A TEST OF NAPHTHALENE ACETIC ACID FOR PREVENTION OF SEED SHATTERING

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by

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THESIS

INTRODUCTION

The loss of seed from shattering before, during, or after, harvest is a matter of considerable economic importance in the production of a number of different seed crops. The successful use of growth substances, particularly naphthalene acetic acid, for the prevention or reduction of preharvest fruit drop by apple trees suggested the possibility of reducing seed shattering by similar treatments. The experiments herein reported were designed to test the possible value of naphthalene acetic acid sprays for the reduction of seed shattering in certain herbaceous crops in which shattering frequently results in lowered seed yields, and consequently, considerable economic loss.

REVIEW OF LITERATURE

It has been known for some time that certain so-called growth substances were effective in delaying the formation of the abscission layer of various plant organs.

Nixon and Gardner (9) found that when certain growth substances were applied to inflorescences of dates, they had a marked influence in delaying the abscission layer. Gardner and Marth (4, 5) say that these substances appear to prevent the formation of an abscission layer at the base of the flower's pedicle.

Gardner, Marth, and Batjer (2, 3) found that the formation of the abscission layer of several varieties of apples was delayed by the use of naphthalene acetic acid, naphthalene acetamide, indole-acetic, indolebutyric and indolepropionic acids.

According to Murneek (7) and confirmed later by Southwick and Shaw (10), 0.001 per cent naphthalene acetic acid gave the best results with respect to reducing drop of apples. These authors claimed that the effect of hormone application was usually evident by the third or fourth day and persisted from 8 to 12 days.

Hoffman, Edgerton, and Van Doren (6) found that there was no appreciable difference between a dust and a spray application of the growth substance. Murphy (8) found that an early application was preferable.

Batjer (1) suggested that 75° F. was approximately the best temperature for effective application. At higher temperatures the effect did not change, while fruit-drop increased with temperatures below this level of 72° F.

These, and other, reports of work done on tree fruits were suggestive of possibilities with herbaceous plants whose tendency towards seed shattering and loss were known by experience. No work on such crops had been done and reported, and hence, the undertaking of the experiments herein described and presented.

MATERIALS AND METHODS

The experiments were conducted during the season of 19[illegible] on the seed farm of the Ferry-Morse Seed Co., at Rochester, Michigan. Use was made of chosen portions of fields under cultivation for seed production.

The plants selected for use were the radish (Raphanus sativus), variety Scarlet Globe Medium Top; spinach (Spinacea oleracea), variety Giant Thick Leaved; scarlet sage (Salvia splendens), variety Bonfire; and borage (Borago officinalis).

The plot arrangement employed was a 4 x 4 Latin Square for each of the three crops: radish, spinach, and scarlet sage. For each of these crops, the treatments were four in number with four replications, making a total of 16 plots. The planting and culture of the crops were in accordance with the procedures ordinarily followed on the company's seed farm. The borage was planted in a 3 x 3 randomized block layout with three treatments and three replications. Naphthalene acetic acid, in the form of a spray, was used as the growth substance. For the spraying, a three-gallon air compressor sprayer was used. All applications were thoroughly made; the plants and especially the flowering parts were covered just to the point where dripping of the spray would have begun. The naphthalene acetic acid was dissolved in a few c.c. of weak ammonium hydroxide and subsequently enough water was added to make a stock solution of [illegible] per cent concentration. This was then available for various dilutions. Ammonium hydroxide was used precedently as solvent of naphthalene acetic acid by van Overbeek, Conklin, and Blakeslee (11). The stock solution was freshly prepared every two weeks. The concentrations of the growth substance used for the spraying of radish, spinach, and scarlet sage were four in number: zero (water check), 0.01%, 0.005%, and 0.0001%. For the borage, with its three types of treatment, the concentrations were zero (water check), 0.01%, and 0.005%.

The number of applications, the intervals of application, and the quantity of solution used, varied with the species. Radish and spinach received five applications: July 17, 22, 27, August 1 and 3. Three-fourths of a litre was the quantity of the spray material used for each plot at the time of each application. In the case of borage six applications were made: August 7, 13, 22, 24, 30, and September 5. One litre per application of the spray material was used. Seven applications were made on the scarlet sage: August 4, 9, 14, 22, 24, 29, and September 4. From one to 1 1/2 litres was the quantity used, which had been increased with the development of the plants.

