1959

Leafy Spurge Studies of Vegetative Weed Activity and Seed Development

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LEAFY SPURGE STUDIES OF VEGETATIVE WEED ACTIVITY AND SEED DEVELOPMENT

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of
Agronomy, South Dakota State
College of Agriculture
and Mechanic Arts

June, 1959

LEAFY SPURGE STUDIES

OF VEGETATIVE WEED ACTIVITY

AND SEED DEVELOPMENT

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

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ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. Lyle A. Derscheid for his assistance and guidance during these studies and the writing of this manuscript, to Dr. David Holden and Mr. Ray C. Kinch for their helpful suggestions and laboratory facilities and to the writer's wife for typing the initial copies.

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INTRODUCTION

Leafy spurge (Euphorbia esula L.) has been a problem for many years in the northern Great Plains and the Prairie Provinces of Canada. It is a deep-rooted perennial plant that reproduces from underground parts and seeds. It is difficult to eliminate. Excellent control of top growth is obtained with 2,4-D, but there is always regrowth. This regrowth arises from buds on roots. If the top growth is intact, these buds are quiescent. However, when top growth is removed by mowing or chemicals, buds become active. One or two of the buds will progress faster than the others and once they reach a certain length, or when a new leafy shoot is produced, the growth of the other buds stops until something happens to the new shoot. It appears that root bud activity is regulated by apical dominance.

Leafy spurge seeds offer a continuous source of infestation. They aid in the enlargement of established infestations and, when transported to other areas, start new patches. Seeds of various colors have been observed, but it is not certain if all serve as a source of infestation.

The purpose of this study was to obtain preliminary data about the vegetative underground buds and about seed development. The study was divided into three parts (1) experiments to learn about the effects of environment on the dormancy of root buds, (2) experiments to learn about the effects of auxin and antiauxin on vegetative buds and (3) experiments to learn about the development of seeds.

REVIEW OF LITERATURE

The review of literature is divided into two parts. Part one consists of vegetative buds and part two deals with seed maturation.

Vegetative Buds

Leafy spurge has vegetative buds on above-ground as well as on underground parts, but only those buds underground aid in vegetative propagation. Coupland and Alex (3) found that the majority of the buds were located just below the soil surface and the number of buds decreased with increasing depth. There may be a dozen or more buds on the first 6 inches of the root below the soil surface. The number of visible buds varies during the year. Hanson and Shafer (21) stated that "new buds are initiated following the development of new growth in the spring".

Terminology varies and is uncertain when the buds on the roots or underground parts of leafy spurge are concerned. Hanson and Rudd (11) reported pinkish buds on underground stems above and below the zone of transition. Coupland and Alex (3) used the term "vegetative buds" in their work on the underground parts of leafy spurge. Hanson and Shafer (21) referred to the term "buds" in their studies on leafy spurge. Terms like "shoot buds", "adventious buds" and "root buds" were used by Bakke (1).

Effects of Environment on Root Buds

Leafy spurge transplanted in the greenhouse during the fall produced plants that showed a lack of vigor which may be an expression of dormancy or partial dormancy (20). A rest period is normal for buds

of tubers, bulbs and woody plants found in the temperate zone. Dormancy has been reported in quack grass (Agropyron repens L.) (12), leafy spurge (Euphorbia esula L.) and ironweed (Vernonia baldwini Torr.) (20, 21, 22).

Dormancy is caused by a shortening of the day's length. Temperature is usually instrumental in breaking this dormancy. In potatoes the dormancy period can be shortened by storage at 35°C. Low temperatures will not shorten the duration of dormancy (19). In gladiolus the dormancy period is shortened by low temperature storage. Trees of the temperate zone go into dormancy during late summer or early fall and dormancy is broken by cold weather during fall, winter and spring. The temperature range found to be effective in breaking dormancy of buds on various kinds of trees and shrubs was between 0° and 10°C. High temperatures and below freezing temperatures were not effective (4). Hansen et al. found that dormancy in leafy spurge and ironweed was broken naturally by low temperatures (22). Denny and Stanton (7) determined that the seat of dormancy is located in the individual buds when they treated individual buds of lilacs with chemical vapors of ethylene chlorhydrin.

Coville (4) found that the duration of the dormant period of woody shrubs may be shortened by exposure to low temperatures for certain periods. Results of Denny and Stanton (8), when working with chemical treatment of dormant buds, indicated that the untreated shrubs retained their dormancy for a long period, and when they did start to grow, growth was irregular. The treated shrubs opened simultaneously and were uniform in development.

Effects of Auxin and Antiauxin

Working with Vicia faba and Phaseolus multiflorus, Snow (26, 27) showed that the inhibition of the lateral buds was caused by the terminal bud. This inhibition is called apical dominance. Thimann and Skoog (29) found that inhibition caused by the terminal bud is due to high concentration of auxin. If the terminal bud is removed, the lateral buds begin to grow and at the same time produce auxin. These buds then act like terminal buds and inhibit the growth of other lateral buds. The growth of the laterals can be prevented when the terminal bud is removed by placing auxin on the decapitated stem.

Went (31) demonstrated in the Oenothera macrosiphon that the bud inhibition by auxin is the same in stems and roots and that the polarity of auxin in the root is continuous with that of the shoot.

Auxins play an important role in the general control of organ differentiation and are a factor in determining whether a cluster of cells will be differentiated into callus, roots, vegetative buds or flower buds (17).

Antiauxins have a wide range in antagonizing the effects of auxin. Leopold (17) suggests that antiauxins may find important uses in the modification of any of the many auxin functions in plants such as abscission, flowering, apical dominance, prolonging dormancy and modification of herbicide effects.

Seed Maturation

Bakke (1) describes the seed of leafy spurge as roundish oval, somewhat kidney-shaped, smooth, yellow, brown or gray in color and

usually between two and two and one-half millimeters in length and one and one-half millimeters in width. A conspicuous caruncle is present at the narrow end.

The seeds develop in a three-chambered capsule. The chambers are called locules. As the capsules approach maturity, they dry out until enough pressure is placed on the capsule so that it breaks open, sometimes shooting the seeds to a distance of 15 feet (1).

Leafy spurge seeds have various colors. Besides Bakke (1), Hanson and Rudd (11) noticed considerable variation in the color of leafy spurge seed. They noticed that the most typical color is light gray tinged with purple and the less mature seeds are purplish-brown with very little of the gray tinge. They also noted that a large number of seeds are light gray mottled with purplish-brown.

Bakke (1) used 10 lots of 25 seeds per lot and found that there was a difference in the weight of brown and gray seeds. The average weight of the brown seeds was 78.7 milligrams while the gray seeds had an average weight of 63.5 milligrams. He said that the brown seeds were fully mature and the gray seeds were immature. The germination percentage was 76 for brown seeds and 52 for gray seeds.

Selleck and Coupland (23) obtained results in Canada that agree closely with those of Bakke (1). They used 1000 gray and brown seeds. The brown seeds were larger and heavier. They weighed 377 milligrams and the gray seeds weighed 325 milligrams per 100 seeds. A few more of the gray seeds germinated, but the difference was not significant.

VEGETATIVE BUDS

The main purpose in the study of vegetative buds was to learn the effects of environment or auxin and antiauxin on bud activity. However, several miscellaneous observations appeared to be worthy of comment.

Miscellaneous Observations

While vegetative buds on above-ground parts originate from stem tissue, it appeared that buds on underground parts may arise from both stem and root tissue. For example, the vegetative or reproductive bud elongates. This tissue would be stem tissue. Reproductive or vegetative buds may arise from this shoot and will originate from beneath leaf scales. Therefore, they could be called axillary buds. If this shoot were allowed to grow a year, the leaf scales would not be visible; and if there were buds coming out at irregular locations on the stem, it might be assumed that this was root since it was underground. At the most, it may be considered a stem-root transition zone. There are buds found on small roots that are similar to the buds found on the underground stems. They are capable of producing shoots the same as the other buds. These could be called adventitious buds because they do not arise in the axils of leaves. However, adventitious buds are generally formed by stimulation from an injury, and these are formed without stimulation from injury. The different buds found on leafy spurge are diagrammed on Figure 1. Figure 2 shows transplants of leafy spurge that have grown in greenhouse pots for approximately 60 days.

