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Some Agronomic Aspects of Seed Chalcid *Bruchophagus roddi* Gussakovsii Resistance in Alfalfas

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SOME AGRONOMIC ASPECTS OF SEED CHALCID *BRUCHOPHAGUS RODDI* GUSSAKOVSII RESISTANCE IN ALFALFAS

by

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INTRODUCTION

Previous studies have indicated that certain alfalfa varieties and clones are more resistant than others to alfalfa seed chalcid damage. This resistance varies in all cases and data on infestations indicate that agronomic characteristics may be responsible for some of the apparent resistance. Since this is a major pest in alfalfa seed producing areas, and cultural and chemical controls have been essentially ineffective, it was decided to determine if resistance was associated with certain pod characteristics in order to find a partial solution to the problem.

The objectives of this study were to determine: (1) the 1962 chalcid infestation of certain previously evaluated alfalfas so comparisons could be made; (2) if the resistance factors of certain alfalfa varieties and clones to the chalcid noted in earlier studies (Minion, 1961; Bunker, 1959; and Rowley, 1962) were due to particular pod characteristics of resistant plants; (3) the optimum temperature range for chalcid activity in the field as derived from the available climatological and insect population data.

REVIEW OF LITERATURE

Classification

The alfalfa seed chalcid, a small black wasp, has for years been referred to as the clover seed chalcid Bruchophagus gibbus (Boheman). Recent morphological studies have shown that what has been called the clover seed chalcid, B. gibbus is actually three distinct species, B. roddi, B. gibbus, and B. kolobovae (Kolobova, 1950; Nikol'skaya, 1952; Fedoseeva, 1954). Strong (1962) reported that separation is possible on the basis of the female genitalia.

First description of the chalcid in the United States came in 1897 by Howard who considered it a parasite of the seed midge, and named it Eurytoma funebris. Ashmead changed the name to Bruchophagus funebris believing it parasitized seed weevils (Bruchidae). Urbahns (1920) reported that in 1891 Dr. Hopkins, after careful observations, found the chalcid was a pest of the clover seed. The pest, known for some time as B. funebris, was then changed to B. gibbus (Boheman).

The present classification is as follows: Order Hymenoptera, superfamily Chalcidoidea, family Eurytomidae, under which there are three specific names depending on which crop the species infests. The species infesting clovers (Trifolium spp.) has been designated B. gibbus (Boh.). The species infesting birdsfoot trefoil (Lotus corniculatus) has been designated B. kolobovae. The species infesting alfalfa has been designated B. roddi (Guss.), subspecies medicaginis (Strong, 1962). Some question has risen in the past year (Haws, 1962) concerning the priority of these names, but since no formal action has been taken to change them, the name Bruchophagus roddi (Gussakovsii) will be used in this thesis for the alfalfa seed chalcid.

Description, distribution, damage and life cycle

Urbahns (1914) and Sorenson (1930) have described the alfalfa seed chalcid, and its damage, and Urbahns (1914), Sorenson (1930), Wildermuth (1931), and Kolobova (1950) have discussed its world wide distribution.

The life cycle of the alfalfa seed chalcid is well known, and has been studied and reported by numerous authors (Urbahns, 1914 and 1920; Sorenson, 1930 and 1934; Wildermuth, 1931; Vinogradov, 1941; Lieberman and Knowlton, 1955; and Strong, 1962).

Control

Methods of cultural and natural control have been described by Urbahns (1914 and 1920), and Sorenson (1930).

There are insecticides available to the public as well as numerous experimental chemicals that will quite effectively control the adult chalcid (Shabbir, 1961). The use of such chemicals is not feasible in field' practice, however, because chalcids are present in the field and on the plants at the same time of day that pollinators are, and use of such insecticides would eliminate a large portion of the pollinators. Equally important is the fact that chalcids emerge intermittently all season so that perhaps many applications of insecticides would be required to control chalcids.

Crothers (1962) used several systemic insecticides which were lethal to adult chalcids both at the time of application, and for periods of time up to 9 days. It should be noted, however, that adults protected from contact with the insecticide or allowed access to a protected raceme after the application, were not affected for several days and high rates of infestation were noted. Mortality of adult chalcids increased after the third day and remained high for 6 to 9 days. Concurrent studies discovered that the nectar from these plants was very toxic to bees for at least 3 to 4 days.

There are a number of studies being conducted at present to try to find suitable effective chemical control of adult chalcids. Some of these include soil applications, emulsifiable insolubles in irrigation water, and level of toxicity studies (Haws, 1962).

Several investigators have reported no chalcid parasites (Butler et al. 1959; Neunzig and Gyrisio, 1958; Nikol'skaya, 1932; and Tilley, 1960). Ten or more species are discussed, with different ones more prevalent in particular localities. Most of these parasites parasitize the larval stage and the benefits of a natural control program would be limited to a reduction in future numbers. It is not now known if there are any specific predators of the adult chalcid (Tilley, 1960).

Resistance

"Plants which are inherently less damaged or less infested than other under comparable environmental conditions in the field are called resistant." (Painter, 1958). This resistance may be the result of one of the following, either singly or in combination with each other: 1) plants may be non preferred due to lack of certain qualities conducive to insect infestation, 2) Antibiosis may be in evidence, wherein the resistant plant adversely affects the biology of the insect, 3) resistant plants may be tolerant in that they can undergo severe attacks of the insect and still develop where a susceptible plant would be killed or severely injured. Painter (1958) considered this third characteristic a component of resistance even though the insect may not be repelled in any way by the plant.

Significant differences in infestation by the alfalfa seed chalcid have been recorded among alfalfa varieties at several locations in Utah (Bunker, 1959; Minion, 1951; Rowley, 1962). Several plant introductions along with Lahontan and Nemestan have been consistently low in infestation, while Rhizoma and Vernal were consistently found among the highest infested.

PROCEDURES, RESULTS, DISCUSSIONS

Five separate experiments were performed: (1) To determine and compare the 1962 percentage chalcid infestation in alfalfa varietal nursery 367-60-101, Evans Experimental Farm. (2) To determine and compare the 1962 percentage chalcid infestation in the greenhouse and field in alfalfa nursery 367-62-121, USDA ARS greenhouse and Evans Experimental Farm. (3) To examine the average pod thickness of 17 varieties, selected for susceptibility or resistance as indicated by previous studies, to see if susceptible and resistant varieties vary in this characteristic. (4) To determine the average number of curls per pod of 17 varieties selected for susceptibility or resistance to see if susceptible and resistant varieties vary in this characteristic. (5) Temperature data and chalcid population data for the growing seasons of 1960, 1961, and 1962 were compared.

Each experiment is treated as a separate unit.

Experiment 1. Seed chalcid alfalfa varietal nursery, 367-60-101, Evans Experimental Farm, Logan, Utah.

