whose larvae feed in the seeds of *Xanthium*.

The adults which emerged gave the necessary clue for what insects to look for in the fields. The adults were plentiful on cocklebur plants after that date. Males were more numerous than females during the first week after the appearance of the flies and toward the latter part of the season the females appeared to be more plentiful.

A trip was made through 19 counties on August 30, 31, and September 1 in order to find the distribution of the flies in Kansas. They were present in every field where stops were made except one in Ness County, Kansas. Collections of *E. aequalis* were made on the trip from fields in the counties of Republic, Cloud, Mitchell, Osborne, Rooks, Graham, Logan, Lane, Rush, and Ellsworth.

The first pairs to mate were observed on August 19. Ovipositions were made in the green burs when they were fully grown or nearly so. On a few occasions the adults were seen taking up juice that had exuded from wounds in the plants which were made by *Rhodobaenus*.

Extensive data were taken on the infestation of burs by the larvae of *Euaresta aequalis*. Burs were collected from 21 fields for the purpose of obtaining these data. Burs were collected by the writer in sixteen fields and by other persons from five of the fields. All the fields were in Kansas except field Number 1 which was in Missouri. The burs were examined for infestation by the methods described before. Table I shows the manner in which the data were taken.

Table I.

NAME - Cocklebur Insects
E. aequalis

PLACE - Republic County, Kansas.

DESCRIPTION - Bur Infestation (*X. pennsylvanicum*)

DATE - December 23, 1929.

FIELD NO. 4

No.	L	U	No.	L	U	No.	L	U
1	I	I	6	I	D	11	N	I
2	D	D	7	D	D	12	N	I
3	I	I	8	N	D	13	D	D
4	D	D	9	N	N	14	N	N
5	I	N	10	I	N	15	I	N

Upon examination of the table it can be seen that the complete condition of each bur was recorded. The method of recording was described under the methods given before.

The data from the infestation records were summarized and compiled in tabular form as represented by Table II.

In order to understand the significance of the table one must keep in mind that the burs examined represent only half the number of seeds because there are two seeds in each bur.

The table shows that the number of burs examined from each field varied from 149 to 1900. The most common number examined was 500 which was enough to get a fair representation of infestation and was a convenient number to use in making calculations. The total number of burs examined was approximately 16,000.

The table also shows that the bur infestation varied from 2.8 per cent to 50.6 per cent, the average for all burs examined being 26.85 per cent. The burs with both seeds infested had a maximum percentage of infestation of 15.2, a minimum of 0, and an average of 3.92 per cent. The percentage of infestation is probably caused by factors which will be explained later.

Further examination of the table shows that in every case the lower seeds were more heavily infested than the upper seeds, the average percentage of infestation for the lower ones being 19.84 while the upper seeds had 11.07 per cent infestation. The selection of the lower seed for oviposition is probably a matter of chance due to convenience rather than selection. This is due to the fact that the surface of the bur near the lower seed is more exposed. The burs are so arranged on the plant that the upper seed is on the side of the axil formed by the stem and bur. The arrangement does not hold ture when there are several burs in one cluster; in such cases, oviposition is likely to occur in either capsule.

Further examination of the table reveals the fact that many seeds were found dead due to other causes. Those causes may have been due to several factors, such as lack of pollination, abortion, or injury by <u>Euaresta aequalis</u> when the