Although some buds on underground parts may actually arise from stem tissue, the term "root bud" is used in this paper for the purpose

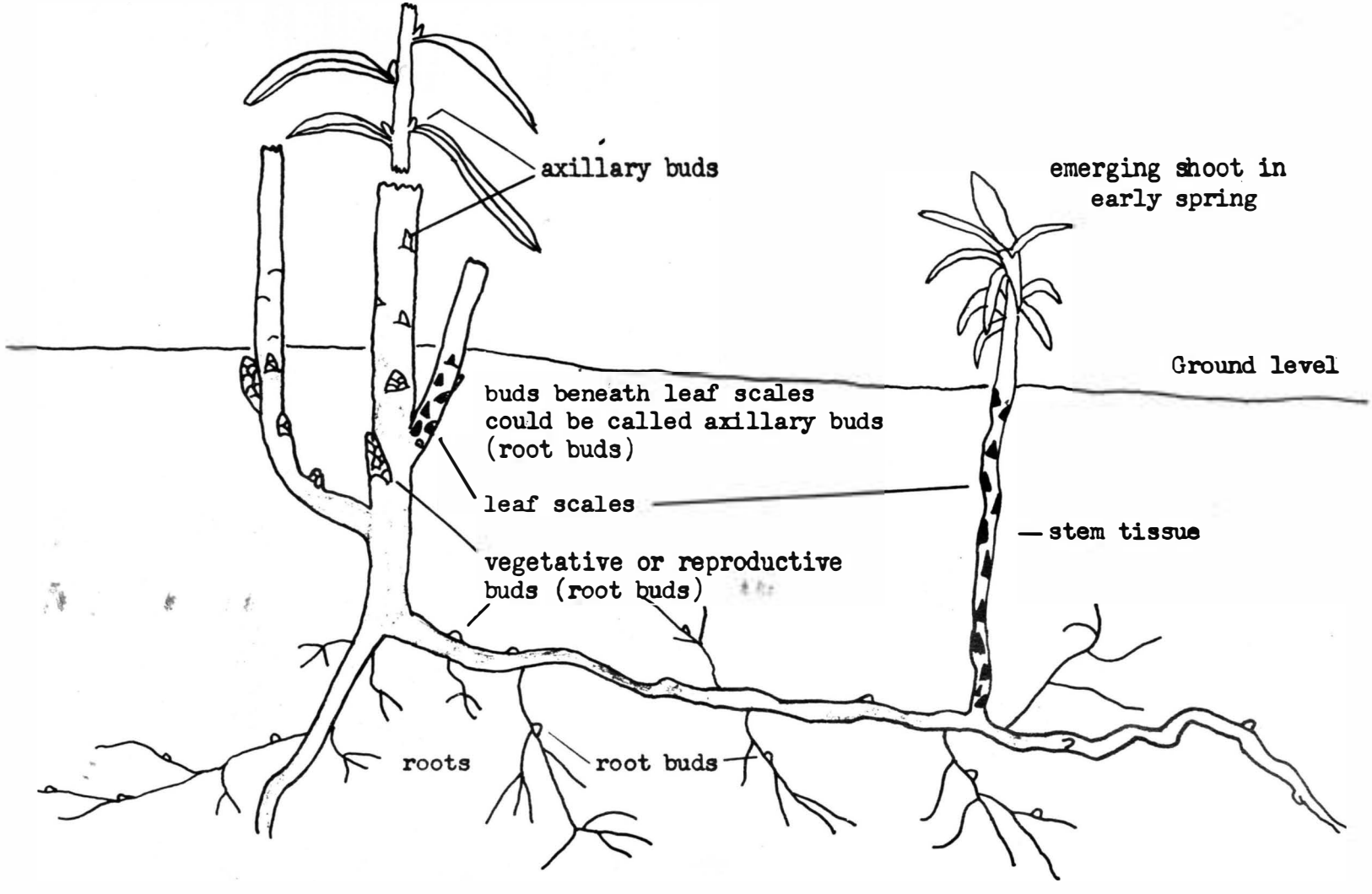

Figure 1. Diagrammatic Representation of Leafy Spurge Buds.

of brevity.

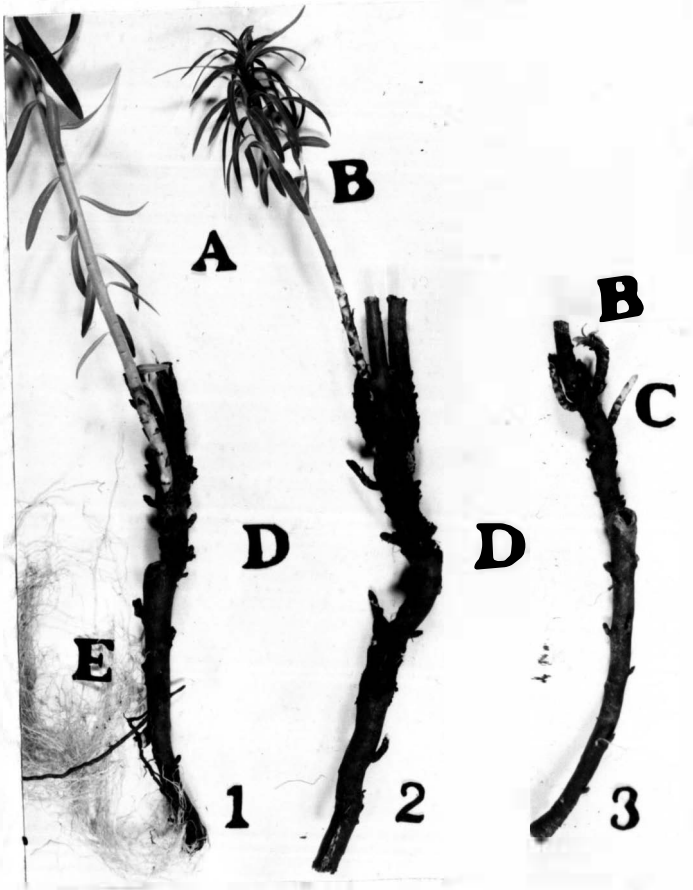

Figure 2. Leafy Spurge Transplants that Have Been Grown in Greenhouse Pots for 2 months Showing: (A) Normal Elongation of Internodes, (B) Restricted Elongation of Internodes, (C) an Active Root Bud, (D) Inactive Roots and (E) Rootlets.

In the fall of 1956 and 1957, six to eight-inch verticle roots of leafy spurge were exhumed. They were cut up into one and two-inch sections. Intact roots were used as controls. The root sections and intact roots were layed in chronological order in greenhouse flats and covered with soil. Shoots emerged from each section and only one or two shoots grew from intact roots. These results indicate that some unknown factor controlled the number of shoots that arose from root

buds. Upon cutting the roots in sections, this unknown factor did not limit root buds from producing shoots. This phenomenon is believed to be apical dominance and the unknown factor is an auxin.

Root buds initiated in the spring are difficult to notice; however, they become more noticable as fall approaches. In August the buds are easy to see. By late August and early September the buds have started to increase in length. In October buds are very prominent -- they remain in a similar condition over winter. In the spring one or two or perhaps more of these buds will grow. The remaining larger buds appear to wither and die, but the others become less prominent until they are a small protrusion above the epidermis of the root.

Effects of Environment

In one experiment leafy spurge roots were exhumed at weekly intervals and transplanted in greenhouse pots to secure an indication of the effect of natural environment on root bud activity. In two experiments transplants were exposed to different temperatures and photoperiods to learn the effect of these factors on root bud development.

Experimental Procedure and Results

In a preliminary study leafy spurge roots were transplanted from the field to the greenhouse on October 4, 1956. Shoots from the buds on the roots emerged in approximately 10 days. On October 22, 1956, other leafy spurge roots were exhumed and transplanted. These failed to grow new shoots within 10 days. Emergence of new shoots extended over a long period of time with no pattern of emergence. After 5 months there were still some dormant buds. They appeared to be alive but for some reason

failed to grow. Those buds near the soil surface were green in color, while those below the soil surface were pink.

This irregular growth pattern produced shoots of various types, as shown in Figure 3. Some were normal; some failed to elongate and had

Figure 3. Irregular Growth of Shoots from Leafy Spurge 110 Days After Roots Were Dug and Transplanted October 22, 1956.

short internodes and thick leaves; some elongated near the base and failed to elongate near the apex. Others elongated near the apex but failed to lengthen near the base. There seemed to be no set pattern of growth. It was suspected that these buds failed to grow normally because they were in a state of dormancy or quiescency.

Since those dug on October 4 were active and those dug on October 22 appeared to be dormant, it was suspected that differences in environment may have had some effect. Therefore, a more comprehensive experi-

ment was conducted in 1957 in which leafy spurge roots were dug and transplanted in the greenhouse periodically throughout the late summer, fall and winter. Roots were exhumed each week from August 29 until December 27, 1957, and again on January 11, 1958. Attempts were made to take roots of uniform age. A five-inch section measuring from the soil surface down was utilized from each root. Five root sections were transplanted in six-inch clay pots and placed under an 18-hour photoperiod. The buds were counted and measured before the sections were transplanted.

For each date of transplanting, the date of emergence was observed and the shoot growth was measured at weekly intervals for a period of 11 weeks after emergence. The flowering date was also recorded.

The air temperatures during the period that the plants were being transplanted and the mean number of days required for emergence are given in TABLES I and II, respectively. Both sets of data are plotted together in Figure 4.

The length of time for the emergence of leafy spurge shoots was approximately 10 days for the first five dates. It increased gradually for two dates and increased sharply for the October 19 planting. A week later the time then tended to decrease for the next five dates until late November and December when the average time required fluctuated between 4 and 9 days.

It is interesting to note that a killing frost occurred each year shortly before roots, that required the maximum number of days for emergence of new shoots, were transplanted. In 1956 the temperature dropped to 22°F. on October 9. Buds on the roots that were transplanted October 22 were dormant; whereas, buds from the same location 18 days earlier

TABLE I. MAXIMUM AND MINIMUM AIR TEMPERATURES BETWEEN AUGUST 1, 1957, AND JANUARY 11, 1958.