This nursery was established in 1960 and consisted of 100 varieties of alfalfa from many areas of the world. The 100 varieties were replicated 10 times. There were five plants per plot, 25 plots per belt, and 4 belts made up one replication. Plants within the plots were 18 inches apart with 36 inches between plots in both directions. Only 5 of the 10 replications were used in this study.

Mature alfalfa pods were collected from each plant in the first five replications of the nursery. Individual vials were used to hold the seeds from each plant. Second crop seed was gathered in October 1962. Random sampling in the field was insured by picking all the seeds from entire stems and by selecting stems from a variety of places on each plant.

The seeds were shelled by hand to prevent the crushing of infested seeds, and 100 from each plant were selected at random. The percentage infestation was determined with the aid of desk binoculars. For statistical analysis the average infestation of all five plants in a plot was used.

Results - Experiment 1. Table 1 shows the ranked means of the percentage infestation among the 100 varieties. Infestation ranged from 1.80 percent to 16.39 percent with an overall average of 6.48 percent. The differences among varieties were not significant, but the block effect was significant at the 1 percent level of probability.

None of the 100 varieties were completely free of chalcid infestation, but because the crop was late there were numerous plants, and in some cases entire plots, which produced no seed.

Conclusions and discussion - Experiment 1. Chalcid infestation in this nursery was much lower in 1962 than in the two previous years (Rowley, 1962). A number of factors combined to reduce infestation, until differences among varieties were not significant. Chalcid populations were much lower than in previous years, and this combined with the early frost which froze all immature seeds and probably killed the adult chalcids in the field, resulted in a very low rate of infestation.

Rowley (1962) found three plants free of chalcid infestation

Table 1. Field study of alfalfa resistance to seed chalcid. Experiment 367-60-101, Evans Experimental Farm, Logan, Utah, 1962. Percentage chalcid infestation based on samples from 5 plants in each row over 5 replications.

Rank	Variety no.	Variety	Mean percentage infested
1	11	Vernal cert. W-52 N.K.	16.39
2	90	M. sativa Denmark P.I. 217,419	15.94
3	94	(Afghanistan) P.I. 220,668	14.39
4	18	Tuna FC 35219	14.20
5	58	Franconian Schmidt Alf. Cal. FC 352567	12.79
6	13	Weibull Lucerne (1959)	12.06
7	55	S.C.S. P 550 Caged seed (1950)	11.87
8	50	39 - Utah Syn C-2 (1959)	10.38
9	48	Alfa (Calif. grown) (1959)	10.16
10	54	Meeker Baltic FC 23909	10.07
11	89	Socheville alfalfa P.I. 205,891	10.05
12	38	Brigham Young Strain (1953)	9.97
13	45	Rhizoma Reg. Can. Cert. 2299	9.87
14	86	Peru P.I. 209,090	9.86
15	70	M. sativa var. gaetual (Algeria) P.I. 239,953	9.60
16	53	U 0615 Sweden P.I. 233,056	9.53
17	6	919 Nevada N.K.	9.20
18	31	U 0611 (Sweden) P.I. 233,055	9.20
19	33	Syn Z O.P. A-251 (Utah) 1957	8.98
20	62	Teton So. Dakota (1959) FC 35346	8.94
21	51	Altfranken Schmidt (Ger.) (1959)	8.92
22	77	(Afghanistan) P.I. 212,105	8.72
23	83	Askhabad Turkestan 19304 4/17/52	8.59
24	68	M. sativa var. gaetual (Algeria) P.I. 239,954	8.16
25	34	919 (20s) N.K. (1953)	8.00
26	40	DuPuits FC 24340	7.85
27	64	Claude Fosters - Coal Springs	7.77
28	72	Espana Alfalfa Zona Gallegro (Elbro)	7.33
29	30	Williamsburg FC 24152	7.32
30	82	M. sativa (Poland) 8-25-59 P.I. 225,178	7.28
31	98	(Turkey) P.I. 205,198	7.22
32	67	M. sativa, var. gaetual (Algeria) P.I. 239,956	7.02
33	65	Lebanon Compositae (1958) P.I. 212,132 - 38	6.94
34	96	Uinta Basin 262-10 Compositae 4/17/52	6.88
35	80	(Afghanistan) P.I. 212,104	6.84
36	92	M. sativa x M. falcata (Aust) FC 32675	6.57
37	14	Stafford (1959)	6.52
38	76	(Afghanistan) P.I. 211,607	6.51
39	43	Common (Cameron Adams)	6.47
40	91	(Iraq) P.I. 217,648	6.41

Table 1. Continued

Rank	Variety no.	Variety	Mean percentage infested
41	7	Nevada H-5	6.40
42	2	Ranger alf. cert. U 388 R NK	6.37
43	32	Syn 7 Clone A 253	6.37
44	29	Northern Synthetic A 225 FC 24355	6.19
45	1	African "Ariz" 1952 A4-35	6.18
46	4	Syn C x Lahontan	6.12
47	12	Sevelra FC 24364	6.07
48	87	(Montpellier, France) FC 32674	6.00
49	63	Hairy Peruvian PA-C54-1 Ariz. cert. (1954)	5.99
50	71	Espana alf. Zona Urgel (Lerida)	5.95
51	8	Nemastan (1946)	5.78
52	81	Turkestan 19316 Na 375	5.78
53	85	(Iran) P.I. 222,178	5.78
54	26	A 224 Syn - 1 (1955)	5.75
55	61	39 - Utah Syn H-2 (1959)	5.73
56	84	(Iran) P.I. 222,733	5.62
57	23	Terra Verde N.K. (1953)	5.61
58	52	New Mexico Common	5.51
59	9	Arnin (Germany) (1959) FC 35256	5.47
60	56	A-169 Ecotype (1958)	5.46
61	93	(Spain) P.I. 210,763	5.40
62	57	Zia (1909)	5.11
63	35	Arizona Chilean FC 23669	5.09
64	27	Indiana Syn F Leaf Hopper Res. FC 33188	5.05
65	41	39 - Utah Syn G-2 (1959)	5.00
66	100	Turkestan 88696 No. 377 4/17/52	4.97
67	15	Syn S.A. -3(1959)	4.94
68	44	39 - Utah Syn F-2 (1959)	4.85
69	36	Grimm (cert) N331766 (1959)	4.82
70	46	Chartainvilliers (1959) FC 34715	4.76
71	24	39 - Utah Syn E-2 (1959)	4.74
72	99	Turkestan 88696 No. 385	4.71
73	37	39 - Utah 9 x 34 (1959)	4.66
74	78	(Afghanistan) P.I. 212,106	4.52
75	74	(Afghanistan) P.I. 211,609	4.51
76	60	Talent FC 32139	4.41
77	47	Caliverde FC 32594	4.41
78	69	M. sativa var. gaetual (Algeria) P.I. 239,953	4.39
79	49	Syn Y. O.P. A-250 (1951)	4.30
80	66	W-58 Alfalfa (1959)	4.29
81	28	Lahontan cert. FF 0643 N.K. (1959)	4.24
82	73	(Afghanistan) P.I. 211,610	4.14
83	3	#1 Cody Syn-1	4.05
84	95	(Afghanistan) P.I. 220,530	3.97

