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A Study of the Seasonal History of Alfalfa Flowers as Related to Seed Production

John W. Carlson
Utah State University

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A STUDY OF THE SEASONAL HISTORY OF ALFALFA FLOWERS AS RELATED TO SEED PRODUCTION

A

Thesis

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John W. Carlson

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INTRODUCTION

A few researches have been concerned with the structure and pollination of alfalfa flowers. Others have considered the biological problems concerned in the pollination and fecundation of the flowers. In none of these studies, however, has an attempt been made to follow carefully the alfalfa flowers through various stages of development. Nor has any effort been made to determine what effect the condition and duration of these stages may have upon the resulting seed crop.

The work that follows is a study of the changes through which the alfalfa flowers pass during the season while functioning as organs of seed production. Special effort has been made to study the condition and duration of the stages as they are related to the subsequent seed crop.

Stripping.

Stripping is a term used by the seed grower to indicate that the flowers, while in the process of seed formation, have fallen from the raceme before they have formed seed pods. The pods also, especially those containing immature or poorly developed seeds, are known to strip. The exact cause of stripping is at present unknown. Many reasons have been suggested, but few, if any of them, are based upon experimental data.

It is obvious that the time and amount of stripping may seriously endanger the chances for a good seed crop. If it takes place early in the season new flowers usually appear which may still produce a seed crop. If it occurs late in the season and

involves most of the flowers, the seed crop for that season is likely to be a failure. Ordinarily, however, stripping is only partial and occurs to some extent with every crop of flowers. As a rule it is the survivors of several crops of flowers which succeed in completing their function that produces the final seed crop.

Stripping of flowers and pods, and control over irregularity in flower development, present perhaps the most fundamental problems in alfalfa seed production in the Uintah Basin. With the present limited knowledge of these phenomena it would seem there can be no way of telling, with any degree of certainty, whether or not a particular raceme of flowers will later bear pods or if most of the flowers are to wilt and fall off.

In view of the importance of the matter to alfalfa seed growers, an investigation of this subject was undertaken on the Uintah Basin Alfalfa Seed Experiment Farm beginning with the season of 1926. It became at once evident that the studies would have to be continued for many seasons before any strictly reliable and conclusive data could be obtained. The data here reported are for the season of 1926 and are in no way intended as final, in the first place, because they represent studies of but a single season and, in the second place, because this season, for the Uintah Basin at least, was somewhat abnormal and not ideal for the production of alfalfa seed. A report on the data at this time, however, is thought to be desirable because certain phases of the investigation have produced data that confirm the findings of previous investigators and show their work to be partly applicable to the Uintah Basin seed area.

EXPERIMENTAL WORK

The first step in the investigation was to study the amount of stripping without inquiring much into the causes of it. When the commercial seed grower examines his crop and thinks of it in terms of probable yield he notes first the apparent number of racemes containing mature pods. He also notes carefully the relative number of individual pods on these racemes. It is obvious that both a large number of racemes bearing pods and a reasonably large number of pods on each raceme are essential to a good crop of seed. To study the first of these conditions the following experiment was carried out:

The Percentage of racemes that bear pods containing mature seed.

Eleven representative locations were chosen in six fields of the Uintah Basin seed area. At each of these locations a stake was set and in its vicinity 100 racemes of alfalfa flowers were labelled. Most of these flowers were in full bloom at the time of labelling. They were not visited again until the field in which they were located were ready and about to be harvested. A count was then made of the number of these racemes on which were found pods containing mature seed. No distinction was made between racemes bearing many and those bearing only a few pods. The identity of a considerable percentage of the blooms labelled was lost by having the strings with which they were marked blown away or whipped to pieces by the wind. The lost racemes were left out of consideration in the final count. The data obtained is presented in Table I.

An examination of this Table shows the highest percentage of racemes with pods is 98.5 and the lowest is 57.1. The average for the 906 racemes of which a record was obtained is 74.7 per cent.

Had all of the flowers, on all of the racemes bearing pods, developed and each formed a pod of mature seed the seed crop would still be on the average only about 75 per cent of that theoretically possible. The experiment, while it does by no means indicate the true behavior of the flowers, does show how the complete stripping of all the flowers from part of the racemes may affect the seed crop.