In all instances the first spray was applied soon after the seeds were formed and the last one was applied after the vegetative growth had finished.

In any instance, when rain immediately followed the spraying, the plants were re-treated. This explains the shorter intervals between the fourth and the fifth sprays in the case of the radish and spinach; the third and fourth sprays for the borage; and the fourth and fifth sprays on scarlet sage.

Every plot had at least one buffer row except for the borage where the border rows of the field were the only ones used. Three seed pickings were made with the scarlet sage--August 2[illegible], September 12, and September 1[illegible]. For each of the other crops, there was a single harvest, made at the time of full maturity of the seed. The plants were cut off above the surface of the ground and the plants from each plot were placed together into cloth bags. The bags were spread out on benches, at room temperature until their contents came to air dryness. Following this, they were placed in electrically heated driers, kept at around 90° F., and thus brought to uniform oven dryness.

The fully dried seeds were threshed out by the use of a flail, passed through a cleaning mill, and weighed for yield.

EXPERIMENTAL RESULTS

1. Spinach:

The results for this crop and the Latin Square field arrangement are shown in table 1. In this table the top figure in each cell indicates the number of plants observed; the lower figure the yield of dried seed in grams, and the capital letter the treatment with naphthalene acetic acid. With respect to the treatments, "A" signifies treatment with 0.01% naphthalene acetic acid; "B" with 0.005%; "C" with 0.0025%; and "D" with plain water (check).

Table 1. Spinach--number of plants and yields by treatments per plot

D 54 347	A 62 430	B 57 234	C [illegible] 371
B 60 319	C 74 433	D 66 303	A 71 325
A 59 316	B 56 344	C 56 306	D 50 317
C 55 220	D 66 [illegible]	A 51 356	B 50 265

Table 2 gives the total number of plants for the four plots, their total yields of seeds, and their average yields per plot per treatment.

Table 2. Spinach--number of plants, total yield, and mean yield per plot per treatment

Treatment	No. of plants	Total Seed Yield (Grams)	Mean Yield per plot (Grams)	Mean Yield Adjusted for Stand
A (0.01%)	243	1427	357	357
B (0.0005%)	223	1212	303	307
C (0.00001%)	267	1330	333	[illegible]
D (water)	236	1363	341	342

The data in table 2 show no consistency of variation in yield with the different concentrations of the treatments. The order of yield from highest to lowest is A, D (check), C, B. The difference between A and B is [illegible] grams, which amounts to about 17 per cent. In order to determine whether or not this difference was significant, the data were analyzed by the covariance method. Statistical analysis for testing significance is given in table 3.

Table 3. Analysis of variances and covariance of stand and yield of spinach

Source	D.F.	x S.S.	x M.S.	xy product	y S.S.	y M.S.	Errors of Estimate S.S.	Errors of Estimate D.F.	Errors of Estimate M.S.
Total	15	1256		3380	47[illegible]5				
Row	3	463	154	1405	5958	1977			
Column	3	179	59	1640	25036	8345			
Treatment	3	256	85	535	6097	2032			
Error	6	358	60	300	10830	1805	10579	5	2116
Tr. & Er.	9	614		835	16927		15791		
Treatment	3						5212	3	1737

From the error line of this table b = 300/358 = .838

From table 3, it can be seen that there were no significant differences between treatment stand averages and also between treatment yield averages. Since the stands were not exactly the same for each treatment and since there appeared to be a correlation between stand and yield, a covariance analysis was carried out for testing for significance between treatment yield averages after adjusting for stand differences. The last three columns and the last two rows in this table indicate that there are no significant differences between yield averages after adjusting for stand. The F value (after adjusting yield) 1739/2111 = 0.821 clearly indicates no significance between these averages. For significance this value should be at least [illegible].70. The averages after adjusting for stand are shown in the fifth column in table 3.

This experiment indicates that these particular treatments were no better than check for seed production.