Table 1. Continued

Rank	Variety no.	Variety	Mean percentage infested
85	22	919 (15) N.K. 1953 Lot W 5784	3.96
86	79	(Afghanistan) P.I. 212,612	3.96
87	19	Bamm (Iran) 1956 Charles Hymas	3.92
88	10	New Mexico 11-1	3.73
89	20	39 - Utah Syn D-2	3.45
90	75	(Afghanistan) P.I. 211,608	3.32
91	25	Buffalo cert. C.B. 1845 (1956)	3.20
92	42	Nomad FC 24033	3.16
93	5	Ladak	3.02
94	39	Syn 4-clone A-252 O.P. (1951)	2.95
95	16	Nevada Syn 0 (1959)	2.82
96	59	Kansas Common (1959) FC 24072	2.79
97	17	Atlantic FC 24044	2.69
98	97	Widtsoe No. 269-3 4/17/52	2.53
99	88	(Iran) P.I. 222,999	2.04
100	21	Nevada Syn P	1.80
		$\overline{X}$	6.48
		F value for varieties 1.17 N.S.[a]	
		F value for replications 10.84**	

[a]Not significant.
**Significant at 1 percent level of probability.

in 1961 in this nursery. Plant Introduction number 222,178 from Iran had one chalcid free plant, and was the entry with the least infestation in 1960, but in 1962 it had some infestation in all its plants with an average infestation of 5.78 percent, and ranked 53rd from the most infested. The second entry in which a plant was found free of chalcid infestation in 1961, Plant Introduction number 212,104 from Afghanistan, was the 3rd least infested in 1960, but in 1962 it ranked 35th from the most infested and had an average of 6.84 percent infestation. Entry 919 (15) NK 1953 Lot W5784, contained the third chalcid free plant in 1961. It ranked 38th from the least infested in 1960 and in 1962 it ranked 16th from the least infested.

Since many plants in this alfalfa varietal nursery produced no seed in 1962, comparison of 1962 infestations with 1960, or 1961 infestations for immune plants may be questionable, and conclusions drawn from such comparisons may be unreliable.

Experiment 2. Greenhouse and field study of selected low infestation plants in nursery 367-62-121.

This plot consisted of 95 entries; 33 from nursery 367-60-101, 26 from Nevada, and 36 from Arizona. The entries from nursery 367-60-101 were individual plants which had low chalcid infestation during the 1960 and 1961 seasons.

Cuttings were made of these 95 plants in October of 1961 and placed in clean sand to develop roots. On January 20th, 1962, these rooted cuttings were removed from the sand and planted in a bed in the USDA ARS greenhouse located in Logan. They were planted in four replications of 108 entries each. (Some of the Utah entries were duplicated to bring the number of entries up to 108.) Each replication consisted of 9 rows with 12 plants per row. Six inches were maintained between rows and between plants within a row. A continuous recording hygrothermograph in the greenhouse recorded temperature and relative humidity.

The plants grew remarkably well and some entries exceeded 7 feet in in height. Leaf cutter bees (Megachile rotundata Fabr.) collected by Dr. G. E. Bohart, were moved into this greenhouse to cross-pollinate the plants. These bees were very effective in tripping the flowers and an exceptionally heavy seed set resulted. Chalcids were provided by Dr. B. A. Haws, of the U.S.U. Entomology department, from seed raised in Utah, and from Dr. F. E. Strong in California. Lady-bird beetles were introduced to control aphids.

When mature, seed from individual plants was harvested, hand shelled, and 400 seeds from each entry were evaluated for chalcid infestation.

During the first week in July, 1962, these greenhouse plants were transplanted in a field at the Evans Experimental Farm in Logan, Utah. Entries were planted in the identical randomized positions as they were in the greenhouse, but more distance between plants and rows was allowed. Alkali bees and leaf cutter bees, again supplied by Dr. G. E. Bohart, were placed in the field at blossom time to cross-pollinate the plants, and natural populations of chalcids were allowed to infest them. Seed was harvested when mature, and chalcid infestation was determined. Results of these two crops are recorded in tables 2 and 3, respectively.

Results - Experiment 2. Table 2 shows the ranked mean percentage infestation of the greenhouse crop. Statistical analysis (Duncan, 1955) showed that there were significant differences among varieties at the 5 percent level of probability.

Table 2. Greenhouse study of alfalfa resistance to seed chalcid. Experiment 367-62-121, Logan, Utah, 1962. 108 entires, 4 replications. Average percentage infestation based on 400 seeds per entry.

Rank	Entry	Mean percentage infestation	Least significant ranges[a] at the 1% level (Duncan's Multiple Range Test)
1	56-9-5	17.25	1
2	1002b Ut.	16.70	1
3	Y-56-628 Ariz.	14.95	2
4	Y-56-146 Ariz.	14.65	2
5	1002d Ut.	13.08	3
6	N-905	12.45	3-4
7	N-1186	12.40	3-4
8	S-9-43 Ariz.	12.30	3-4
9	N-2047	12.08	3-5
10	56-9-7 Ariz.	11.85	3-5
11	0201d Ut.	11.70	3-5
12	L-85 Ariz.	11.08	5-6
13	56-10-14 Ariz.	10.80	5-7
14	1066a Ut.	10.20	6-8
15	0201a Ut.	10.08	6-9
16	0201b Ut.	10.08	6-9
17	56-10-16 Ariz.	9.78	6-10
18	56-9-6 Ariz.	9.70	6-11
19	L-114 Ariz.	9.70	6-11
20	1066e Ut.	9.65	6-12
21	0201c Ut.	9.55	7-13
22	0176b Ut.	9.40	7-14
23	0168a Ut.	9.10	8-15
24	56-9-37 Ariz.	9.00	8-16
25	N-1-113	8.95	8-17
26	L-9 Ariz.	8.70	9-18
27	L-11 Ariz.	8.65	9-19
28	S-9-40 Ariz.	8.55	10-20
29	N-552	8.53	10-21
30	C-906	8.30	11-21
31	0981c Ut.	8.20	11-22
32	0201c Ut.	8.00	12-22
33	0663d Ut.	7.98	14-23
34	0176b Ut.	7.83	15-23
35	56-9-5 Ariz.	7.75	15-23
36	56-10-5 Ariz.	7.73	15-23
37	L-37 Ariz.	7.73	15-23
38	0168c Ut.	7.65	15-24
39	N-902	7.58	16-25
40	0168e Ut.	7.58	16-25