This study appeared to indicate that the percentage of flowers stripping from the individual raceme to be proportionally greater and more important, from the standpoint of the seed crop, than the complete stripping from part of the racemes.

Percentages of flowers in individual racemes that form pods containing mature seed.

To study this point the following experiment was conducted:

Ten representative locations were chosen on the plats of the Experimental Farm. Each location was marked with a stake and in the vicinity of each 10 racemes were labelled. The number of flowers in each raceme was also recorded. The ten locations were numbered from 1 to 10 consecutively. The ten racemes at each location were also numbered. One hundred racemes containing a total of 1535 flowers were thus included in the experiment. For convenience in tabulating the data the racemes were classified into 10 groups. All the racemes numbered 1 constituted a group by themselves; all of those numbered 2 constituted a second group and so on to 10. In this way the members of each group represented each of the 10 locations.

Inasmuch as previous investigators (1) had emphasized the importance of tripping before seed could set freely, it was thought advisable to observe this point closely in this set of experiments. Further to emphasize the importance of this point it was thought

to be advantageous to do some artificial tripping of flowers. In order to provide for this phase of the experiment a special system was employed in selecting the 100 racemes described above. At each of the locations racemes number 1 and 2, 3 and 4 and so on to 10 were considered as pairs for comparison of natural development versus artificial tripping. Both members of a pair were always located on the same secondary branch of the alfalfa plant. They were in about the same stage of development at the beginning of the experiment and also had nearly the same number of flowers. In general they were exposed to the same environmental conditions during the course of the experiment. The racemes having the odd number of the pair were permitted to develop naturally as they would, whereas the even number of the pair was tripped artificially by inserting a pencil point between the standard petal and the keel.

An examination was made of all the flowers every morning from the time of labelling, until they had either formed green pods or had fallen off. This covered a period of about 10 or 12 days. No further examination was made after this time until the field was ready for harvest. A count was then taken of the surviving pods.

The flowers on the same raceme and on different racemes did not all develop uniformly or together. Those at the base of the racemes were usually the first to begin development, followed in a day or two by those above and nearer the top. Some of the flowers remained in the full-bloom stage for several days before wilting and forming pods. About 11 per cent of them made the transition from the late bud stage to that of wilting in less than 24 hours. The period of full bloom had been so short that the opportunity to trip them artificially had been lost during the interval between visits.

The data obtained from these studies are summarized in Table II.

An examination of the data shows that on the average only 25.6 per cent of the flowers on a raceme set pods under natural conditions of development. Of this number 59 per cent were lost by subsequent stripping. Of the flowers artificially tripped 56.6 per cent set pods of which 62.6 per cent were lost through subsequent stripping. The data shows clearly that in this experiment artificial tripping is at least twice as effective in favoring the setting of pods as is natural development. However, subsequent stripping of pods goes on to about the same extent in both cases.

Piper et al, (1) found a ratio between the number of flowers setting pods under natural conditions of development and those where artificial tripping was used, to be very near the same as that found by the writer. A comparison of data follows:

Table III

Percentage of flowers bearing pods

Percentage of flowers bearing pods	Piper	Writer
Natural conditions	16.76	25.60
Artificial tripping	30.68	56.60
Ratio of flowers artificially tripped to flowers naturally developed	1 to 1.8	1 to 2.2

While the ratios in the two experiments indicate a similar relationship between the two methods of development, the total number of pods set under both conditions was much greater in the writer's experiment. This may be explained on the basis of the difference in natural adaptation for seed production of the areas in which the experiments were conducted. The Uintah Basin being especially favorable.

The affect of the number of flowers per raceme on the percentage of pods set.