	August		September		October		November		December		January	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1.	91	68	90	67	79	49	61	45	42	26	9	0
2.	98	70	83	58	80	47	50	37	45	16	26	-5
3.	90	61	73	59	78	48	37	30	24	16	20	3
4.	75	55	66	53	69	47	32	30	29	21	23	8
5.	74	47	70	50	77	49	34	31	41	25	30	11
6.	79	60	68	44	74	51	38	26	40	21	48	18
7.	88	68	71	46	62	53	48	31	27	17	18	-5
8.	93	70	75	52	61	43	38	20	25	10	20	10
9.	83	65	80	49	48	40	24	10	34	25	55	20
10.	82	55	68	47	44	33	38	21	54	13	54	18
11.	86	63	73	51	47	41	50	32	13	-2	44	26
12.	88	65	78	52	49	45	52	36	19	9		
13.	91	70	68	38	54	47	51	38	47	30		
14.	82	55	70	41	69	51	46	39	48	18		
15.	91	59	68	45	59	55	43	38	45	25		
16.	82	57	60	36	65	47	43	30	47	34		
17.	80	61	65	55	56	29	31	25	42	31		
18.	78	53	82	57	58	26	26	22	34	32		
19.	76	50	63	40	59	29	23	19	34	25		
20.	79	60	54	32	62	31	37	23	47	18		
21.	76	60	62	41	49	43	28	20	46	23		
22.	80	61	65	40	50	47	24	12	44	33		
23.	73	59	66	36	51	45	37	33	44	27		
24.	71	49	66	44	45	27	50	12	40	22		
25.	74	57	76	40	32	17	32	24	40	24		
26.	82	50	68	44	24	21	44	25	44	12		
27.	64	52	62	42	38	21	46	32	36	28		
28.	59	55	64	45	49	27	36	19	35	13		
29.	62	57	72	48	52	25	46	15	24	0		
30.	72	62	81	47	45	34	17	3	9	3		
31.	80	65			55	37			21	1		
Mean	80.0	59.3	70.2	46.6	58.0	38.9	38.7	25.9	36.2	19.2	31.5	9.4

TABLE II. NUMBER OF DAYS FOR EMERGENCE OF SHOOTS FROM ROOTS EXHUMED BETWEEN AUGUST 29, 1957, AND JANUARY 11, 1958.

	Date exhumed									
Plant	8/29	9/5	9/12	9/19	9/26	10/3	10/11	10/19	10/24	11/1
1	10	8	8	9	11	11	15	33	18	6
2	12	8	8	8	10	14	18	40	20	17
3	12	13	12	5	8	25	11	33	34	12
4	10	10	*	11	10	11	14	50	34	14
5	12	13	11	13	13	14	23	26	6	41
Mean	11.2	10.4	9.8	9.2	10.4	15.0	16.2	36.4	22.4	18.0

	Date exhumed								
Plant	11/8	11/15	11/22	11/30	12/6	12/13	12/20	12/27	1/11
1	24	15	20	7	10	6	4	6	5
2	25	15	5	5	12	6	4	17	3
3	32	22	8	5	4	3	6	6	5
4	44	23	*	5	7	5	2	7	3
5	9	27	7	5	4	6	4	8	5
Mean	20.8	20.4	10.0	5.4	7.4	5.2	4.0	8.8	4.2

* Roots died before emergence.

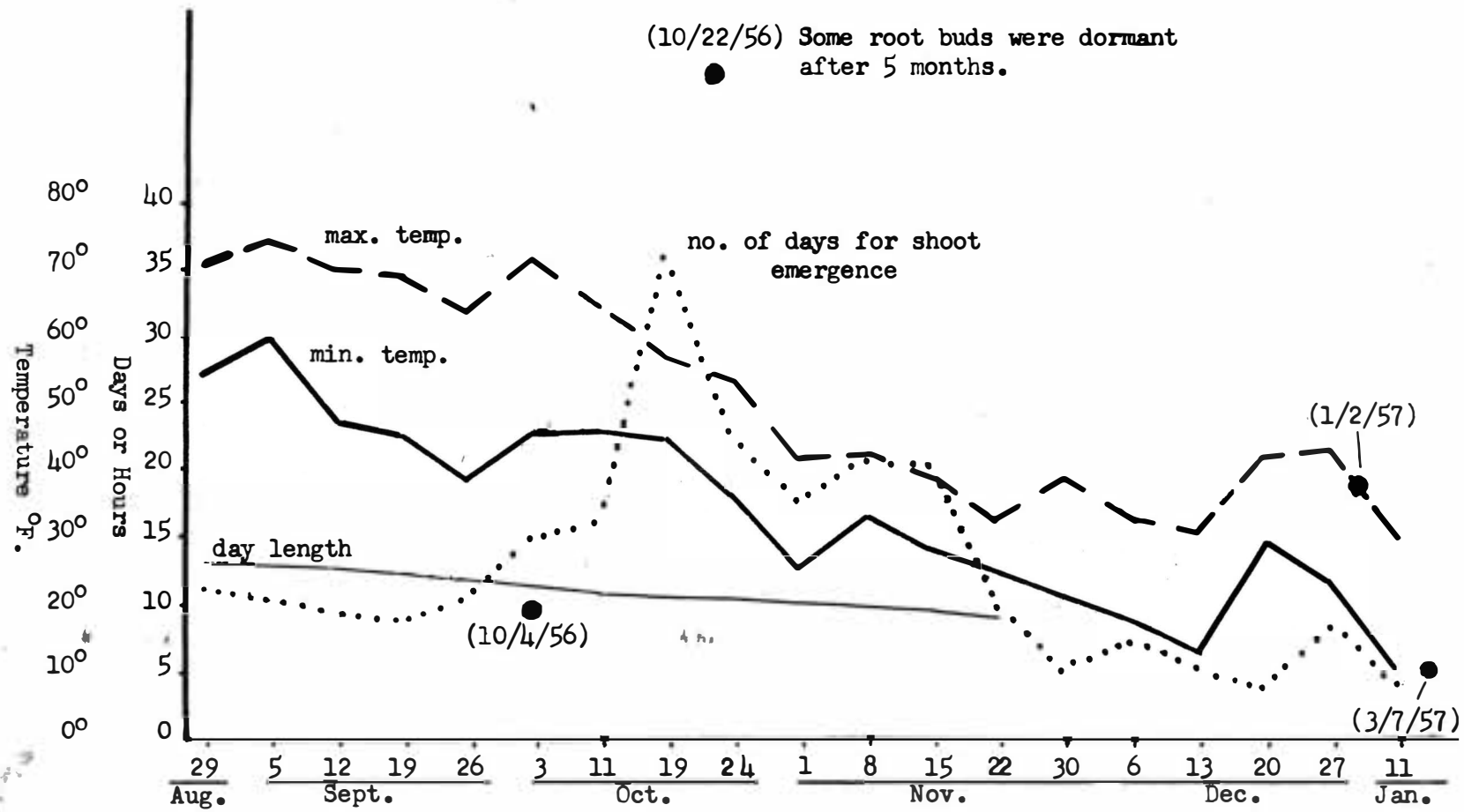

Figure 4. Weekly Average Maximum and Minimum Temperatures and Day Length Between August 29, 1957 and January 11, 1958, Mean Number of Days for Emergence of Shoots from Transplanted Roots Exhumed at Weekly Intervals During Same Period and Similar Data for Roots Exhumed at Four Dates During 1956-57.

were not dormant. In 1957 the temperature dropped to 29°F. on October 17 and to 26°F. a day later. The buds from roots dug October 19 were dormant; whereas, the buds on roots taken from the same location 9 days earlier were not.

The average number and length of root buds found on the five roots for each date are located in TABLE III. These data indicate that the root buds continued to grow in length until at least late October.

Eight-week old leafy spurge shoots grown from roots that were dug and transplanted on October 10, 19, 24 and November 22 are shown in Figures 5, 6, 7 and 8. The average plant height was 17.2, 5.2, 16.5 and 20.1 mm., respectively, for the four dates. The three flowering plants from the November 22 planting flowered by the sixth week. The same was true for most of the shoots from roots dug and transplanted after that date.

The time between emergence and flowering of shoots from transplanted roots decreased from 115 days for the September 5 sampling date to 31 for the January 11 date (TABLE IV).

In a second series of experiments, leafy spurge plants were grown under controlled conditions in the greenhouse and laboratory. Two experiments were conducted in which plants were grown under different photoperiod and temperature conditions, in an attempt to learn if these factors affected the development of root buds. One experiment was conducted between July 22, 1957, and September 11, 1957. Twenty nonflowering and 20 flowering leafy spurge plants were each exposed to four sets of conditions. The potted leafy spurge plants were placed in cold chambers and artificial light was used in the photoperiods. The light bulbs were 300 watt heat bulbs.

TABLE III. AVERAGE NUMBER AND LENGTH OF BUDS ON FIVE LEAFY SPURGE ROOTS ON SAMPLING DATE WHEN EXHUMED BETWEEN SEPTEMBER 19, 1957, AND JANUARY 11, 1958.