Table 2. Continued

Rank	Entry	Mean percentage infestation	Least significant ranges[a] at the 1% level (Duncan's Multiple Range Test)
41	L-75 Ariz.	7.50	16-25
42	56-9-17 Ariz.	7.50	17-25
43	0201a Ut.	7.43	18-26
44	1022e Ut.	7.35	18-26
45	N-2038	7.35	18-26
46	1059c Ut.	7.35	18-26
47	L-33 Ariz.	7.25	19-26
48	0981d Ut.	7.13	20-26
49	N-529	6.88	21-27
50	L-64 Ariz.	6.78	21-28
51	1022a Ut.	6.78	22-29
52	0981a Ut.	6.60	22-30
53	N-603	6.40	22-31
54	M-56-10 Ariz.	6.40	23-31
55	0201a Ut.	6.40	24-31
56	0176a Ut.	6.40	24-31
57	L-71 Ariz.	6.18	25-31
58	1002b Ut.	6.00	26-32
59	0981c Ut.	6.00	26-33
60	56-10-18 Ariz.	5.83	26-34
61	L-7 Ariz.	5.78	27-34
62	1059e Ut.	5.70	27-34
63	N-787	5.68	27-35
64	L-113 Ariz.	5.53	28-35
65	0201b Ut.	5.45	28-35
66	L-89 Ariz.	5.38	29-36
67	0168b Ut.	5.37	29-36
68	N-1388	5.35	30-36
69	1002b Ut.	5.10	31-36
70	0201d Ut.	5.08	31-36
71	M-56-11 Ariz.	4.98	31-36
72	Y-56-225 Ariz.	4.98	31-36
73	N-674	4.90	32-36
74	0981a Ut.	4.90	32-37
75	1059a Ut.	4.73	32-37
76	L-132 Ariz.	4.58	32-37
77	1022d Ut.	4.58	33-37
78	N-383	4.35	33-38
79	N-1-155	4.35	33-38
80	1059d Ut.	4.35	34-38
81	N-694	4.28	35-39
82	N-759	3.95	35-39

Table 2. Continued

Rank	Entry	Mean percentage infestation	Least significant ranges[a] at the 1% level (Duncan's Multiple Range Test)
83	L-82 Ariz.	3.95	35-39
84	0176c Ut.	3.95	35-39
85	0663d Ut.	3.95	35-39
86	N-609	3.48	36-39
87	N-676	3.48	36-40
88	L-20 Ariz.	3.48	36-40
89	0981c Ut.	3.48	37-40
90	N-466	2.93	37-40
91	N-388	2.93	37-40
92	L-120 Ariz.	2.93	37-40
93	0201b Ut.	2.93	38-40
94	0168d Ut.	2.93	38-40
95	56-10-3	2.85	38-41
96	1059b Ut.	2.85	38-41
97	N-1555	2.05	39-41
98	N-799	1.43	40-41
99	C-89	1.43	41
100	L-136 Ariz.	1.43	41
101	L-1r Ariz.	1.43	41
102	09813 Ut.	1.43	41
103	C-900	0.00	--
104	N-589	0.00	--
105	1022b Ut.	0.00	--
106	0663d Ut.	0.00	--
107	1001a Ut.	0.00	--
108	56-10-25	0.00	--
	$\overline{X}$	6.93	
	F value for varieties		1.34*
	F value for replications		3.01**
	LSD for 1% level of probability		1.46

[a]Significant difference exists between any two means not found in the same range.
*Significant at the 5 percent level of probability.
**Significant at the 1 percent level of probability.

Infestation was low in comparison to that under natural field conditions. Average infestation was 6.55 percent in the greenhouse.

Table 3 shows the ranked mean percentage infestation at the Evans Experimental Farm. Statistical analysis showed that there were significant differences among varieties at the 5 percent level of probability. Due to many missing numbers, replications were disregarded and the data were evaluated as a completely randomized design with unequal numbers. Average infestation was 17.86 percent in the field. One entry was free of infestation but two of the four replications were missing. Fifty-one seeds of this entry were observed.

Conclusions and discussion - Experiment 2. This experiment was designed to test, under controlled conditions, those entries from nursery 367-60-101 which ranked low in chalcid infestation in 1960 and 1961, especially those found free of chalcid infestation in 1961.

Thirty-three entries were selected for evaluation in this nursery, representing 10 varieties, 7 of which were selected specifically for resistance to the chalcid. Those selected for resistance are as follows, with the variety name in parenthesis and the greenhouse or field study designation immediately following: Variety 20 (39 - Utah Syn D-2) - 0663; Variety 21 (Nevada Syn P) - 1022; Variety 78 (Afghanistan P.I. 212,106) - 1059; Variety 79 (Afghanistan P.I. 212,612) - 0981; Variety 80 (Afghanistan P.I. 212,104) - 0176; Variety 85 (Iran P.I. 222,178) - 0201; Variety 95 (Afghanistan P.I. 220,530) - 0168. All these entries ranked low in infestation in 1960 and 1961 (Rowley, 1962), and all ranked low in infestation in both the greenhouse and the field in 1962, see tables 2 and 3. Varieties 20,

Table 3. Field study of alfalfa resistance to seed chalcid. Experiment 367-62-121, Logan, Utah, 1962. 108 entries, 4 replications, Average percentage infestation based on 400 seeds per entry.

Rank	Entry	Mean percentage infestation	Least significant ranges[a] at the 1% level (Duncan's Multiple Range Test)
1	N-674	43.00	1
2	Y-56-146 Ariz.	39.79	1-2
3	56-10-16 Ariz.	39.00	1-2
4	C-900	38.25	1-3
5	S-9-43 Ariz.	38.00	1-3
6	N-2047	36.78	1-4
7	0168a Ut.	35.25	2-4
8	56-9-17 Ariz.	35.00	2-4
9	L-120 Ariz.	33.61	2-5
10	L-136 Ariz.	33.00	3-6
11	56-9-6 Ariz.	32.62	3-7
12	1002b Ut.	30.75	4-8
13	N-902	30.50	4-8
14	0168b Ut.	28.44	5-9
15	56-9-7	28.07	5-9
16	56-10-18 Ariz.	27.94	5-9
17	L-11 Ariz.	27.19	5-10
18	0663d Ut.	27.00	6-11
19	N-609	26.25	7-12
20	56-9-5 Ariz.	25.75	8-13
21	M-56-11 Ariz.	25.25	8-14
22	1059c Ut.	25.22	8-14
23	N-1388	24.67	8-15
24	L-14 Ariz.	24.66	8-15
25	1066a Ut.	24.50	8-15
26	Y-56-628 Ariz.	23.96	9-16
27	N-2038	23.78	9-17
28	1059e Ut.	23.00	9-18
29	0981c Ut.	22.75	9-18
30	0981e Ut.	22.33	9-19
31	Y-56-225 Ariz.	22.25	9-19
32	L-114 Ariz.	21.00	10-20
33	56-10-5 Ariz.	21.00	10-20
34	M-56-10 Ariz.	20.65	11-21
35	L-37 Ariz.	20.12	12-22
36	C-906	20.00	12-22
37	1022a Ut.	19.66	13-23
38	N-552	19.00	14-24
39	0981c Ut.	18.71	15-25
40	0201c Ut.	18.68	15-25