C. Radish:

Table 4 contains results pertaining to the radish experiment. The presentation is in the same manner as that of table 1 for the [illegible]. The top figure in each cell is the number of plants; the low figure the actual yield in grams, while the letters indicate the treatments.

Table 4. Radish--number of plants and yields by treatments per plot

D 33 476	A 34 372	B 34 559	C 30 670
B 36 525	C 34 484	D 33 530	A 45 394
A 41 291	B 37 400	C 36 502	D 39 292
C 38 394	D 37 420	A 37 360	B 34 360

The data of table 4 are brought together and condensed in table 5.

Table 5. Radish--number of plants, total yield, and mean yield per plot per treatment

Treatment	No. of plants	Total Seed Yield (Grams)	Mean Yield per plot (Grams)	Mean Yield Adjusted for Stand
A (0.016)	157	1417	354	355
B (0.00052)	141	1844	461	457
C (0.00014)	138	2050	512	501
D (water)	142	1718	430	428

The order of difference, shown by table 5, is not the same as that for spinach. It is, from highest to lowest mean yield: C, B, D (check), A. As with spinach, there is the same lack of consistency in the variation of the yields with concentrations of the naphthalene acetic acid treatments. Treatment A, which was highest for spinach, is lowest for radish. The highest yield here is with treatment C, which was third lowest for spinach.

Comparison between $\overset{C}{\text{A}}$ (highest) and D (check) shows the former to be about 13 per cent greater in yield. In order to see whether or not this difference was significant, the data were analyzed by the covariance method. Table 6 gives the result of a statistical analysis of the data.

Table 6. Analysis of variances and covariance of stand and yield of radish

Source	D.F.	x S.S.	x M.S.	xy product	y S.S.	y M.S.	Errors of Estimate S.S.	Errors of Estimate D.F.	Errors of Estimate M.S.
Total	15	160		3531	155087				
Row	3	64	21	-1721	67069				
Column	3	10	3	- 225	10867				
Treatment	3	42	14	-1391	49782	16594			
Error	6	44	7	- 194	27369	4561	26514	5	5303
Tr. & Er.	9	86		-1585	77151		47987		
Treatment	3						21473	3	7157