In the course of the investigation to obtain the data recorded

in Table II, there seemed to be some slight evidence to indicate that the number of pods set was influenced somewhat by the number of flowers in a raceme. The data from 95 racemes from plants in 11 different locations, and containing 1502 flowers, have been classified to add information on this point and are shown in Table IV. In the summary of the same table the percentage of pods set on racemes having flowers ranging in number from 5 to 16 is compared with those having flowers ranging in number from 17 to 27. A similar comparison is made of racemes having 5 to 11 flowers with those having from 21 to 27 flowers. It is not to be understood that because these limits in range are used that racemes are not found that contain fewer than 5 flowers or more than 27, as such is not the case. The above limits happened to apply to the number of flowers in the racemes used for this experiment.

The data in Table IV shows the racemes having flowers ranging in number from 17 to 27 to have set proportionally about 50 per cent more pods than those having flowers ranging in number from 5 to 16. The relationship is very similar when those racemes having flowers ranging in number from 5 to 11 is compared with those with flowers ranging in number from 21 to 27. This comparison, however, when based on the averages does not tell the whole truth. It will be noted that two racemes, one having 26 and the other 27 flowers set 1 and 15 pods respectively. It is not likely that the number of flowers on the racemes could have determined this result.

The coefficient of correlation of the number of flowers per raceme X percentage of pods set was found to be $\pm .321$ which is slightly less than 3 times the probable error. The data follows:

Number of flowers per raceme X Percentage of pods set $= +.321 \pm .126$

The r in this case is probably not significant in the light of its P.E., and will permit of drawing no definite conclusions. It may be that the results obtained are accidental.

Table V contains data obtained from a study of 885 flowers made about 4 weeks after the study of those whose data are recorded in Table IV. The conditions in both cases were those of natural development and the point observed was the effect of the number of flowers per raceme on the percentage of pods set. In the second study it was found that the racemes having fewer flowers set a higher percentage of pods than did those having many. These results are similar to those found by Piper (1). A comparison of the data follows:

Table VI

Effect of the number of alfalfa flowers per raceme on the percentage of pods set.

	Writer's		Piper's	
Number of flowers per raceme	5-16	17-27	2-16	17-26
Average percentage of pods set	20.1	15.3	37.8	19.7

Artificial tripping versus natural development as influencing the effect of the number of flowers per raceme on the percentage of pods set.

To secure information on this point, the data secured from a study of 110 racemes having a total of 1832 flowers have been classified and recorded in Table V. Most of these data were obtained from the same racemes, as were studied in the experiment to learn of the percentage of flowers in individual racemes that form pods under conditions of artificial tripping versus natural development. The conditions of the experiment described for that investigation applies for this one also. Of the 1832 flowers studied 885 were allowed to

develop naturally and 947 were tripped artificially.

An examination of Table V shows that artificial tripping was at least twice as effective in causing the setting of pods on racemes having from 5 to 16 flowers inclusive and from 3 to 4 times as effective on racemes having from 17 to 27 flowers.

Duration of Flower Stages

The second step in the investigation was to observe the length of the duration of the various stages in development of the alfalfa flowers while in the process of seed production. It has been generally supposed, at least by some alfalfa seed growers of the Uintah Basin, that the changes in development from stage to stage should follow in rather rapid succession if a good crop of seed should result. For the flowers to remain in the fresh-looking, full-bloom stage for many days without showing a tendency to wilt, or for them to remain wilted unduly long are generally considered as conditions not favoring seed production. These observations, among others not so closely concerned with the alfalfa flower, have been generally accepted without much experimental data.

To check on and secure information on this point another experiment was conducted. Seven representative locations were chosen on the plats of the experimental farm. These were marked with a stake and in the vicinity of each, 10 racemes were labelled. The flowers in the racemes selected were all in the late bud stage, with the exception of a very few which were fully expanded. Later development of the flowers was carefully studied by making daily observations for a period of 10 or 12 days at the end of which time the flowers had either formed green or brown pods or had fallen away as a result of stripping. The study consisted of a determination of the time intervals between and the duration of the following stages in flower development:

1. Late bud stage
2. First of flowers in full bloom
3. One-half of flowers in full bloom
4. All of flowers in full bloom
5. Flowers wilted
6. " beginning to form green pods
7. Beginning of brown pod stage