Table 3. Continued

Rank	Entry	Mean percentage infestation	Least significant ranges[a] at the 1% level (Duncan's Multiple Range Test)
41	1059d Ut.	18.67	15-25
42	0981d Ut.	18.42	15-25
43	0663d Ut.	18.33	15-26
44	0981c Ut.	17.81	16-27
45	L-20 Ariz.	17.55	16-28
46	0176a Ut.	17.43	17-28
47	0201d Ut.	17.40	17-28
48	N-905	16.87	18-29
49	1022b Ut.	16.76	18-29
50	1002b Ut.	16.68	18-30
51	L-89 Ariz.	16.62	18-30
52	L-71 Ariz.	16.27	19-30
53	N-799	16.24	19-30
54	L-75 Ariz.	16.13	19-31
55	S-9-40 Ariz.	15.76	20-32
56	N-1-155	15.73	20-32
57	N-383	15.46	20-33
58	0981a Ut.	15.40	20-34
59	0201b Ut.	15.12	20-34
60	0981a Ut.	15.00	20-35
61	N-1555	14.65	20-36
62	0168d Ut.	14.58	20-36
63	56-10-14 Ariz.	14.36	21-37
64	C-89	14.33	21-37
65	1022e Ut.	14.28	21-37
66	N-1-113	14.25	21-37
67	0663d Ut.	14.24	21-37
68	56-10-3 Ariz.	14.22	22-37
69	N-676	13.83	22-38
70	1059a Ut.	13.75	22-38
71	1002d Ut.	13.49	23-39
72	N-589	13.25	23-39
73	L-132 Ariz.	13.01	24-39
74	1059b Ut.	13.00	24-39
75	0201c Ut.	12.88	24-39
76	0176b Ut.	12.77	24-39
77	N-388	12.75	24-39
78	L-64 Ariz.	12.67	24-39
79	56-10-25 Ariz.	12.39	25-39
80	0201a Ut.	11.97	26-40
81	1002d Ut.	11.87	27-40
82	L-85 Ariz.	11.87	27-40

Table 3. Continued

Rank	Entry	Mean percentage infestation	Least significant ranges[a] at the 1% level (Duncan's Multiple Range Test)
83	1001a Ut.	11.76	27-40
84	0168c Ut.	11.45	27-40
85	1022d Ut.	11.22	28-41
86	0201b Ut.	10.75	29-42
87	N-466	10.50	29-42
88	N-759	10.27	30-42
89	56-9-37 Ariz.	9.75	31-42
90	0201b Ut.	9.54	32-43
91	L-7 Ariz.	9.12	33-44
92	L-9 Ariz.	9.00	34-44
93	L-82 Ariz.	8.65	35-44
94	0201d Ut.	8.62	35-44
95	N-694	8.56	36-44
96	0176b Ut.	8.50	36-44
97	1059d Ut.	8.35	36-44
98	N-603	8.10	37-44
99	N-787	8.09	37-44
100	0176c Ut.	7.67	38-44
101	1066c Ut.	7.14	39-44
102	N-529	5.75	40-45
103	L-33 Ariz.	5.60	40-45
104	L-113 Ariz.	4.86	41-45
105	0201a Ut.	4.67	42-45
106	0201e Ut.	3.25	43-45
107	0168e Ut.	2.71	44-45
108	N-1186	0.00	45
	$\bar{X}$	17.86	
	F value for varieties = 1.35*		

[a]Significant difference exists between any two means not found in the same range.

21, and 80 (0663, 1022, 1001, respectively) had no infestation in the greenhouse, and Varieties 85 and 95 (0201, and 0168, respectively) ranked second and third from the least infested in the field. Varieties 80 and 85 were entries which had a chalcid free plant in them in 1961.

The entries did not vary significantly in relation to origin. The entries from Arizona had a higher average infestation than those from Utah or Nevada on both crops. The entries from Nevada had the lowest average infestation on the greenhouse crop but the Utah entries were lowest in the field crop (table 4).

Table 4. Mean percentage infestation of greenhouse and field crops according to origin of entries.

Origin	Greenhouse crop	Field crop
Arizona	7.63	20.74
Utah	6.61	15.69
Nevada	5.44	17.74

F value for locations 3.04 N.S.[a]
F value for crops 111.80**

[a]Not significant.
**Significant at the 1 percent level of probability.

Experiment 3. Pod thickness study.

Seventeen alfalfa varieties representing the ten most susceptible and the seven most resistant entries as determined by previous studies (Minion, 1961; Rowley, 1962) were selected from field nursery 367-60-101.

Green pods were selected from each of these 17 varieties approximately 9 days after tripping. A single edged razor blade was used to cut through the swelling on the pod directly over the seed and the thickness of the pod at that point was measured by the use of a calibrated binocular. Care was taken to "draw" the blade during cutting to prevent crushing the cells so an accurate and valid measurement could be taken. Any green pods not measured the day they were picked were refrigerated to preserve turgidity. Five of the ten replications in the nursery were measured.

Results - Experiment 3. Table 5 shows the ranked means of the pod thickness of the 17 varieties selected from field experiment 367-60-101. Analysis shows significant differences at the 1 percent level of probability. Average pod thickness over the 17 varieties ranged from 2.90 units to 4.65 units, the mean being 3.71 units. (4.5 units equals one millimeter.)

Conclusions and discussion - Experiment 3. The 17 varieties were selected for measurement to see if there was a real difference in pod thickness between varieties that were high in infestation and those that were low. It is more meaningful, therefore, to compare the averages of high and low infestations than to make a full range comparison. Those varieties selected for resistance to the chalcid are numbers 20, 21, 78, 79, 80, 85, and 95. Those selected for susceptibility to the chalcid are 9, 18, 26, 29, 40, 45, 64, 69, 82, and 91.

The average pod thickness of those varieties selected for resistance to the chalcid is 3.19 units compared to 4.07 units for the ones selected for susceptibility. Statistical computation showed a close correlation between varieties selected and pod thickness. A correlation coefficient of $r = .936$ was computed from 1962 data. 1961 data had a correlation coefficient of $r = .969$ between the same factors.

Table 5. Ranked means of pod thickness in 17 selected varieties.