Date exhumed	Average no. of buds	No. of buds over 1 mm.	No. of buds 5mm or more	No. of buds 10mm or more	No. of buds 15mm or more	No. of buds 20mm or more	No. of buds 25mm or more
9/19	9.2	5.0	1.2	.4	.4	.0	.0
9/26	13.4	6.0	1.8	.4	.4	.0	.0
10/3	10.8	4.6	1.8	.6	.0	.0	.0
10/11	11.8	6.2	1.4	.4	.0	.0	.0
10/19	34.8	4.0	1.4	.8	.2	.0	.0
10/24	17.2	5.0	3.4	2.4	1.4	.8	.0
11/1	26.0	6.4	3.2	2.6	1.8	1.0	.2
11/8	19.6	8.8	5.6	4.8	3.6	2.2	.8
11/15	15.8	6.2	3.2	2.0	1.8	1.2	.4
11/22	21.4	7.6	3.8	1.6	1.8	1.4	.2
11/30	31.2	6.8	3.0	2.0	.8	.4	.2
12/6	13.8	7.0	5.0	2.6	1.0	.6	.2
12/13	14.6	7.0	3.8	2.4	1.6	.8	.6
12/20	12.8	3.4	1.1	1.0	.6	.4	.2
12/27	22.2	3.6	1.6	1.4	.6	.2	.2
1/11	17.2	6.0	2.8	1.4	1.2	1.0	.4

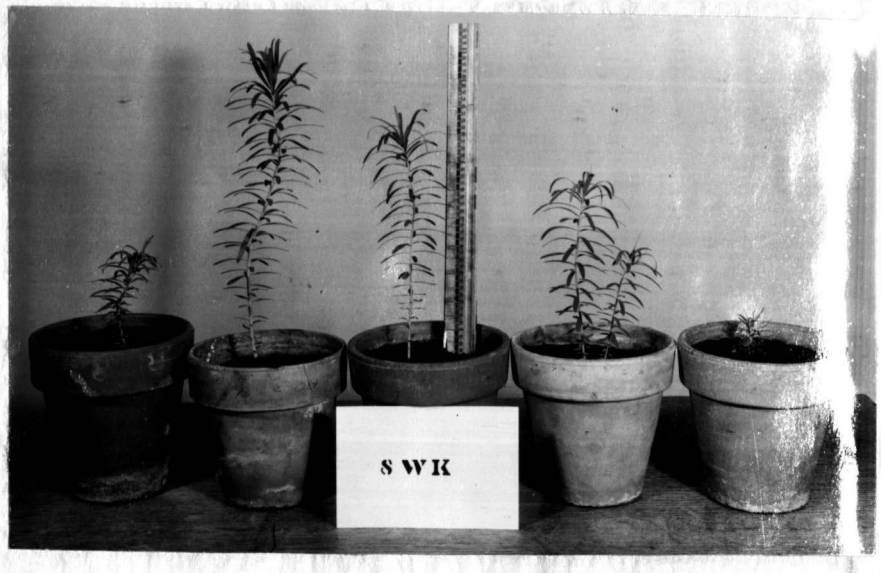

Figure 5. Regrowth of Leafy Spurge Shoots from Roots 8 Weeks After Being Dug and Transplanted October 10, 1957. Average Time Required for Emergence Was 16.2 Days and the Average Height Was 17.2 mm.

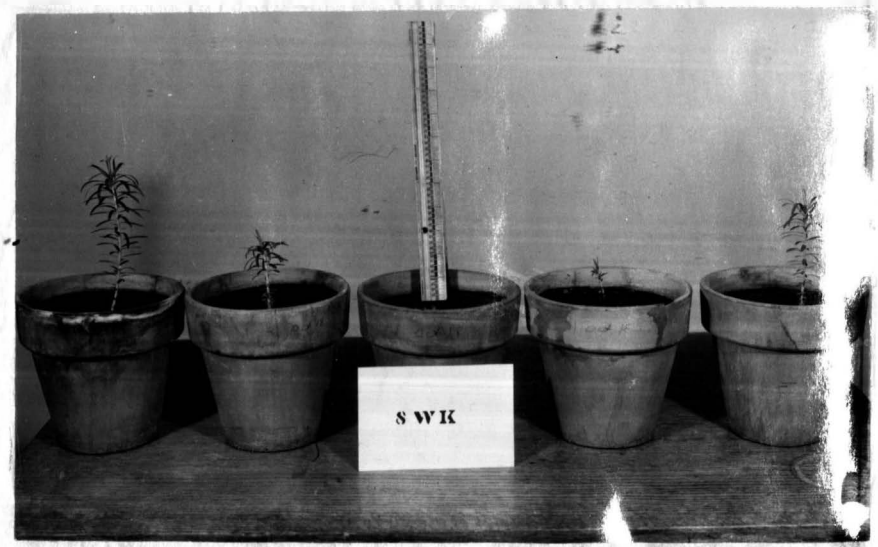

Figure 6. Regrowth of Leafy Spurge Shoots from Roots 8 Weeks After Being Dug and Transplanted October 19, 1957. Average Time Required for Emergence Was 36.4 Days and the Average Height Was 5.2 mm.

Figure 7. Regrowth of Leafy Spurge Shoots from Roots 8 Weeks After Being Dug and Transplanted October 24, 1957. Average Time Required for Emergence Was 22.4 Days and the Average Height Was 16.5 mm.

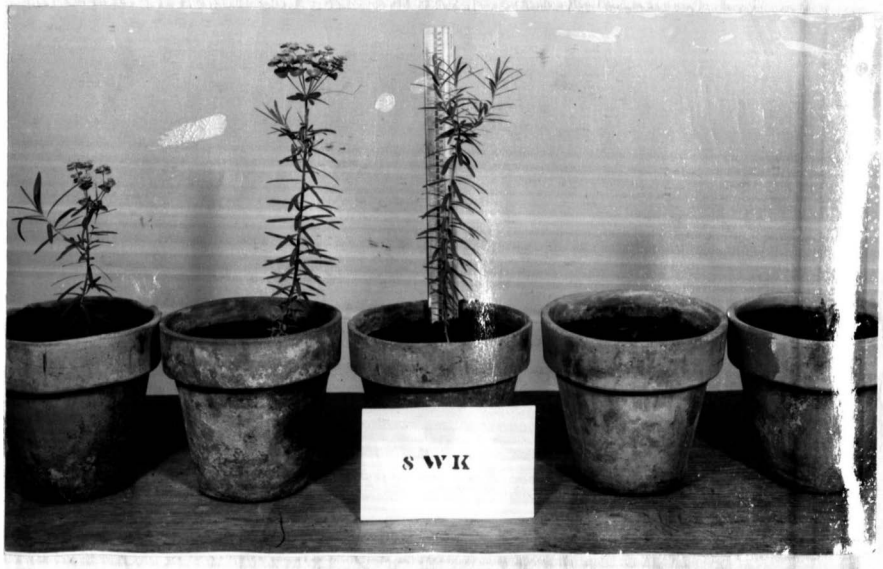

Figure 8. Regrowth of Leafy Spurge Shoots from Roots 8 Weeks After Being Dug and Transplanted November 22, 1957. Average Time Required for Emergence Was 10 Days and the Average Height Was 20.1 mm. No Shoot Emerged from the Fourth Pot from the Left Because the Root Was Dead.

TABLE IV. NUMBER OF DAYS BETWEEN EMERGENCE AND FLOWERING OF SHOOTS FROM ROOTS EXHUMED BETWEEN AUGUST 29, 1957, AND JANUARY 11, 1958.

	Date exhumed									
Plant	8/29	9/5	9/12	9/19	9/26	10/3	10/11	10/19	10/24	11/1
1	*	110	*	120	*	*	*	*	*	*
2	*	114	*	100	*	*	90	88	*	77
3	*	119	*	*	*	80	102	*	*	80
4	*	116	**	108	*	115	*	112	79	48
5	*	119	*	*	*	97	*	*	107	*
Mean		115.4		109.3		97.3	96.0	100.0	93.0	68.3

	Date exhumed								
Plant	11/8	11/15	11/22	11/30	12/6	12/13	12/20	12/27	1/11
1	*	*	18	23	*	27	21	39	*
2	*	*	30	**	**	27	35	**	36
3	*	*	26	25	38	30	*	*	28
4	*	*	**	25	**	28	*	*	30
5	*	*	*	25	31	36	35	*	30
Mean			24.7	24.5	34.5	29.6	30.3	39.0	31.0

* Flowering did not occur.
** Plants died soon after emergence

The four sets of conditions were:

1. Set I. Five nonflowering and five flowering plants were placed under a 15-hour day length at 67°F. The heat bulb raised the temperature to 78°F. at the top of the pot and to 82°F. seven inches higher.
2. Set II. The same conditions as Set I were used except the plants were under a 9-hour photoperiod.
3. Set III. Five nonflowering and five flowering plants were placed under a 15-hour photoperiod at 34°F. The heat lamp raised the temperature to 52°F. at the top of the pot and to 82°F. seven inches higher.
4. Set IV. The same conditions as Set III were used except that a 9-hour photoperiod was used.

After 51 days under these conditions, the plants were removed and the soil was washed from the roots. The number of root buds of one millimeter or more and of 10 millimeters or more in length were counted. The top growth was removed and the roots were repotted and grown under 18 hours of light.

The root bud data were transformed by using $\sqrt{x + \frac{1}{2}}$ because of some zeros. Analyses of variance were conducted on the root bud and emergence of new shoot data. Orthogonal comparisons were made to test for significant differences among treatments.

The number and length of buds from roots of nonflowering and flowering plants appeared to be affected by temperature and length of day. The total number of buds is shown in TABLE V and the analyses of variance are given in TABLE VI. The number of buds 10 or more millimeters long is given in TABLE VII and the analyses of variance are presented in TABLE VIII.

TABLE V. TOTAL NUMBER OF ROOT BUDS ON NONFLOWERING AND FLOWERING LEAFY SPURGE AFTER EXPOSURE TO CONTROLLED TEMPERATURE AND PHOTOPERIOD CONDITIONS FOR 51 DAYS.

Total number of buds									
	Nonflowering					Flowering			
	67°F.		34°F.			67°F.		34°F.	
Plant	9-hr	15-hr	9-hr	15-hr	Plant	9-hr	15-hr	9-hr	15-hr
1.	11	13	17	4	1.	9	3	10	6
2.	8	2	9	2	2.	4	12	18	4
3.	4	4	10	2	3.	13	7	40	8
4.	8	7	8	3	4.	16	6	49	6
5.	7	8	7	3	5.	8	6	16	5
Mean	7.4	6.8	10.2	2.8		10.0	6.8	26.6	5.8
Mean photo	8.8	4.8				18.3	6.3		
Mean temp	7.1		6.5			8.4		16.2	

TABLE VI. ANALYSES OF VARIANCE OF THE TOTAL NUMBER OF ROOT BUDS ON NONFLOWERING AND FLOWERING LEAFY SPURGE AFTER EXPOSURE TO CONTROLLED TEMPERATURE AND PHOTOPERIOD CONDITIONS FOR 51 DAYS.