Table II. Record of Burs Infested by *Euaresta aequalis*

Field Number		1	2	3	4	5	6	7	8	9	10	11	12 (A)
Number of Burs Examined		149 (298 seeds)	1900 (3800 seeds)	786 (1572 seeds)	1000 (2000 seeds)	163 (326 seeds)	1000 (2000 seeds)	1000 (2000 seeds)	940 (1880 seeds)	1000 (2000 seeds)	550 (1100 seeds)	1000 (2000 seeds)	1000 (2000 seeds)
Burs infested	Number	12	450	147	506	29	486	176	117	230	187	397	204
	Percent	8.05	23.7	18.7	50.6	17.79	48.6	17.6	12.44	23	34	39.7	20.4
Burs with both seeds infested	Number	0	20	18	152	3	71	16	2	25	32	41	12
	Percent	0	1.05	2.29	15.2	1.84	7.1	1.6	.21	2.5	5.82	4.1	1.2
Burs with lower seed infested	Number	10	353	119	363	23	350	144	87	174	125	301	148
	Percent	6.71	18.6	15.46	36.3	14.11	35	14.4	9.25	17.4	22.73	30.1	14.8
Burs with upper seed infested	Number	2	117	46	295	9	207	48	32	81	94	138	68
	Percent	1.3	6.15	5.8	29.5	5.51	20.7	4.8	3.39	8.1	17.09	13.8	6.8
Total seeds infested	Number	12	470	165	658	32	557	192	119	255	219	439	216
	Percent	4.02	12.36	10.5	32.9	9.81	27.85	9.6	6.43	12.75	19.91	21.95	10.8
Lower seeds dead due to other causes	Number	41	484	127	289	42	281	387	177	265	107	164	406
	Percent	27.5	25.5	16.15	28.9	25.76	28.1	38.7	18.83	26.5	19.45	16.4	40.6
Upper seeds dead due to other causes	Number	27	318	109	322	16	289	254	277	185	126	137	259
	Percent	18.12	16.9	13.86	32.2	9.81	28.9	25.4	29.89	18.5	22.91	13.7	25.9
Total seeds made unviable	Number	80	1471	401	1269	90	1127	833	573	605	452	740	881
	Percent	26.84	38.7	25.5	63.45	27.61	56.35	41.65	30.47	30.25	41.09	37	44.05

Field Number		12 (B)	13	14	15	16	17	18	19	20	21
Number of Burs Examined		1000 (2000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)	500 (1000 seeds)
Burs infested	Number	110	14	109	242	14	231	83	242	57	251
	Percent	11	2.8	21.8	48.4	2.8	46.2	16.6	48.4	11.4	50.2
Burs with both seeds infested	Number	3	0	10	50	1	43	6	65	4	58
	Percent	.3	0	2	10	.2	8.6	1.2	13	.8	11.6
Burs with lower seed infested	Number	81	11	81	172	11	156	51	180	43	177
	Percent	8.1	2.2	16.2	34.4	2.2	31.2	10.2	36	8.6	35.4
Burs with upper seed infested	Number	32	3	38	120	4	118	38	127	18	132
	Percent	3.2	.6	7.6	24	.8	23.6	7.6	25.4	3.6	26.4
Total seeds infested	Number	113	14	119	292	15	274	89	307	61	309
	Percent	5.65	1.4	11.9	29.2	1.5	27.4	8.9	30.7	6.1	30.9
Lower seeds dead due to other causes	Number	228	25	208	54	41	106	82	89	115	60
	Percent	22.8	5	41.6	10.8	8.2	21.2	16.4	17.8	23	12
Upper seeds dead due to other causes	Number	141	42	154	55	115	85	60	99	95	49
	Percent	14.1	8.4	30.8	11	23	17	12	19.8	19	9.8
Total seeds made unviable	Number	482	81	481	401	171	465	231	495	271	418
	Percent	24.1	8.1	48.1	40.1	17.1	46.5	23.1	49.5	27.1	41.8

seeds were very young, the larvae not developing enough to be recognized at the time of examination. The average percentage of lower seeds dead was 23.83 and of the upper seeds 20.1 per cent were dead. Those dead seeds increased the percentage of unviable seeds. The unviable seeds from the different fields varied from 8.1 to 63.45 per cent and the average for all seeds examined was 37.58 per cent.

An attempt was made to determine the factors affecting the abundance of the insects in the different localities where the collections were made. The record was kept of the soil types and the species of *Xanthium* collected from each field. The rainfall records which were obtained from a climatological sheet compiled by the State Meteorologist of Kansas were found to be of value in collecting data. The data were tabulated and are presented in Table III.