From the error line of this table b = -194/44 = -4.41

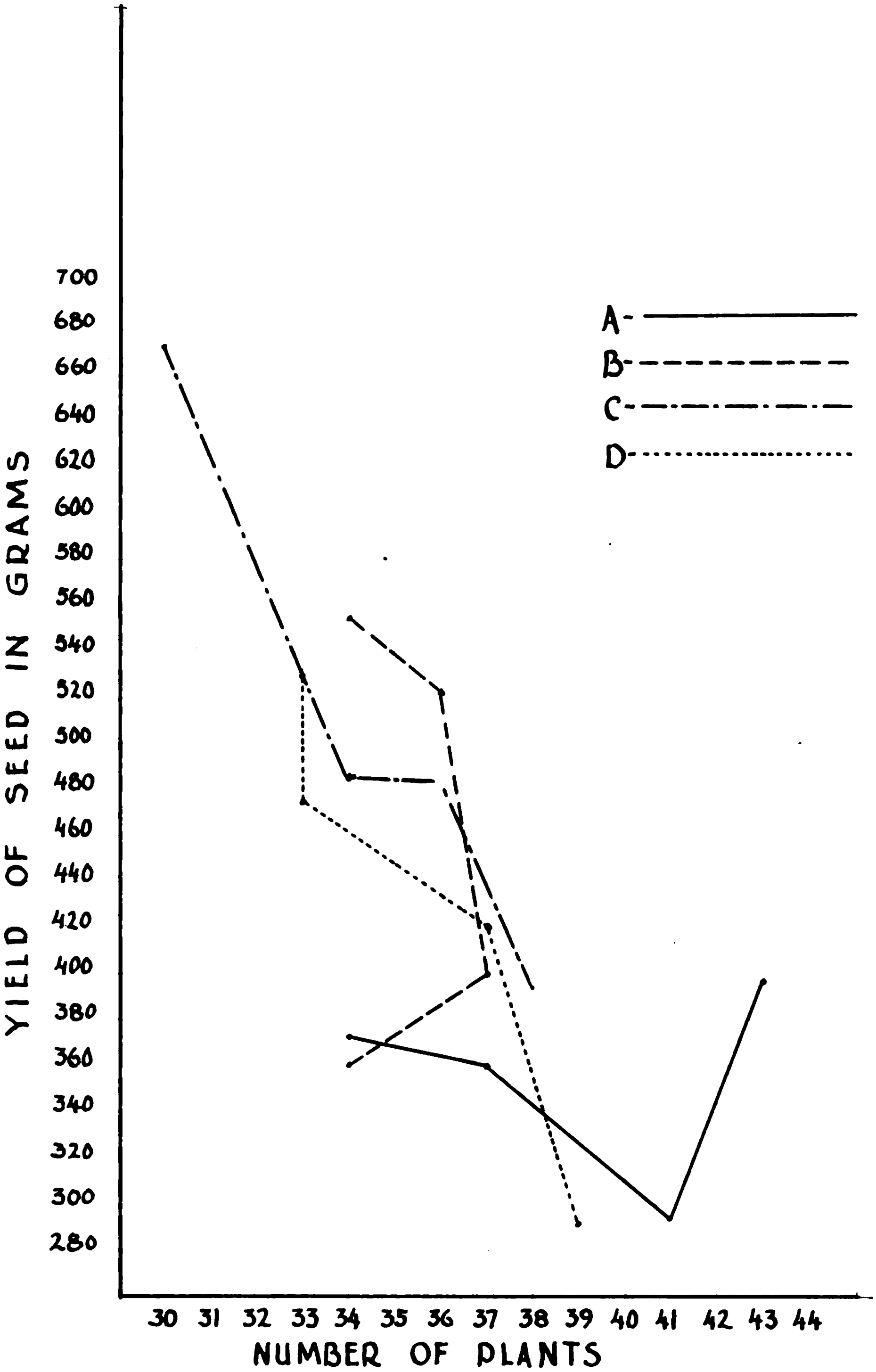
As shown by table 6, the F value pertaining to treatment before adjusting for stand is 16594/4561 = 3.64. This appears to be somewhat high. However, a value of 4.76 for F is required to establish significance.

The regression coefficient in this case is negative. Its value is: 194/44 = -4.41. This means that increase in number of plants is associated with decrease in yield per plot. This is shown graphically in figure 1. This large regression coefficient suggested a covariance analysis.

On examining the means squares pertaining to treatment and error in table 6, it is seen that there are no significant differences between stand averages and yield averages. Since there appears to be a large negative correlation coefficient between stand and yield, a covariance analysis was carried out for testing for significance between yields adjusted for stands. The value of F (after adjusting for stands) 7157/5305 = 1.35 indicates that there are no significant differences between yield averages after adjusting for stand. The yields adjusted for stand are shown in column 5 of table 5.

The quantitative size of the experimental error is 73 grams. The difference of means required for significance is 133 grams at the 5% level. The largest difference shown by table 5 is between A and C, and this amounts to 1[illegible]4 grams, which cannot be considered significant since the F value did not show significance.

The results of this experiment indicate that these particular treatments were no better than the check for seed production of radish.


YIELD OF SEED IN GRAMS
700
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
A-
B-
C-
D-
30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
NUMBER OF PLANTS

3. Scarlet Sage:

As with both spinach and radish, heretofore presented, the data for scarlet sage are given in table 7. The one difference is that of the top figure in each cell indicating length of the observed row (in feet) rather than the number of plants in the plot. The number of plants was 25 for each plot.

Table 7. Scarlet sage--length of rows and yields by treatments per plot

D 42 152	A 44 100	B 40 140	C 45 124
B 42 127	C 44 139	D 43 126	A 41 105
A 40 141	B 42 155	C 40 154	D 36 118
C 39 137	D 46 163	A 44 119	B 43 118

The data of table 7 are collected and given in summary form in table 8.