It is obvious that the line of demarcation between the stages would not be absolutely definite, but each day the racemes were recorded as being in the stage of development they most nearly represented. The time interval of 24 hours between each observation was also found to be a little too long for absolute accuracy in recording the changes in flower development. Irregularity in development became the most outstanding feature observed in the study. The flowers on an alfalfa raceme do not develop simultaneously. Development begins first with those at the lower end of the raceme and proceeds more or less gradually to those near the top. Even this progress is not regular as to rate or length of time required. There was only one change in flower development that was observed to have any regularity, and that is when all flowers after having been tripped while in full bloom would almost invariably be found to have become wilted by the following day. This was found to be true with almost unfailing regularity whether the flowers had been tripped naturally or by artificial means, or whether they later formed pods or fell off through stripping.

Table VII gives the average number of days the racemes remained in each stage during the period of the observations. Table VIII represents the same data graphically. For the purpose of studying the relationship between the duration of these stages and the amount of seed produced, the data has been clasified into groups based on the number of pods formed by each raceme.

An examination of the data thus presented would indicate that the progressive changes through the various stages should take place with reasonable regularity, as regards the length of time between the stages or the duration of them. Three stages, namely, all of the flowers in full bloom, flowers wilted and flowers forming green pods seem to be critical ones where regularity in transition appears to be very important. There is very little difference in the total length of the period from the late bud stage to the beginning of the brown-pod stage. There is, however, considerable difference in the duration of each of the 3 critical stages. It will also be noted that the racemes bearing the highest number of pods remained in the critical stages a fewer total number of days than did those bearing only a few. With the exception of the group bearing no pods the total amount of time required for the 3 stages increased inversely with the number of pods set. It will also be noticed that the total amount of time required for the critical stages is more uniformly and and evenly divided between the 3 stages in the case of those bearing many pods.

In the case of the racemes bearing from 11 to 17 pods the flowers remained in the full-bloom stage 2.6 days, 1.7 days in the wilted stage and 21 days in the forming of green pods. There appeared to be no particular rush or delay at any stage of the development. This relationship is carried on almost, but not quite so well in the case of those bearing from 3 to 6 and from 7 to 10 pods. In the case of those bearing from 0 to 1 or 2 pods this relationship does not occur at all. Development was apparently halted unduly long in the wilted stage, in the case of those bearing no pods and in the full-bloom stage, in the case of those bearing only 1-2 pods. This study tends to confirm the general opinion of growers mentioned in the introductory paragraph of the second part of the investigation.

SUMMARY

1. This paper presents the first known report of a study of the seasonal history of alfalfa flowers as related to seed production.

2. The data are for the season of 1926. It is the intention to continue the study until definite conclusions may be drawn upon the question involved.

3. Some stripping of alfalfa flowers is of common occurence. The pods are also known to strip.

4. From a study of 906 racemes only 74.7 per cent were found to contain pods of mature seed at harvest time.

5. The percentage of flowers stripping from the individual racemes is proportionally greater and of more consequence from the standpoint of the seed crop than is the complete stripping of all the flowers from part of the racemes.

6. Artificial tripping caused 56.6 per cent of the flowers to set pods as against 25.6 per cent in the case of natural or no tripping. Subsequent stripping of the pods occurred to the extent of 62.6 per cent and 59 per cent respectively.

7. Racemes with flowers ranging in number from 17-27 set proportionally about 50 per cent more pods than did those having flowers ranging in number from 5 to 16 when allowed to develop naturally. When the experiment was repeated later in the season and under similar conditions the results were opposite.

8. As compared with natural development artificial tripping was found to be at least 2 times as effective in causing the setting of pods

on racemes having from 5 to 16 flowers and from 3 to 4 times as effective in the case of those having from 17 to 27 flowers.

9. It seems that the progressive changes in flower development, while in the process of seed formation, should take place with some regularity, as regards the length of time between or the duration of each stage.

10. There are 3 stages which seem to be critical ones in the development of the flowers while forming seed. They are: (1) the full bloom stage, (2) the stage in which the flower petals are wilted, (3) when the green pods are forming.