It will be noted that those fields with the lowest infestations, namely Numbers 13 and 16 were from sandy soil. In every case, burs from sandy soil had low infestation. This may be explained by the fact that flies of the Trypetidae family do not favor the high temperatures of sandy soils.

Another factor which seemed to affect the distribution was the amount of rainfall. If infestations in fields of silt loam soil are compared it will be noted that those burs had higher infestations from counties of the least rainfall.

Table III. Record of Fields Where Burs for Infestation Counts were Collected

Field No.	County*	Type of soil	Annual Rainfall (inches)	Species of Xanthium	Date of Collection
1	Buchanan, Missouri	Loess	33.28	Chinense	Oct. 7,1929
2	Riley	Silt Loam	31.43	Pennsylvanicum	Nov. 5,1929
3	Riley	Sandy	31.43	Pennsylvanicum	Dec. 7,1929
4	Republic	Silt Loam	27.07	Pennsylvanicum	Dec.23,1929
5	Reno	Sandy	27.46	Pennsylvanicum	Dec.15,1929
6	Dickinson	Silt Loam	28.09	Pennsylvanicum	Jan. 2,1930
7	Anderson	Silt Loam	36.59	Pennsylvanicum	Jan. 5,1930
8	Pottawa-tomie	Silt Loam	33.84	Pennsylvanicum	Jan. 9,1930
9	Geary	Silt Loam	29.50	Pennsylvanicum	Feb. 6,1930
10	Graham	Silt Loam	20.75	Pennsylvanicum	Feb. 9,1930
11	Ottawa	Silt Loam	25.01	Pennsylvanicum	Feb.10,1930
12(A)	Shawnee	Clay	33.76	Pennsylvanicum	Feb.22,1930
12(B)	Shawnee	Clay	33.76	Chinense	Feb.22,1930
13	Sumner	Sand	30.07	Pennsylvanicum	Mar. 2,1930
14	Atchison	Clay	34.92	Pennsylvanicum	Mar. 7,1930
15	Jewell	Silt Loam	26.40	Pennsylvanicum	Mar. 8,1930
16	Phillips	Sand	22.75	Pennsylvanicum	Mar. 8,1930
17	Ellis	Silt Loam	22.83	Pennsylvanicum	Mar. 8,1930
18	Pawnee	Fine Sand to Silt Loam	22.81	Pennsylvanicum	Mar. 8,1930
19	Rush	Silt Loam	21.75	Pennsylvanicum	Mar. 9,1930
20	Barton	Silt Loam	25.51	Pennsylvanicum	Mar. 9,1930
21	Ellsworth	Silt Loam	26.02	Pennsylvanicum	Mar. 9,1930