Table 8. Scarlet sage--length of rows, total yield, and mean yield per plot per treatment

Treatment	Total row length	Total Seed Yield (Grams)	Mean Yield per plot (Grams)	Mean Yield Adjusted for Stand
A (0.01%)	169	465	116	115
B (0.0005%)	167	540	135	135
C (0.00001%)	168	554	138	138
D (water)	167	559	139	139

The data in table 8, for scarlet sage, differing from those for spinach and radish, show a consistency of variation in yield with changes of concentration for the naphthalene acetic acid treatments. The apparent trend is that of decreasing yield with increasing concentration of the growth substance used in the treatments. The regression coefficient 97/41 = 2.37, suggests a covariance analysis, which was carried out. Statistical analysis of the data appears in table 9.

Table 9. Analysis of variances and covariance of length of row and yield of scarlet sage

Source	D.F.	x		xy product	y		Errors of Estimate		
		S.S.	M.S.		S.S.	M.S.	S.S.	D.F.	M.S.
Total	15	97		23	5030				
Row	3	32		-115	694				
Column	3	24		67	1441				
Treatment	3	0		- 26	1435	478			
Error	6	41		97	1460	243	1230	5	246
Tr. & Er.	9	41		71	2895		2772		
Treatment	3						1542	3	514
From the error line of this table b = -97/41 = 2.37									

From table 9 it can be seen that there are no significant differences between treatment stand averages and also between treatment yield averages. An analysis of covariance was made for testing for significance between treatment yield averages after adjusting for stand differences. The last three columns and the last two rows in this table indicate that there are no significant differences between treatment yield averages after adjusting for stand. The F value (after adjusting for stand) 514/249 = 2.09 shows no significance between these averages. The averages after adjusting for stands are shown in table 8 in the fifth column. The experimental error is 15.68 grams. The difference in means required for significance is 20 grams at the 5% level, and 31 grams at the 1% level. Obviously, no differences appear which give evidence of being significant.

4. Borage:

It will be remembered that the plot arrangement for borage was not of the Latin Square design. Only three replications and three treatments with the growth substance were laid out and made. The design together with the results are given in table 10.

Table 10. Borage--number of plants and yields by treatments per plot

A 23 28	B 59 28	C 53 86
A 35 49	B 64 46	C 60 52
A 74 49	B 28 112	C 53 37

The data of table 10 are brought together and condensed in table 11.

Table 11. Borage--number of plants, total yield, and mean yield per plot per treatment

Treatment	No. of plants	Total Seed Yield (Grams)	Mean Yield per plot (Grams)	Mean Yield Adjusted for Stand
A (0.01%)	132	126	42	39
B (0.0005%)	151	186	62	62
C (water)	166	175	58	61

As shown by table 11, there is no consistency in variation of yield with concentrations of the growth substance used. Treatment B (0.0005%) is highest in yield, followed by C (check) and by A (0.01% concentration). The difference between B (highest) and A (lowest) is nearly 45%, yet this is not statistically significant.

Table 12. Analysis of variances and covariance of stand and yield of borage

Source	D.F.	x		xy product	y		Errors of Estimate		
		S.S.	M.S.		S.S.	M.S.	S.S.	D.F.	M.S.
Total	8	2409		- 939	6147				
Treatment	2	193	87	294	680	340			
Error	6	2216	369	-1233	5467	911	4781	5	956
Tr. & Er.	8	2409		- 939	6147		5781		
Treatment	2	193					1000		500
From the error line of this table b = -1233/2216 = -0.556									

From table 12 it is to be seen that there were no significant differences between treatment stand averages and also between treatment yield averages. A covariance analysis was carried out for testing for significance between treatment yield averages after adjusting for stand differences. The last three columns and the last two rows in this table indicate that there are no significant differences between treatment yield averages after adjusting for stand. The F value, 500/956 = .523, is considerably below that required for significance at either the 5% or the 1% level. The averages after adjusting for stands are shown in the fifth column in table 11.

This experiment indicates that these particular treatments were no better than the check for seed production.