Var. no.	Rank	Variety		Average thickness in units[b] X 10	Least significant ranges[a] 1% level Duncan's Multiple Range Test
95	1	(Afghanistan)	P.I. 220,530	2.90	A
20	2	39-Utah Syn D-2		3.11	B
85	3	Iran	P.I. 222,734	3.15	B-C
79	4	(Afghanistan)	P.I. 212,612	3.16	B-D
80	5	(Afghanistan)	P.I. 212,104	3.23	B-E
21	6	Nevada Syn-P		3.38	E-F
78	7	(Afghanistan)	P.I. 212,106	3.44	E-G
40	8	DuPuits	FC 24340	3.59	F-G
91	9	Iraq	P.I. 217,648	3.63	G-H
82	10	<u>M. sativa</u> (Poland) 8-25-50	P.I. 225,178	3.87	H-I
69	11	<u>M. sativa</u> var gaetual	P.I. 239,955	3.95	H-I
26	12	A-224 Syn-1 (1955)		3.99	H-I
18	13	Tuna	FC 35219	4.19	J-K
45	14	Rhizoma Registered Can. Cert. 2299		4.22	J-K
29	15	Northern Synthetic A-225		4.25	J-L
9	16	Arnin (Germany) (1959)	F.C. 35256	4.34	J-L
64	17	Claude Fosters - Coal Springs		4.65	M
		$\bar{X}$		3.71	
		F value for varieties	6.958**		
		F value for replications	3.168*		

*Significant at the 5 percent level of probability.
**Significant at the 1 percent level of probability.
[a]Significant difference exists between any two means not found in the same range.
[b]4.5 units equal one millimeter.

When the study was started it was theorized that a thick pod would make the seed less susceptible to the chalcid. It can be noted that our studies indicated that the opposite may be true. If pod thickness is a factor in determining infestation by the chalcid, then the females seemingly select a thick fleshy pod. Varieties 45 and 64, Rhizoma and Claude Fosters respectively, are especially "fleshy" and they rank high in infestation.

Experiment 4. Number of curls per pod study.

Mature, dry seed pods harvested in 1961 from nursery 367-60-101 were used for this study. With the aid of a four inch, table mounted, lighted magnifying lens, the number of curls per pod was counted to the nearest half curl. Ten pods from each plant were measured from eight of the ten replications in the nursery. The same 17 varieties used in the pod thickness study were used.

Results - Experiment 4. Table 6 shows the ranked means of the number of curls per pod among the 17 selected varieties. Differences among the varieties were significant to the 1 percent level of probability. The average number of curls over the 17 varieties ranged from 0.83 to 2.86 with a mean of 2.11.

Conclusions and discussion - Experiment 4. Here again it is more appropriate to compare the selected varieties as "resistant" or "susceptible" as it was in the pod thickness study.

Those varieties selected for resistance (see pod thickness study) had an average of 2.38 curls per pod. Those selected for susceptibility had an average of 1.92 curls per pod. Statistical computation showed a close correlation between varieties selected and the number of curls per

Table 6. Ranked means of number of curls per pod in 17 selected varieties.

Var. no.	Rank	Variety		Average curls per pod	Least significant ranges[a] 1% level Duncan's Multiple Range Test
69	1	M. sativa var. gaetual	P.I. 239,955	2.86	A
79	2	(Afghanistan)	P.I. 212,612	2.74	A-B
78	3	(Afghanistan)	P.I. 212,106	2.59	B-C
80	4	(Afghanistan)	P.I. 212,104	2.53	C-D
21	5	Nevada Syn-P		2.37	D-E
95	6	(Afghanistan)	P.I. 220,530	2.33	E-F
40	7	DuPuits	FC 24340	2.21	E-G
18	8	Tuna	FC 35219	2.20	E-H
85	9	Iran	P.I. 222,734	2.11	G-I
82	10	M. sativa (Poland) 8-25-59	P.I. 225,178	2.09	G-J
29	11	Northern Synthetic A-224		2.08	G-K
20	12	39-Utah Syn D-2		2.01	I-L
9	13	Arnin (Germany)(1959)	FC 35256	1.98	I-L
91	14	(Iraq)	P.I. 217,648	1.80	M
45	15	Rhizoma Registered Can. Cert. 2299		1.64	M-N
26	16	A-224 Syn-1 (1955)		1.55	N
64	17	Claude Fosters - Coal Springs		0.83	O
		$\bar{X}$		2.11	
		F value for varieties	9.89**		
		F value for replications	1.29[N.S.]		

**Significant at the 1 percent level of probability.
[N.S.]Not significant.
[a]Significant difference exists between any two means not found in the same range.

pod. A correlation coefficient of r = .863 was computed from 1962 data whereas 1961 data had a correlation coefficient of .893 between the same factors.

For comparison the means of table 5 were ranked from least to greatest and the means of table 6 from greatest to least. This shows the more resistant varieties at the top and the susceptible ones at the bottom on both tables. Varieties 64, 65, and 9 rank in the bottom 5 on both tables 5 and 6; these were selected for susceptibility. Varieties 78, 79, and 80, which were selected for resistance, rank in the top 6 on both tables 5 and 6.

The resistance associated with a high number of curls per pod in an alfalfa variety may be a "physical resistance." A pod which has many tight curls does not expose as much vulnerable area to chalcid oviposition as an open pod with few curls. The tightness of the curls is a major factor and a pod which has open curls would still be susceptible to infestation even though it may have numerous curls. An example of this is variety 69, (see table 6) which has the largest number of curls per pod, yet it was selected for susceptibility. Observing the plant in the field will explain this. It has a very open type pod. Contrast this with variety 79 which has a very tightly curled pod.

Experiment 5. Temperature-chalcid population study.

During the summers of 1960, 1961, and 1962, chalcid populations were sampled in alfalfa nursery 367-60-101. This was done with a standard 15-inch insect net and the number of chalcids per 50 sweeps was determined. These counts were plotted in a graph to compare chalcid populations during the 3 years.