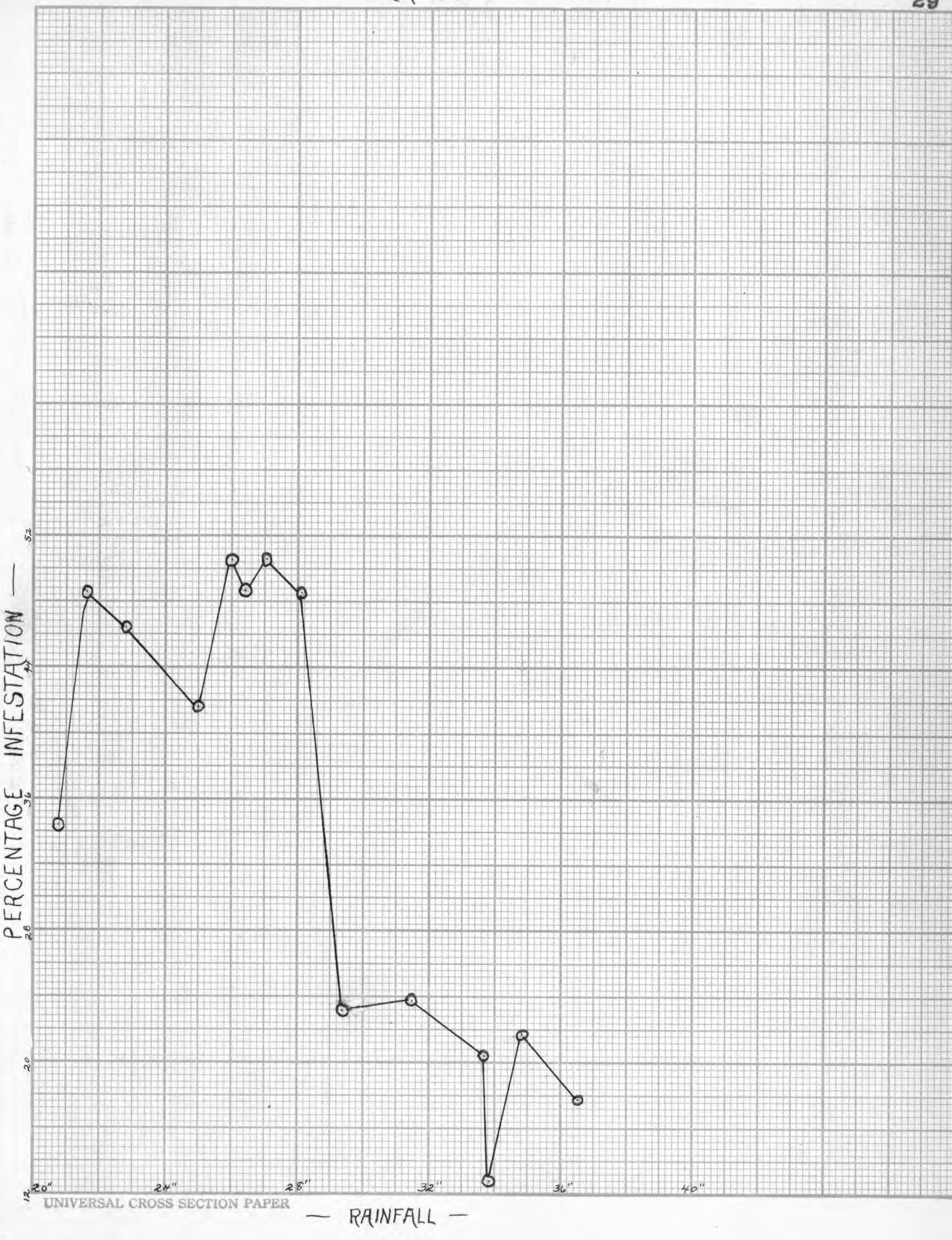
* Unless otherwise stated the counties are in Kansas.

For example, Anderson County, which has a rainfall of 36 inches had 17.6 per cent infestation, while Ellsworth County with a rainfall of 26 inches, had 50 per cent infestation in burs from the same type of soil. Other comparisons can be made to test the assertion.

The infestations of X. pennsylvanicum in fields of loam soil were compared with the rainfall of the respective counties as shown in the graph. It can be seen that there is an inverse correlation between rainfall and infestation. Field Number 20 was excluded from the graph because there seemed to be a good reason why the infestation did not agree more closely with infestations in burs from neighboring counties. The field was a large one and had been neglected during that year so that the entire field was badly infested with the plants. The plants in the other fields were confined to small "patches", a fact which would tend to make the concentration of the insects higher, thus making a comparison of the infestations with those of field Number 20 unreasonable. The large number of plants in field Number 20 appeared to be due to an infestation of cocklebur that had occurred suddenly during the year because it could be seen that the field had been abandoned after the crop of corn had been planted on account of a flooded condition.