11. The racemes bearing many pods required a fewer total number of days for development in the 3 critical stages than did those bearing only a few pods. This time period was also more equally divided between the 3 stages. It seems that either undue haste or delay of development in any one of the critical periods will re-act unfavorably on seed formation.

LITERATURE CITED

(1) Piper, C. V. et al

Alfalfa Seed Production; Pollination Studies, U. S. Dept. of Agriculture Bul. No.75 (1914, 32pp.)

Table I

Percentage of Racemes that bear Pods Containing Mature Seed

Location No.	No. of racemes labelled	Racemes with pods		Racemes with flowers stripped		Racemes lost
		No	Per cent	No.	Per cent	
1	100	84	87.5	12	12.5	4
2	100	40	75.4	13	24.5	47
3	100	74	82.2	16	17.7	10
4	100	44	70.9	18	29.1	38
5	100	70	98.5	1	1.5	29
6	100	65	75.5	21	24.5	14
7	100	64	74.5	22	25.5	14
8	100	71	77.1	21	22.9	8
9	100	52	57.1	39	42.9	9
10	100	57	68.0	27	32.0	16
11	100	56	58.9	39	41.1	5
		677 Total	74.7 Av.	229 Total	25.3 Av.	194 Total

Note:

The percentage of racemes with pods and with flowers stripped is based on the original 100 racemes labelled minus the number lost.

Percentages of flowers in individual racemes that formed pods containing mature seeds.

(Natural development vs artificial tripping.)

Table II

Natural development or artificial tripping	Natural		Artificial	
Total number of flowers	740		795	
	Number	Per cent	Number	Per cent
Total No. flowers tripped	46	6.2	707	88.9
Total maximum number pods formed	190	25.6	450	56.6
Total number pods remaining at end of season	78	41.0	168	37.3
Total number flowers stripped	550	74.3	345	43.3
Total number pods stripped	112	58.9	282	62.6

Table IV

Effect of the number of alfalfa flowers per raceme on the percentage of pods set

(Natural conditions of development)

Number of flowers per raceme	Number of racemes	Number of flowers	Number of Pods	Av. Number of Pods per raceme	Percentage of flowers setting pods
5	2	10	2	1.0	20.0
6	1	6	0	0.0	00.0
7	2	14	3	1.5	21.4
8	2	16	1	0.5	6.2
9	2	18	7	3.5	38.9
10	9	90	7	0.6	7.7
11	3	33	4	1.3	12.1
12	4	48	6	1.5	12.5
13	6	78	12	2.0	15.3
14	10	140	18	1.8	12.8
15	5	75	19	3.6	25.1
16	7	112	19	2.8	16.9
17	7	119	23	3.2	19.3
18	7	126	42	6.0	33.3
19	4	76	10	2.5	13.1
20	3	60	28	9.3	46.6
21	7	147	37	5.2	25.1
22	4	88	20	5.0	22.7
23	3	69	10	3.3	14.4
24	1	24	3	3.0	12.4
25	4	100	26	6.5	26.0
26	1	26	1	1.0	3.8
27	1	27	15	15.0	55.5
	95	1502	313	3.4	20.0
	Total	Total	Total	Average	Average

Summary of Table ~~III~~ IV

	Percentage of Pods Set		
	Minimum	Maximum	Average
Racemes with number of flowers ranging from 5 to 16 inclusive	0.0	38.9	15.7
Racemes with number of flowers ranging from 17 to 27 inclusive	3.8	55.5	24.7
Same with flowers 5 to 11 inclusive	0.0	39.8	15.1
Same with flowers 21 to 27 inclusive	3.8	55.5	22.8

Table V

Influence of artificial tripping vs natural development on the number of alfalfa flowers per raceme and on the percentage of pods set.