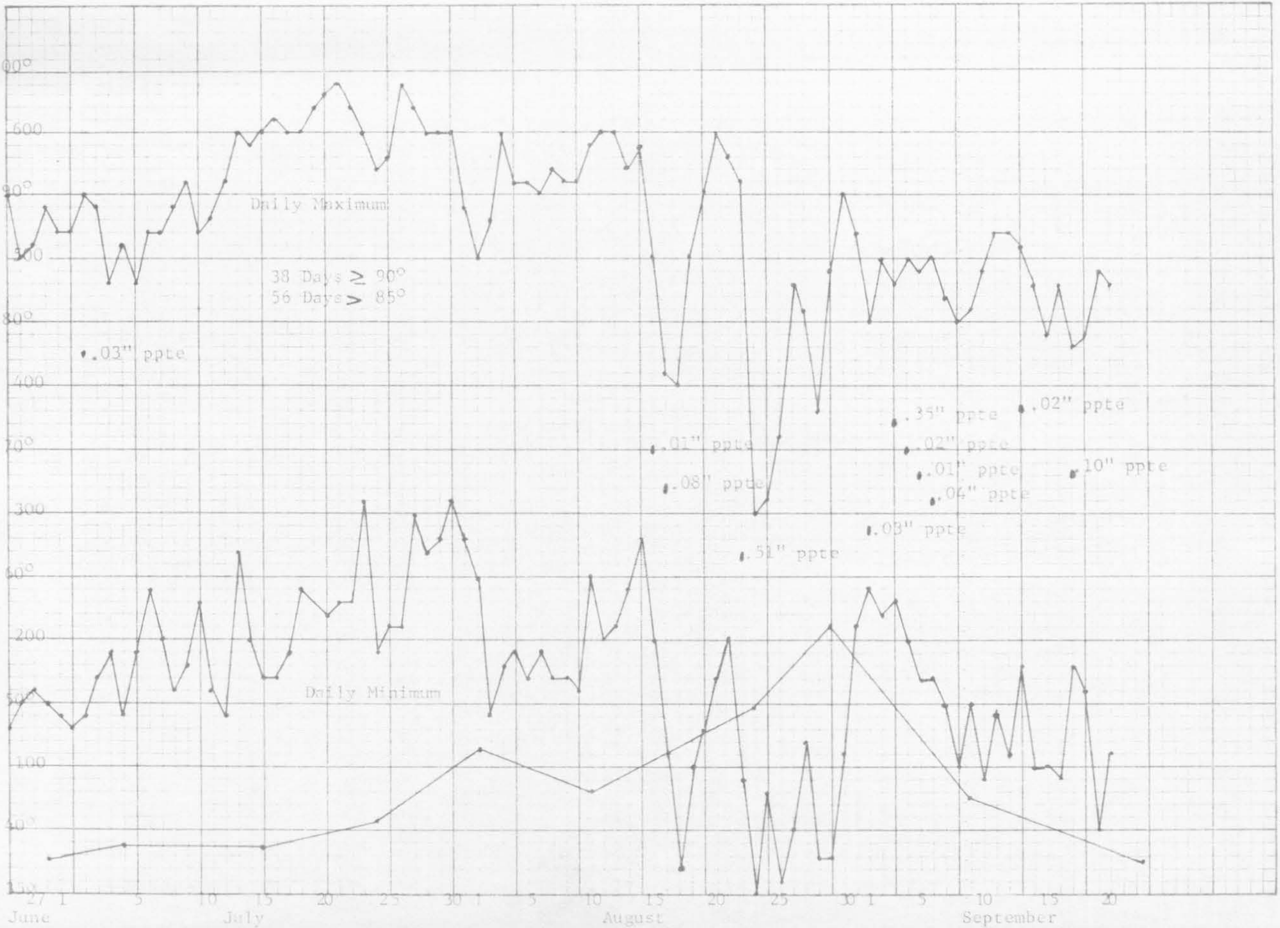
Temperature data were taken from the United States Department of

Commerce publication "Climatological Data" for the State of Utah. Logan Greenville farm data were used. Daily maximum and minimum temperatures for a period of 88 days, from June 25 to September 20 inclusive were recorded on graphs, and the summer temperatures for the three years 1960, 1961, and 1962, were compared with the corresponding chalcid populations for each year. Precipitation data were also included in the figures.

Results - Experiment 5. Figures 1, 2, and 3 indicate the alfalfa seed chalcid population in relation to the daily maximum and minimum temperatures. The populations of chalcids varied greatly during the 3 years. Chalcid counts per 50 sweeps reached 214 in 1960 and 511 in 1961, yet the high in 1962 was 27 insects per 50 sweeps. Average infestation in the alfalfa nursery 367-60-101, over which the sweeps were taken, was 51.5 percent in 1960, 26.7 in 1961 (Rowley, 1962) and 6.48 in 1962.

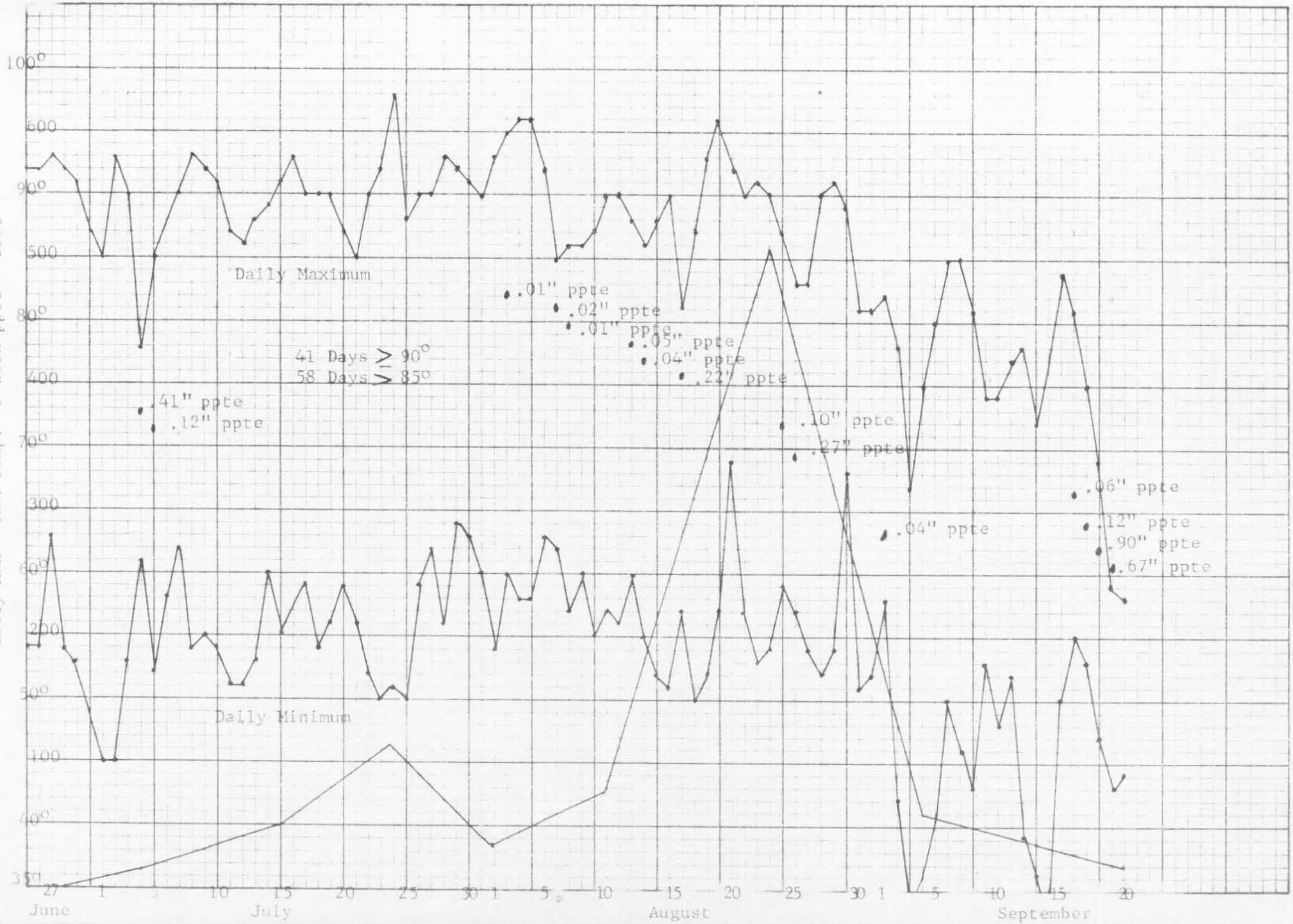
Conclusions and discussion - Experiment 5. The relative summer temperatures did not vary as much as chalcid populations but a decline in daily maximum temperatures can be noted during July 1962 (figure 3). This is a critical period for the chalcid because the first summer brood is emerging. High temperatures are favorable for this, and in 1962, when temperatures were down over this period, chalcid counts fell off to almost zero. During 1960 and 1961 temperatures were much higher during July and insect populations were much greater, especially in 1961.