	Nonflowering		Flowering	
Source of variation	d f	M. S.	d f	M. S.
Between	3	1.80**	3	6.60**
67°F. vs 34°F.	1	.18	1	3.50
9-hrs vs 15-hrs	1	3.36**	1	11.42**
Interaction	1	1.85*	1	4.91*
Within	16	.30	16	.90
Total	19		19	

* Significant at 5 per cent level.
** Significant at 1 per cent level.

More buds were initiated under the 9-hour photoperiod than under the 15-hour photoperiod for both the nonflowering and the flowering plants. There was an interaction between day length and temperature for both the flowering and the nonflowering plants. More buds were initiated under cool temperature and short day length than warm temperature and

short day length, but more buds were initiated under warm temperature and long photoperiod than under conditions of cool temperature and 15-hour photoperiod.

TABLE VII. NUMBER OF ROOT BUDS 10 MILLIMETERS OR MORE IN LENGTH ON NONFLOWERING AND FLOWERING LEAFY SPURGE AFTER EXPOSURE TO CONTROLLED TEMPERATURE AND PHOTOPERIOD CONDITIONS FOR 51 DAYS.

	Number of buds 10 mm. or more in length								
	Nonflowering					Flowering			
	67°F.		34°F.			67°F.		34°F.	
Plant	9-hr	15-hr	9-hr	15-hr	Plant	9-hr	15-hr	9-hr	15-hr
1.	1	2	0	0	1.	1	2	0	0
2.	0	2	0	0	2.	1	0	0	1
3.	2	1	1	0	3.	0	5	2	0
4.	1	2	0	0	4.	2	2	0	0
5.	0	1	0	0	5.	2	5	0	0
Mean	0.8	1.6	0.2	0.0		1.2	2.8	0.4	0.2
Mean photo	0.5	0.8				0.8	1.5		
Mean temp	1.2		0.1			2.0		0.3	

TABLE VIII. ANALYSES OF VARIANCE OF THE NUMBER OF ROOT BUDS 10 MILLIMETERS OR MORE IN LENGTH ON NONFLOWERING AND FLOWERING LEAFY SPURGE AFTER EXPOSURE TO CONTROLLED TEMPERATURE AND PHOTOPERIOD CONDITIONS FOR 51 DAYS.

	Nonflowering		Flowering	
Source of variation	d f	M. S.	d f	M. S.
Between	3	.53**	3	.85*
67°F. vs 34°F.	1	1.26**	1	2.04**
9-hrs vs 15-hrs	1	.08	1	.18
Interaction	1	.25	1	.34
Within	16	.06	16	.20
Total	19		19	

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Under 67°F. nyctotemperature more buds grew to 10 millimeters in

length than under the 34°F. nyctotemperature.

In TABLE IX the data are presented for the emergence of new shoots from roots of the nonflowering and flowering leafy spurge plants that had been exposed to the controlled temperatures of photoperiod conditions for 51 days prior to transplanting. The analyses of variance are presented in TABLE X.

TABLE IX. THE NUMBER OF DAYS REQUIRED FOR EMERGENCE OF SHOOTS FROM TRANSPLANTED ROOTS OF NONFLOWERING AND FLOWERING LEAFY SPURGE PLANTS THAT HAD BEEN EXPOSED TO THE TEMPERATURE AND PHOTOPERIOD FOR 51 DAYS PRIOR TO TRANSPLANTING.

Nonflowering						Flowering				
	67°F.		34°F.				67°F.		34°F.	
Plant	9-hr	15-hr	9-hr	15-hr		Plant	9-hr	15-hr	9-hr	15-hr
1.	9	8	9	14		1.	11	9	9	2
2.	9	9	9	12		2.	7	9	10	11
3.	10	15	13	7		3.	6	8	9	5
4.	5	9	9	19		4.	4	12	12	17
5.	7	6	11	16		5.	6	9	9	9
Mean	8.0	9.4	10.2	13.6			6.8	7.8	9.8	8.8
Mean photo	9.1	11.5					8.3	8.3		
Mean temp	8.7		11.9				7.3		9.3	

TABLE X. ANALYSES OF VARIANCE OF THE NUMBER OF DAYS FOR EMERGENCE OF NEW SHOOTS FROM NONFLOWERING AND FLOWERING LEAFY SPURGE AFTER EXPOSURE TO CONTROLLED TEMPERATURE AND PHOTOPERIOD CONDITIONS FOR 51 DAYS.

	Nonflowering		Flowering	
Source of variation	d f	M. S.	d f	M. S.
Between	3	28.3	3	8.3
67°F. vs 34°F.	1	51.2*	1	20.0
9-hrs vs 15-hrs	1	28.8	1	0.0
Interaction	1	5.0	1	5.0
Within	16	9.7	16	10.8
Total	19		19	

* Significant at 5 per cent level.

Significantly less time was required for emergence of shoots from nonflowering leafy spurge that had been exposed to night temperatures of 67°F. than those that were exposed to 34°F. Although there was a similar trend, it was not established that temperature had an effect on the time required for emergence in the flowering group; likewise, photoperiod had no effect for either group. New shoots arose from the root of one of the flowering plants under cool, 9-hour photoperiod that had short internodes similar to those in Figure 3.

Five shoots from the flowering group had flowered within 50 days after they had been transplanted. At this time they were discarded. The shoots that flowered were: one from the 9-hour 67°F. nyctotemperature and two each from the 9- and 15-hour 34°F. nyctotemperature. The shoots from the nonflowering group did not flower.

The second experiment was conducted in the fall of 1957. Leafy spurge roots were dug and transplanted in pots during the last week of August. On September 13, when the plants were six to eight inches high, 10 plants were placed under each of the following temperature and photoperiod treatments.

1. 9-hour photoperiod and 72°F. in the greenhouse (9-hr ID).
2. 12-hour photoperiod and 72°F. in the greenhouse (12-hr ID).
3. 18-hour photoperiod and 72°F. in the greenhouse (18-hr ID).
4. 12-hour photoperiod outdoors (12-hr OD).
5. 18-hour photoperiod outdoors (18-hr OD).

On November 5, after 52 days under the above conditions, the plants were removed and the soil was washed from the plant roots. The number and length of root buds were determined. Five roots from each treatment

were replanted and placed under an 18-hour photoperiod. Dates of emergence were recorded and shoot heights were measured every 7 days beginning 1 week after the average emergence for the five plants. Date of flowering was also recorded.

The number of buds 10 or more millimeters in length was transformed by using $\sqrt{x + \frac{1}{2}}$. Analyses of variance were conducted on all data. Orthogonal comparisons were made to test for significant differences among treatments.

The total number of root buds is given in TABLE XI, and the analysis of variance is given in TABLE XII.

TABLE XI. TOTAL NUMBER OF ROOT BUDS ON LEAFY SPURGE AFTER EXPOSURE TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1.	26	32	37	17	41
2.	28	40	19	8	45
3.	19	14	9	50	22
4.	31	21	20	30	28
5.	32	29	16	27	18
6.	43	35	9	24	39
7.	6	46	30	35	41
8.	39	33	33	13	17
9.	33	24	18	40	52
10.	46	24	12	15	21
Mean	30.3	29.8	20.3	25.9	32.4
Mean photo	30.3	27.8	26.4		
Mean temp		26.8		29.2	

There was no significant difference in the total number of root buds found in the five different conditions.

The number of root buds more than one millimeter in length is presented in TABLE XIII with the analysis of variance given in TABLE XIV.

TABLE XII. ANALYSIS OF VARIANCE OF THE TOTAL NUMBER OF ROOT BUDS FOUND ON LEAFY SPURGE EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Source of variation	d f	M. S.
Between	4	228.15
9-hr ID vs all others	1	81.92
12-hr ID x 18-hr ID vs 12-hr OD x 18-hr OD	1	168.10
12-hr ID vs 18-hr ID	1	451.25
12-hr OD vs 18-hr OD	1	211.25
Within	45	131.76
Total	49	

There were significantly more root buds one millimeter or more in length under the 9-hour photoperiod in the greenhouse than under any other treatment. In comparing 12- and 18-hour photoperiods between the indoor and outdoor treatments, more buds were activated outdoors under cold temperatures than in the greenhouse under warm temperatures. Significantly more buds developed under the 12-hour than under the 18-

TABLE XIII. NUMBER OF ROOT BUDS MORE THAN ONE MILLIMETER IN LENGTH ON LEAFY SPURGE AFTER EXPOSURE TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1.	14	5	9	15	16
2.	9	15	6	8	26
3.	19	7	3	18	12
4.	23	7	5	12	15
5.	11	7	4	9	10
6.	29	7	4	18	8
7.	6	9	4	12	6
8.	12	15	7	6	7
9.	15	10	4	20	13
10.	16	19	3	11	11
Mean	15.4	10.1	4.9	12.9	12.4
Mean photo	15.4	11.5	8.6		
Mean temp		10.1		12.6	

TABLE XIV. ANALYSIS OF VARIANCE OF THE NUMBER OF ROOT BUDS MORE THAN ONE MILLIMETER IN LENGTH ON LEAFY SPURGE EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Source of variation	d f	M. S.
Between	4	157.13**
9-hr ID vs all others	1	226.85**
12-hr ID x 18-hr ID vs 12-hr OD x 18-hr OD	1	265.23**
12-hr ID vs 18-hr ID	1	135.20*
12-hr OD vs 18-hr OD	1	1.25
Within	45	25.46
Total	49	

* Significant at 5 per cent level.
** Significant at 1 per cent level.

hour day length in the greenhouse, but there was no difference outdoors.