Number of flowers per raceme	Number of Racemes		Number of Flowers		Number of Pods		Average number of pods per raceme		Percentage of flowers setting pods		Number of flowers tripped	
	Nat.	Art.	Nat.	Art.	Nat.	Art.	Nat.	Art.	Nat.	Art.	Nat.	Art.
5	1	0	5	0	0	0	0.0	0.0	0.0	0.0	0	0
6	0	1	0	6	0	1	0.0	1.0	0.0	16.6	0	1
7	1	1	7	7	1	1	1.0	1.0	14.2	14.2	0	1
8	1	1	8	8	5	5	5.0	5.0	62.5	62.5	6	8
9	1	1	9	9	0	1	0.0	1.0	0.0	11.1	1	4
10	1	1	10	10	2	8	2.0	8.0	20.0	80.0	0	9
11	2	3	22	33	2	16	1.0	5.3	9.0	48.4	0	27
12	5	1	60	12	16	10	3.2	10.0	26.6	83.3	7	10
13	5	4	65	52	15	31	3.0	7.7	23.0	59.9	8	51
14	4	7	56	98	15	50	3.7	7.1	26.7	51.0	6	89
15	4	1	60	15	15	3	3.7	3.0	25.0	20.0	4	12
16	5	4	80	64	28	31	5.6	7.5	35.0	48.4	4	49
17	3	5	51	85	2	58	0.6	11.6	3.9	68.2	1	77
18	3	1	54	18	24	12	8.0	12.0	44.4	66.6	2	15
19	8	4	152	76	38	48	4.7	12.0	25.0	53.1	5	75
20	2	3	40	60	2	32	1.1	10.5	5.0	53.3	0	55
21	4	3	84	63	15	37	3.7	12.3	17.8	58.7	1	58
22	0	4	0	88	0	41	0.0	10.2	0.0	46.6	0	80
23	2	4	46	92	16	43	8.0	10.7	34.7	46.7	2	84
24	0	2	0	48	0	21	0.0	10.5	0.0	43.7	0	43
25	2	2	50	50	13	24	6.5	12.0	26.0	48.0	2	45
26	1	1	26	26	3	18	3.0	18.0	11.5	69.2	0	22
27	0	1	0	27	0	19	0.0	27.0	0.0	71.1	0	27
Totals	55	55	885	947	212	510	3.7 (average)	9.2	24.1 (average)	50.9	49 55%	842 88.9%

Summary of Table ~~IV~~ V

Racemes with number of flowers ranging from	Percentage of Pods Set					
	Minimum		Maximum		Average	
	Nat.	Art.	Nat.	Art.	Nat.	Art.
5 to 16	0.0	0.0	62.5	83.3	20.1	41.2
17 to 27	0.0	43.7	44.4	71.1	15.3	56.8
5 to 11	0.0	0.0	62.5	62.5	15.1	33.2
21 to 27	0.0	43.7	34.7	71.1	12.8	54.8

Table VII

Duration of stages in the development of alfalfa flowers while in the process of seed production.

Stages in flower development	Number of pods formed by racemes: 0	1-2	3-6	7-10	11-17
	Number of days in each stage				
1. Late bud	1.3	1.9	1.6	2.1	1.4
2. First of flowers in full bloom	1.7	1.0	1.2	1.1	.8
3. One half of flowers in full bloom	.7	1.3	1.0	1.0	2.0
4. All of flowers in full bloom	2.3	5.0	3.2	3.3	2.6
5. Flowers wilted	4.3	2.4	2.1	1.6	1.7
6. Flowers forming green pods	0	.5	1.0	1.6	2.1
7. Beginning of brown pod stage	Period ended as soon as this stage was reached				
Total number days	10.3	13.4	10.1	10.7	10.6
No. records	3	16	25	18	6

Total: 68

Utah Agricultural Experiment Station,
Uintah Basin Alfalfa Seed Exp., Farm,
Research Project No. 75 A.

Thesis Problem Data

A Study of the Seasonal History
of Alfalfa Blooms as Related to
Seed Production. (Season 1926)

Table VIII

Division II. "To determine as nearly as possible the duration of the various stages in the development of the Alfalfa flower toward the production of seed.

Date of Labeling	Days Consecutive ~~Dates~~ After Labeling												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Late Bud Stage													
First of Flowers in Full Bloom													
One- half of Flowers in Full Bloom													
Flowers all in Full Bloom													
Flowers Withering													
Beginning to Form Green Pods													
Flowers Stripping													
Green or Brown Pod Stage