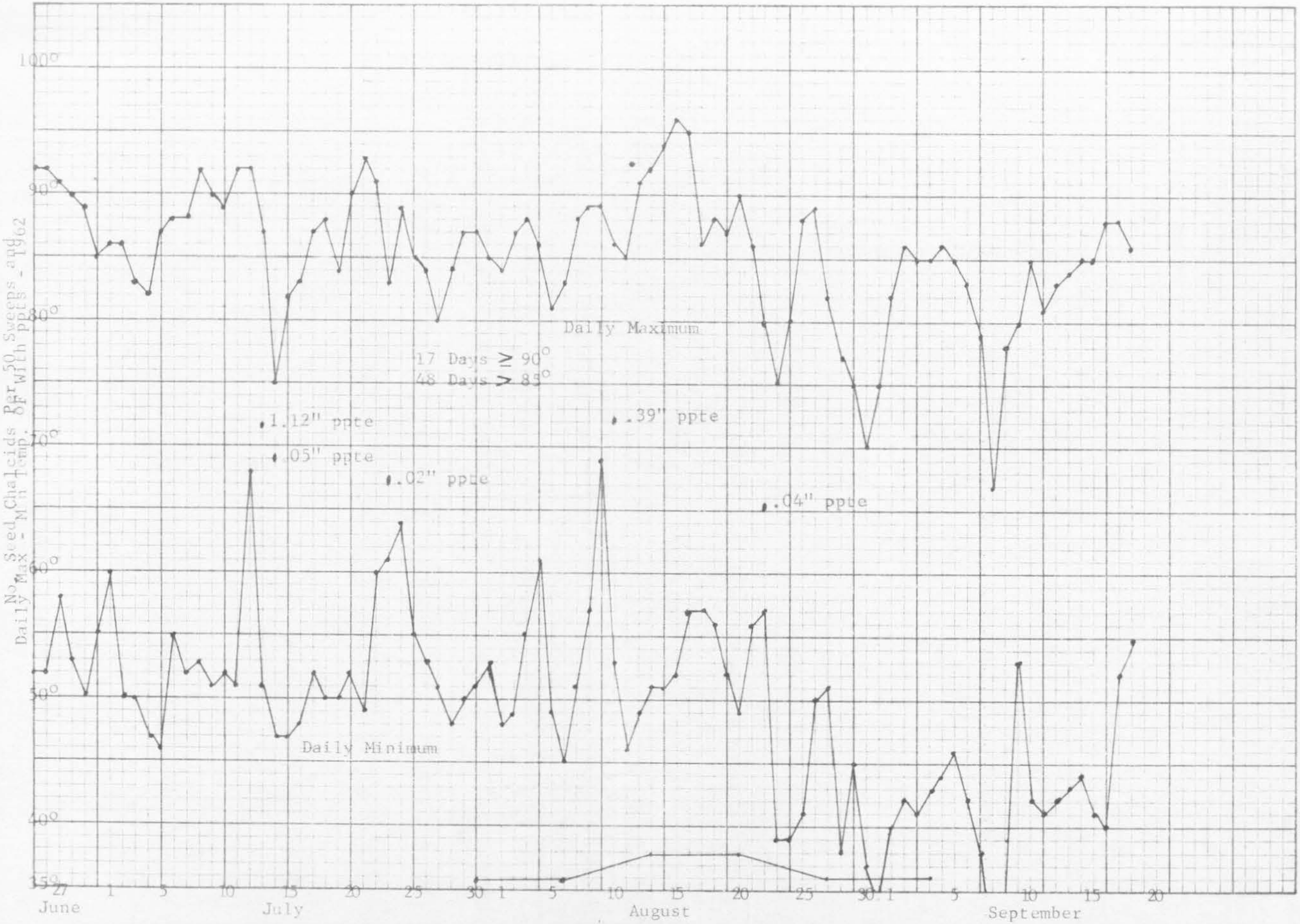
During the 88-day period - June 25 to September 20 - shown in figures 1, 2, and 3, there were 38 days during 1960 when the maximum temperature was 90° F or higher. There were 41 such days during 1961, but during 1962 the number of days 90° F or higher was only 17. The number of days during these same periods when temperatures rose to 85°



N. Seed Chalcids P r 50 Sweeps and Daily Max - Min temp. °F With ppte - 1960

Daily Max - Min Temp. °F With ppte - 1961





No. Seed Chalcids Per 50 Sweeps and
Daily Max - Min Temp. °F With ppts - 1962
100°
90°
80°
70°
60°
50°
40°
35°
Daily Maximum
17 Days ≥ 90°
48 Days ≥ 85°
1.12" ppte
.05" ppte
.02" ppte
.39" ppte
.04" ppte
Daily Minimum
27
1
5
10
15
20
25
30
June
July
August
September

or higher are as follows: 1960 - 56 days, 1961 - 38 days, and 1962 - 48 days. On May 1, 1962, the minimum temperature was 30° F. This same temperature was recorded as a minimum on June 7, 1962.

The low summer temperatures indicated above seemed to have a definite reducing effect on chalcid populations.

SUMMARY

The objectives of this study were: (1) to determine the chalcid infestation of certain previously tested alfalfas; (2) to determine if chalcid resistance in alfalfas is associated with some unique pod characteristics; (3) to determine the optimum temperature range for chalcid activity in the field.

Field nursery 367-60-101, which had been previously evaluated for chalcid infestation, was tested in 1962 but no significant differences among varieties was found even though a fairly wide range of infestation was recorded.

Two seed crops (greenhouse and field) of experimental nursery 367-62-121 were evaluated for infestation and both yielded significant differences between entries. Individual plant comparisons between the two crops were made and varieties with low infestation were compared with the same varieties in the 1960 and 1961 seed crops from field alfalfa nursery 367-60-101 from which some of these entries originated.

One hundred and ninety-five varieties of alfalfa were evaluated in the above experiments; ninety-five of them were evaluated twice.

The pod thickness experiment performed on the 17 selected varieties yielded results which indicated that a thick fleshy alfalfa seed pod was more susceptible to chalcid infestation than those with thinner flesh.

Evidence collected indicated that a higher number of curls per pod and the tightness of the curls were factors in chalcid resistance.

Temperature data and chalcid population data were compared for the years 1960, 1961, and 1962. Temperatures and chalcid counts were below

normal during 1962 and infestation rates were low in alfalfa for that year. Previous studies suggest that chalcid activity in the greenhouse became ineffective below a Fahrenheit temperature of 85° F. Comparisons of field data indicated this was true under natural conditions also.

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