The number of root buds 10 millimeters or more in length is given in TABLE XV, the number of shoots is presented in TABLE XVI, the number of 10-millimeter buds plus the shoots are shown in TABLE XVII and the analyses are found in TABLE XVIII.

TABLE XV. NUMBER OF ROOT BUDS 10 OR MORE MILLIMETERS IN LENGTH ON LEAFY SPURGE AFTER EXPOSURE TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1.	6	1	0	3	4
2.	3	2	1	5	4
3.	3	1	1	7	1
4.	0	2	1	3	6
5.	0	0	1	3	1
6.	4	0	0	3	3
7.	2	2	0	0	1
8.	2	1	1	1	4
9.	4	2	0	5	2
10.	3	3	1	4	5
Mean	2.7	1.4	0.6	3.4	3.1
Mean photo	2.7	2.4	1.8		
Mean temp		1.6		3.2	

TABLE XVI. NUMBER OF SHOOTS FROM LEAFY SPURGE ROOTS EXPOSED TO VARIOUS PHOTOPERIOD CONDITIONS INDOORS AND OUTDOORS FOR 52 DAYS.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1.	2	2	2	1	1
2.	3	1	3	1	1
3.	2	2	4	1	1
4.	3	2	2	1	1
5.	3	2	1	1	1
6.	1	1	1	1	1
7.	3	2	1	1	1
8.	2	2	3	1	1
9.	2	2	2	1	2
10.	1	1	1	1	1
Mean	2.2	1.9	2.0	1.0	1.1
Mean photo	2.2	1.4	1.6		
Mean temp		2.0		1.1	

TABLE XVII. NUMBER OF ROOT BUDS 10 OR MORE MILLIMETERS IN LENGTH PLUS THE NUMBER OF SHOOTS FROM LEAFY SPURGE ROOTS EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1.	8	3	2	4	5
2.	6	3	4	6	5
3.	5	3	5	8	2
4.	3	4	3	4	7
5.	3	2	2	4	2
6.	5	1	1	4	4
7.	5	4	1	1	2
8.	4	3	4	2	5
9.	6	4	2	6	4
10.	4	6	2	5	5
Mean	4.9	3.3	2.6	4.4	4.1
Mean photo	4.9	3.8	3.4		
Mean temp		3.6		4.2	

TABLE XVIII. ANALYSES OF VARIANCE OF THE NUMBER OF ROOT BUDS 10 OR MORE MILLIMETERS IN LENGTH, THE NUMBER OF SHOOTS, AND THE TOTAL OF THESE TWO FOR LEAFY SPURGE EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Source of variation	d f	Buds M. S.	Shoots M. S.	Total M. S.
Between	4	1.39**	3.03**	8.33*
9-hr ID vs all others	1	.26	3.92**	13.52*
12- & 18-hrs ID vs 12-& 18-hrs OD	1	4.80**	8.10**	16.90*
12-hr ID vs 18-hr ID	1	.48	.05	2.45
12-hr OD vs 18-hr OD	1	.02	.05	.45
Within	45	.23	.43	2.55
Total	49			

* Significant at 5 per cent level.
** Significant at 1 per cent level.

There were significantly more 10-millimeter buds on the roots of plants under 12- and 18-hour photoperiods outdoors than there were under the same photoperiods indoors. Significantly more shoots were produced under the greenhouse conditions than those of outside. When the number of 10-millimeter buds and the number of shoots were added together, there was significantly more development under 9-hour photoperiod indoors than under 12- or 18-hour day length indoors or outdoors. Likewise, more shoots developed outdoors under cool temperature and 12- and 18-hour photoperiods than were developed under the same day length in the greenhouse.

The number of days required for emergence of new shoots from roots that had been exposed to the various photoperiods indoors and outdoors on 52 days is presented in TABLE XIX and the analysis of variance is given in TABLE XI.

Both temperature and day length tended to affect time required for emergence of the new shoots from leafy spurge roots. The plants under 12- and 18-hour day length outdoors required more time for emergence than

TABLE XIX. NUMBER OF DAYS REQUIRED FOR EMERGENCE OF SHOOTS FROM TRANSPLANTED ROOTS OF LEAFY SPURGE PLANTS THAT HAD BEEN EXPOSED TO VARIOUS PHOTOPERIOD CONDITIONS INDOORS AND OUTDOORS FOR 52 DAYS PRIOR TO TRANSPLANTING.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1	16	6	4	14	12
2	10	7	6	19	18
3	5	6	5	20	14
4	5	9	9	19	16
5	14	4	10	19	6
Mean	10.0	6.4	6.8	18.2	13.2
Mean photo	10.0	12.3	10.0		
Mean temp		7.7		15.7	

TABLE XX. ANALYSIS OF VARIANCE OF THE NUMBER OF DAYS FOR EMERGENCE OF NEW SHOOTS FOR LEAFY SPURGE ROOTS THAT WERE EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Source of variance	d f	M. S.
Between	4	120.57**
9-hr ID vs all others	1	5.29
12-hr ID x 18-hr ID vs 12-hr OD x 18-hr OD	1	414.05**
12-hr ID vs 18-hr ID	1	.40
12-hr OD vs 18-hr OD	1	62.50*
Within	20	12.48
Total	24	

* Significant at 5 per cent level.
** Significant at 1 per cent level.

the same photoperiods in the greenhouse, and more time was required outdoors under 12 hours of light than under 18 hours.

Shoots from roots that had been exposed to the various photoperiods indoors and outdoors for 52 days are shown in Figure 9. They reveal that longer day length and warm temperature are conducive to emergence of shoots. Photoperiod and temperature did not appear to affect early growth; however, all plants were of equal size when each

was two weeks of age.

Figure 9. New Shoots from Leafy Spurge Roots Exposed to Various Photoperiods Indoors and Outdoors for 52 Days.

The number of days between emergence and flowering is given in TABLE XXI and the analysis of variance is presented in TABLE XXII.

TABLE XXI. THE NUMBER OF DAYS BETWEEN EMERGENCE AND FLOWERING OF SHOOTS FROM LEAFY SPURGE ROOTS EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS AND UNDER 18-HOUR PHOTOPERIOD INDOORS THEREAFTER.

Plant	9-hr ID	12-hr ID	18-hr ID	12-hr OD	18-hr OD
1	107*	117*	119*	75	43
2	113*	80	117*	93	70
3	113	112	118*	51	73
4	118*	76	114*	104*	18
5	109*	119*	113*	104*	117*
Mean	112.0	110.8	116.2	85.4	64.2

* Did not flower after this many days.

TABLE XXII. ANALYSIS OF VARIANCE OF THE NUMBER OF DAYS BETWEEN EMERGENCE AND FLOWERING OF SHOOTS FROM LEAFY SPURGE ROOTS EXPOSED TO VARIOUS PHOTOPERIODS INDOORS AND OUTDOORS FOR 52 DAYS.

Source of variance	d f	M. S.
Between	4	2,262.86**
9-hr ID vs all others	1	1,656.45
12-hr ID x 18-hr ID vs 12-hr OD x 18-hr OD	1	5,678.45**
12-hr ID vs 18-hr ID	1	592.90
12-hr OD vs 18-hr OD	1	1,123.60
Within	20	469.48
Total	24	

** Significant at 1 per cent level.

The cold treated plants flowered in significantly less time than plants in the greenhouse, but photoperiod had little effect. Some of the plants did not flower. In these cases the number of days between emergence and conclusion of the experiment was used as the number of days required for flowering.

Discussion

The limited data from 1956 and 1957 indicated that leafy spurge root buds began to go dormant during the late summer and early fall. As the nights became colder and the days became shorter, there was a gradual transition from an active to a semi-dormant condition. Roots dug and transplanted during this period required 9 to 16 days to produce shoots. When the temperature dropped to below freezing, the buds on the leafy spurge roots became dormant. Those on roots exhumed and transplanted in the greenhouse at this time either sent up shoots that failed to elongate or the buds failed to become active, and no shoots were produced for a period of time. Thirty-six days were required to produce shoots by roots transplanted at this time in 1957 and some dug in 1956 required over 5 months. However, after a period of cold weather, it appeared that the buds had gone through an after-ripening period and were no longer dormant. After 27 of 38 days of below-freezing temperature, roots dug and transplanted produced shoots within 5 days.

Flemion (9, 10) found in Rhodotypos kerrioides and peaches that seedling plants grown from dormant embryos were dwarfish. They had very short internodes and thick, deep green leaves, which was very similar to the response obtained from the buds on leafy spurge roots dug shortly after freezing in this study. Flemion also reported that this dwarfishness may persist for weeks, months or even years or until some growth condition after-ripened the bud so that it acquired vigor of growth. An effective after-ripening condition was a period of low temperature. Monson (20) found a reduction of growth in leafy spurge dug and transplanted in the greenhouse during late summer and fall. The transplants regained their

vigor after the soil temperature in the field dropped to or below freezing.