Field Number 12 had both X. pennsylvanicum and X. chinense growing in it. The infestations of the two species

GRAPH I



PERCENTAGE INFESTATION —
52
44
36
28
20
12
20"
24"
28"
32"
36"
40"
UNIVERSAL CROSS SECTION PAPER
— RAINFALL —

can be compared by looking at Table II where it can be seen that X. pennsylvanicum had a much higher percentage of infestation.

The infestations of burs in Kansas gave the hope that the insect would be valuable in Australia if sent without any parasites or disease. No parasites have been found attacking the insect but a fungus was found associated with some dead larvae while infestation counts were being made. It was not known whether the fungus or the low temperatures were the causes of the deaths, the fungus being saprophytic on the dead larvae.

It seemed that this insect was well worthy of consideration to be introduced into Australia to attack Xanthium. Since the time for the emergence of the adult coincides exactly with the time for the formation of the burs, it seems reasonable to assume that the insect is a specific insect of Xanthium and since it attacks different species of the genus, it would be a valuable insect for the purpose.

It was necessary to change the life cycle of the insects sent to fit the seasons of Australia, which are opposite from those in the United States. It was necessary to change the emergence date of the adults from September to March or April, which is the time the burs are formed in Australia. A small consignment of infested burs which had been subjected to a cold shock in November were sent with the hope that they would emerge at the time of bur formation. At the same time similar burs were put in the laboratory in a heated building. They were examined on May 7, 1930, and it was found that some adults had emerged but were dead. On May 9, a normal, live adult emerged. In the meanwhile *E. aequalis* of both sexes emerged in Australia before April 10 from burs of the shipment made in November. The burs were forming there at the time and plans are being made to send large consignments after the first cold shock in November, 1930.

A consignment was also sent on April 27. The burs had been exposed to winter conditions here and by sending them on that date they will be exposed to the winter in Australia. By exposing them to the following summer weather, it is hoped that they will emerge in April, 1931, thus delaying the emergence six months. The plan will be discontinued, however, because the correct emergence of the flies can be attained by the first method mentioned.

No insects of any of the species studied are to be liberated in Australia until they have been thoroughly tested on all food plants that seem liable to their attack. The principal plants to be used for the tests belong to the family Compositae, but a few others which seem liable to attack will be used. Extreme care is necessary to prevent the introduction of insects which will change to Australian plants of economic value.

SUMMARY

1. A survey of cocklebursgrowing in Kansas showed a number of insects attacking Xanthium, some of which may be of value in controlling the weeds in Australia.

2. Approximately sixty species of insects were collected on Xanthium, the majority of which are known to attack plants of economic value. Studies were made only with those insects which did not seem likely to attack plants of positive economic importance.

3. Insects which seem to be of minor importance are two small Rhyncophora and a Lepidopterous gall former. These insects appear to be specific feeders on Xanthium and promise to be of some aid in control of the weeds in Australia.

4. Two other insects which injure the plants to a greater extent are the cocklebur billbug (Rhodobaenus tredecumpunctatus) and a cerambycid beetle (Ataxia hubbardi). These insects hinder the development of the plants and may be of value if proved to be specific feeders on Xanthium.

5. The insect which promises to be the most important is the Trypetid fly (Euaresta aequalis), whose larvae feed in the seeds. Infestation counts showed that bur infestation varied from 2.4 to 50.6 per cent with an average percentage

of infestation of 26.85 in 16,000 burs, representing 21 different localities. A method has been devised by which infested burs can be introduced so the adults will emerge at the correct time for oviposition in green burs in Australia.

6. Any single species of insects is not expected to reduce the weeds in Australia to a very great extent but the combined attack of several of the important ones is considered necessary.

7. Insects which are to be introduced will have to be thoroughly tested here and in Australia before they can be safely liberated.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude and appreciation to those who have aided him in the work. Many thanks are due to Dr. R. J. Tillyard and Professor George A. Dean for making the problem possible, and their helpful suggestions as the work progressed; and to Mr. H. R. Bryson, major instructor, who gave many needed aids, both in the work of the problem and the writing of the thesis.

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