DISCUSSION AND CONCLUSIONS

The operators of seed farms, such as that of the Ferry-Morse Seed Co., of Detroit, Michigan, know from every-day observations that the shattering, and the loss of seeds by certain plants is a common occurrence. They know too that this undesired phenomenon is especially pronounced with their crops of spinach, scarlet sage, and borage. With respect to the radish plant. the loss is not so great, but still is significant. In this case, when the crop is allowed to dry in the field, many of the pods, as wholes, may absciss, drop off, and be lost, before the crop is finally gathered in and conserved. Could this situation be improved by the use of a growth substance, such as naphthalene acetic acid, applied at some time, or times, prior to seed maturation and harvest?

The experimental results, which have been presented, give a negative answer to that question. In no case was a consistently positive and recommendable result obtained. This outcome, however, should not be taken as the final word in the matter at hand.

Only one growth substance was tried--naphthalene acetic acid. Among the many others available, and that could be used experimentally, some one, or more, of them might prove to be effective on the plants treated in this experiment.

Again, only three concentrations of the growth substance were used in the spraying. The highest of these three was 0.01 per cent. The result from this highest one was not consistently higher, or lower, than that from any one of the concentrations below it, including the check. Therefore, although the highest, it even may have been too low. The concentrations which were used have been shown by other investigations to be effective, it is true, but those operators worked with different plants and under different conditions, mostly with respect to the premature dropping of fleshy fruits from fruit trees.

Furthermore, it appears from the results obtained by workers on the problem of premature fruit drop that the growth substance, when sprayed on, must hit, and stay on, the peduncle of the flower (stem of the fruit) in order to be effective. And besides, it seems that the closer this contact and absorption of the material is to the peduncle's point of attachment to the stem the better the consequence. The problem of accomplishing this necessity with tree fruits, suspended as they are on relatively long and open peduncles, or pedicels, is much simpler than that of reaching the points of attachment of the fruits (seeds, so to speak) in herbaceous plants, such as spinach, scarlet sage, borage, and even radish. The author frankly acknowledges a failure to have fully overcome this difficulty.

The growers of these herbaceous plants for seed production are truly aware of the tendency for premature seed shattering. They take this to be a form of outright loss. That is, they look upon it as being the loss of good seeds. Apparently, however, it is a loss not of good seeds (mature and vital) but of what might become good seeds should they remain longer, or to the end, on the plants. In this work, the author made collections, at intervals of six days, of the shattered seeds of scarlet sage from off the ground. Examination of these seeds showed them, almost without exception, to be either embryoless or possessed of aborted and imperfect embryos.

In view of this finding, assuming its truth for the other crops used in the experiment, the idea of recovering and conserving shattered seeds by spreading and fastening down paper or cloth around the plants, to catch the seeds as they drop, would seem to be poorly conceived. The "catch" would be mostly valueless. The proper expedient appears to be added effort to find a means, possibly a growth substance and its proper application, that will tend to promote good embryonic development and that will cause the fruit, with its seed or seeds, to remain attached to the plant until the point of full and normal maturity is reached, and the harvest made.

The results obtained in the work do not justify any recommendation that is practical in its nature. They do, however, permit suggestions as to further experimentation:

(a) Naphthalene acetic acid should be tried at higher concentrations, in alcoholic, as well as ammoniacal, solution.

(b) An operative way for causing the growth substance to reach more certainly and thoroughly the points of attachment of the fruits (seeds, so to speak) should be devised and used. This would have to be tried with an atomizer on a small scale experiment.

(c) Growth substances other than naphthalene acetic acid may well be selected and tried.

(d) The treatments should be started earlier in the life of plants, perhaps at or even before the pollination and fertilization of the ovules and continued at short intervals from this time onward to the end of seed development.

(e) And finally, in any event, further experimentation should involve the use of a larger number of plots per treatment. that the ultimate tests for the significance of differences may be more substantial and more satisfactory.

SUMMARY

A test was made with naphthalene acetic acid spray on four seed crops for the reduction of seed shattering.

The crops used were: radish (Raphanus sativus), spinach (Spinacea oleracea), scarlet sage (Salvia splendens), and borage (Borago officinalis).

Three concentrations of naphthalene acetic acid were applied: 0.01%, 0.0005%, and 0.0001%.

A replicated plot design was employed and the seed yield data was subjected to analysis of variance. No naphthalene acetic acid treatment gave a significant increase in yield over the treatment with a water spray which was used as the check.

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