The controlled temperature and photoperiod experiment indicated that more buds were initiated under short photoperiods (9-hrs) than the longer photoperiod (15-hrs); and more were initiated under cooler nyctotemperature (34°F.) than under warmer nyctotemperature (67°F.). These conditions are similar to those that occur naturally in the late summer and early fall. It is probable that buds elongate more under warm conditions than under cold conditions. It is possible that more buds are initiated from roots that have large root reserves and this may be the reason why more buds were produced by roots of flowering plants than by those of nonflowering plants.

In the indoor and outdoor experiment there was no significant difference in the total number of buds among treatments but there was a difference in the number that became more than one millimeter in length. Since the roots were exhumed in late August, it is probable that the buds had previously been initiated. Therefore, the treatments had little or no effect on the total number of buds present. However, treatments did have an effect on activity of the buds. Significantly more buds over one millimeter in length were obtained under the short (9-hr ID) photoperiod. There were significantly more buds longer than one millimeter and 10 millimeters under cool outdoor temperature than under the warm indoor temperature when the photoperiods were 12 and 18 hours in length. However, more new shoots developed under the warm greenhouse temperatures than under cool outside temperatures.

In general, the two experiments dealing with photoperiod and temperature were similar when comparisons were made between total buds in the first and those more than one millimeter in length in the second, and between the number of buds 10 millimeters in length in the first and the number of new shoots in the second. There are two possible reasons why the results in the number of buds 10 or more millimeters in length are different in the two experiments. These two are very closely related with growth: one is temperature and the other is time of bud initiation.

The average minimum temperature from September 13 to November 5 was 6°F. higher than the minimum temperature in the controlled photoperiod and temperature experiment. Half of the indoor and outdoor experiment (September 13 - October 16) was 11°F. higher than the 34°F. for the controlled photoperiod and temperature experiment. Went (32) referring to A. H. Blaauw's work with the actual development of the growing point in tulip and hyacinth, as a function of storage temperature, stated that "The development can be arrested by both low (1.5°C.) and high (35°C.) temperature. The cessation of development near freezing is not amazing, since it occure in most plants." It is, therefore, possible that the 34°F. temperature used in this study may have been too cold for bud elongation, while a few degrees higher would have permitted growth.

It is almost certain that bud initiation had already taken place before the plants were placed under the conditions of the indoor and outdoor experiment. Therefore, it appears that the use of a slightly higher temperature would accelerate bud elongation. If this were true, the shoots in this experiment would be comparable to the 10-millimeter

buds in the controlled photoperiod and temperature experiment.

The true dormant condition was not obtained in the two experiments dealing with temperature and photoperiod, although there were differences in the number of days required for emergence. It took more time for emergence from roots placed under the short photoperiods and colder temperatures than under longer photoperiods and warmer temperatures. This is similar to the response of leafy spurge roots dug in the fall and transplanted in the greenhouse, except plants with thick leaves and short internodes were not produced. However, this characteristic was expressed in one plant from the controlled photoperiod and temperature experiment. This plant came from the flowering group that was under 9-hour photoperiod with a nyctotemperature of 34°F.

Cold temperatures were very effective in inducing flowering in leafy spurge, as was shown in the natural bud dormancy studies. Laude et al. (15) reported that Ladino clover overwintering outside under natural winter temperatures hastened flowering by as much as 8 weeks compared to those overwintering in the greenhouse. Thermoperiodism is also important in inducing flowering in other plants such as Camellia japonica (2), and peaches (14).

Effects of Auxin and Antiauxin

Auxin and antiauxin were applied in various concentrations to the cut surfaces of decapitated leafy spurge shoots to determine the effect of those hormones on the development of the axillary buds above-ground and the root buds.

Experimental Procedure and Results

Indole-3-acetic acid[1] was chosen as the auxin and trans-cinnamic acid[1] as the antiauxin used in this study, because both have been found to occur naturally in some species of plants.

During September of 1957, leafy spurge plants were exhumed and the roots were cut into 5-inch sections measuring from the soil surface down. The sections were planted in soil in 5-inch clay pots and exposed to an 18-hour photoperiod in the greenhouse.

On December 1, 1957, 360 plants were selected that were uniform and had only one main shoot. The top growth was removed from 320 plants two and one-half inches above the surface of the soil. Indole-3-acetic and trans-cinnamic acids were mixed separately in lanolin at concentrations of 250, 500 and 1000 ppm. Each lanolin mixture was applied to the cut surface of 40 decapitated leafy spurge shoots. These treatments were compared with three controls: (1) decapitation only, (2) decapitation plus lanolin and (3) nondecapitated. Treatments were made every 3 days for a period of 4 weeks. Before each application, an additional

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[1]Indole-3-acetic acid and trans-cinnamic acid are abbreviated as IAA and TC, respectively.

one-fourth inch of the stem was removed so that treatments could be made to freshly cut stems. At the end of each week (December 7, 14, 21 and 28), the soil was washed from roots of 10 plants from each treatment. The number of axillary shoot buds and the number of root buds were counted and their lengths determined. Primary interest was to observe the effects of treatments on root buds. The number and length of axillary buds were recorded to determine if their activity was comparable to the activity of the root buds, and to determine if the technique of application was satisfactory. If similar results were obtained, the theory that apical dominance controls the activity of leafy spurge root buds would be substantiated. Since the removal of one-fourth of an inch of the stem before each application reduced the number of the axillary shoot buds, the number of shoot buds was counted on the first two dates only.

Since the data contained some zeros, they were transformed by using $\sqrt{x + \frac{1}{2}}$; and analyses of variance were conducted on all data. Orthogonal comparisons were made to determine significant differences among treatments. Duncan's Multiple Range Test was used to test the significance of the mean comparisons.

The mean number and length of axillary shoot buds together with a statistical comparison of the means with Duncan's Multiple Range Test are given in TABLE XXIII, and the analyses of variance of transformed means are given in TABLE XXIV.

One week after the first date of application there was a significant difference in the number of axillary buds produced by plants under the various treatments (TABLE XXIII). Duncan's Multiple Range Test indicated that the number of buds on plants treated with the two lower rates

TABLE XXIII. MEAN NUMBER AND LENGTH OF LEAFY SPURGE AXILLARY SHOOT BUDS ONE MILLIMETER OR MORE IN LENGTH ONE AND TWO WEEKS AFTER FIRST TREATMENT WITH AUXIN AND ANTIAUXIN AND STATISTICAL COMPARISON OF THESE MEANS WITH DUNCAN'S MULTIPLE RANGE TEST.

	Dec. 7 (one week)				Dec. 14 (two weeks)			
Treatment	Number of buds	Stat. sig.*	Length of buds	Stat. sig.	Number of buds	Stat. sig.	Length of buds	Stat. sig.
Nondecap	0.0	d	0.0	c	0.0		0.0	
Decap	5.8	a	6.1	a	4.1	ab	16.2	b
Lanolin	4.4	ab	6.3	a	2.5	a	24.7	ab
TC 1000	4.1	b	6.1	a	4.1	a	46.6	a
TC 500	4.3	ab	6.7	a	3.4	a	41.9	a
TC 250	4.6	ab	6.3	a	3.1	a	30.8	ab
IAA 1000	0.2	d	0.2	c	1.3	c	5.7	c
IAA 500	1.3	c	1.9	b	1.6	bc	6.3	c
IAA 250	0.6	c	0.9	bc	1.7	bc	11.0	c

* Stat. sig. means statistical significance at 5 per cent level. Means followed by letter "a" are significantly different from those means not having "a"; those followed by "b" are significantly different from those not having "b", etc.

TABLE XXIV. ANALYSES OF VARIANCE OF THE NUMBER AND LENGTH OF LEAFY SPURGE AXILLARY BUDS ONE MILLIMETER OR MORE IN LENGTH ONE AND TWO WEEKS AFTER FIRST APPLICATION OF AUXIN AND ANTIAUXIN.

	Number				Length			
Source of	Dec. 7		Dec. 14		Dec. 7		Dec. 14	
variance	df	M. S.	df	M. S.	df	M. S.	df	M. S.
Between	8	4.96**	8	2.16**	8	7.09**	8	42.13**
Within	81	.14	81	.17	81	.23	81	2.50

** Significant at 1 per cent level.

of TC did not differ from the decapitated and the lanolin checks and that the number on plants treated with all three rates did not differ from the number on the lanolin treated plants. There were significantly more axillary buds found on the TC treated plants than on the IAA treated and the nondecapitated plants. However, nondecapitated plants and those treated with 1000 ppm of IAA had significantly fewer buds than those receiving 500 and 250 ppm of IAA.

There was also a difference in the mean length of the axillary buds that were one millimeter or more in length. There was no difference among plants treated with TC, lanolin, or those that were decapitated, but all had buds that were significantly longer than the IAA treated and the nondecapitated plants. There was no significant difference in the length of the axillary buds on plants that were decapitated and those treated with 250 or 1000 ppm of IAA. These results indicate that IAA applied to decapitated plants suppressed the activity of axillary buds but that TC did not effect activity.

The number of axillary buds changed very little during the second week. However, the average number of buds on plants treated with IAA increased. Treated plants had significantly more buds than the nondecapitated plants.

After two weeks, the axillary buds had grown considerably. The buds on the TC treated plants had elongated the most, followed by those on the lanolin and the decapitated plants. The axillary buds on the IAA treated plants grew the least, and those on the nondecapitated plants remained inactive. The application of IAA appeared to have suppressed activity, but had not inhibited it. The application of TC, especially the two higher rates, appeared to have stimulated growth.

The data for the total number of root buds were analyzed but it was not established that treatment with TC or IAA had any effect on the number of buds. The data for the number of root buds one or more millimeters in length were analyzed as it was felt that they would serve as an indication of bud activity. The data for the total length of buds were analyzed to secure information concerning growth. However, the

results indicated that total length was dependant on the number of buds one millimeter or more in length as the results for the two sets of data were almost identical. An analysis of the average length of buds confirmed the fact that total bud length was dependant on the number of buds one millimeter or more in length and failed to establish that treatment with TC or IAA had any effect on growth.

Although the four sets of data were analysed, the results indicated that the only meaningful data were those on the number of buds one millimeter or more in length.

The mean number of root buds one millimeter or more in length together with a statistical comparison of the means with Duncan's Multiple Range Test are given in TABLE XXV and the analyses of variance of transformed means are given in TABLE XXVI. The difference in the

TABLE XXV. MEAN NUMBER OF LEAFY SPURGE ROOT BUDS ONE MILLIMETER OR MORE IN LENGTH ONE, TWO, THREE AND FOUR WEEKS AFTER FIRST TREATMENT WITH AUXIN AND ANTIAUXIN AND STATISTICAL COMPARISON OF THESE MEANS WITH DUNCAN'S MULTIPLE RANGE TEST.

	Dec. 7		Dec. 14	Dec. 21	Dec. 28		
Treatment	Number of buds	Stat. sig.*	Number of buds	Number of buds	Number of buds	Stat. sig.	Mean
Nondecap	9.9	ab	6.2	10.1	14.1	a	10.1
Decap	10.4	a	9.5	9.9	8.0	bc	9.5
Lanolin	9.8	ab	8.3	5.9	9.3	ab	8.3
TC 1000	7.1	abc	6.1	5.5	8.1	bc	6.7
TC 500	6.1	bc	4.6	6.9	9.4	ab	6.8
TC 250	5.6	bc	6.6	6.8	9.3	ab	7.1
IAA 1000	4.9	c	6.1	8.3	7.6	bc	6.7
IAA 500	5.7	c	7.5	6.8	7.0	bc	6.8
IAA 250	6.0	c	6.5	9.5	4.7	c	6.7
Mean	7.3		6.8	7.7	7.8		

* Stat. sig. means statistical significance at 5 per cent level. Means followed by letter "a" are significantly different from those means not having "a"; those followed by "b" are significantly different from those not having "b", etc.

TABLE XXVI. ANALYSES OF VARIANCE OF THE NUMBER OF LEAFY SPURGE ROOT BUDS ONE MILLIMETER OR MORE IN LENGTH ONE, TWO, THREE AND FOUR WEEKS AFTER FIRST TREATMENT.

Source of variance	Dec. 7		Dec. 14		Dec. 21		Dec. 28	
	df	M. S.	df	M. S.	df	M. S.	df	M. S.
Between	8	1.48*	8	.61	8	.93	8	1.75*
Within	81	.49	81	.40	81	.62	81	.64

* Significant at 5 per cent level.

numbers of root buds between treatments was significant, but only on December 7 and 28, 1 and 4 weeks after initial treatment, respectively. In examining the means for these two dates, it was found that the chemicals did not effect the root buds like they had effected shoot buds. In the December 7 measurement, there was no significant difference in the number of root buds on plants treated with TC and IAA. Significantly more root buds were found on the nondecapitated, decapitated and lanolin treated plants than on those treated with IAA. There was a significant variation in the number of buds found on the roots in the December 28 measurement. There were more buds on the nondecapitated plants than on any other treatment. However, the difference was not significantly different from the number on plants treated with lanolin, or 250 or 500 ppm of TC. Plants that were nondecapitated, or treated with lanolin, or with TC at 250 or 500 ppm had significantly more buds than those treated with 250 ppm of IAA. Since Duncan's Multiple Range Test should not be used when there is not a significant F test, this test was not used for the December 14 and December 21 measurements.

The analysis of variance of the combined number of root buds for the four dates is presented in TABLE XXVII. There was a significant difference in "treatments", "dates" and "dates x treatments" interaction.

TABLE XXVII. ANALYSIS OF VARIANCE OF THE COMBINED NUMBER OF THE LEAFY SPURGE ROOT BUDS ONE MILLIMETER OR MORE IN LENGTH FOR THE FOUR MEASUREMENT DATES.

Source of variance	d f	Number M. S.
Plant	9	.96
Treatment	8	2.06*
Checks vs others	1	14.86**
Nondecap vs lan x decap	1	.07
Lan vs decap	1	.51
TC vs IAA	1	.68
TC 1000 vs TC 500 x TC 250	1	.07
TC 500 vs TC 250	1	.20
IAA 1000 vs IAA 500 x IAA 250	1	.03
IAA 500 vs IAA 250	1	.06
Error (a)	72	.91
Dates	3	1.38**
Dec 7 vs others	1	.43
Dec 14 vs Dec 21 x Dec 28	1	2.50**
Dec 21 vs Dec 28	1	1.02
Dates x treatments	24	1.75**
Error (b)	243	.33
Total	359	

* Significant at 5 per cent level.
** Significant at 1 per cent level.

The mean number of buds on plants receiving the three check treatments was significantly higher at the 1 per cent level than the mean number on plants treated with TC and IAA. However, it was not established that there was a difference among the various TC and IAA treatments, indicating that all such treatments suppressed root bud activity to the same degree.

Although the number of buds on December 7 was not significantly different from the mean of the other three dates, there were significantly fewer buds present on December 14 than on December 21 or December 28. The "date x treatments" interaction indicated that there was a fluctua-

tion in the number of root buds for the various treatments at the different dates of measurement.

Discussion

IAA in lanolin paste tended to arrest development of the axillary buds for one week following application to decapitated stems. Similar results have been reported in other plants (6, 29). The inhibition was proportional to the increase in auxin concentration. Delisle (6) reported that when decapitated stumps of Aster novae-angliae were treated with IAA, the inhibition on the development of the lateral buds was approximately in proportion to the concentration used--the greater the concentration the greater the inhibition.

Two weeks after application it was apparent that the rate of diffusion of IAA was not fast enough, or the concentration was not high enough, to prevent the axillary buds from becoming active. It is also possible that formation of callus on the cut surface reduced the effect of the auxin. Another possibility is that another substance in the plant inactivated the IAA. Even though IAA was less effective at the end of the second week than at the end of the first week, it had reduced axillary bud activity and growth significantly.

There was not much difference in the number of axillary buds and their length on the TC treated plants when compared with the decapitated and the lanolin treated plants after the first week. At the end of two weeks, application of TC at 500 and 1000 ppm showed significant increase in length over decapitated, nondecapitated and the IAA treatments. Van Overbeek et al. (30) reported that TC inhibited growth and the inhib-

ition may be reversed by auxin. Apparently, this occurred when TC was applied to decapitated leafy spurge stems. One week after application there was little difference among the decapitated, lanolin and the TC treatments. However, TC had not inhibited nor stimulated axillary bud activity at this stage. Later, when enough auxin was produced by the axillary shoots, the growth stimulus was greater on plants treated with TC than on the decapitated and lanolin treated plants.

It is possible that the antiauxin disrupted apical dominance. However, one would expect an increase in bud number instead of bud length if this were true.

Counts made on the number of root buds indicated that they were not affected in the same manner as the axillary buds on the same plants. When weekly readings were considered separately, a significant difference among treatments was noted at the end of the first and fourth weeks for number of buds; however, there was no difference at the end of the second and third weeks after initial treatment. In each case where a difference was noted, there were, in general, more buds on plants that were not treated with TC or IAA. When all four weekly readings were combined into one analysis of variance for number, it became apparent the plants given the three check treatments; namely, nondecapitated, decapitated plus lanolin and decapitated without lanolin, had significantly more root buds than plants receiving the TC or IAA treatments. It appears that both TC and IAA inhibited the number of root buds. It also appears that TC did not stimulate the growth of the root buds as it did in the axillary buds. Possible reasons for failure may be due to an inhibitor in the shoot and only when enough of the stem was removed was there a

stimulation. The same concentration that caused stimulation to axillary buds on the shoots resulted in inhibition of the root buds.

The inhibition of the axillary buds on the nondecapitated plants was probably a function of apical dominance but the reason for an increase in the number of root buds on the same plants was not apparent. Perhaps the root buds had already been supplied the stimulus when the roots were transplanted in the greenhouse. When the plants were decapitated, a shock was placed on the plant. The shock was greater when application of TC or IAA was made to the exposed surface of the wound. Another reason may have been the result of the loss of apical dominance as flowering approached (6). Since the loss of apical dominance can be contributed to a lowering of the auxin level, this may have been enough to change the auxin level in the entire plant and as a result the root buds began to develop.

The auxin, IAA, seemed to cause inhibition of both the axillary and the root buds, which is similar to the work conducted by Went (31) on the Denothera macrosiphon. He found that the polarity of auxin in roots was continuous with that in the shoot and the phenomenon of auxin-inhibition of buds was the same in stems and roots.

The effect of an inhibitor may also have been blocking the effect of the auxin and the antiauxin. Phytotoxic effects of aqueous extract of leafy spurge have been reported (18). These aqueous extracts inhibited root growth of pea and wheat seedlings.

SEED MATURATION

Two experiments were conducted to determine the relationship between color of leafy spurge seed and maturity by harvesting seeds from capsules of known age. Seed color was correlated with seed weight, ability to germinate and age of capsules.

A third experiment was conducted to determine the latest date that an application of 2,4-D would prevent the production of viable seed.

Experimental Procedure and Results

The first experiment was conducted between June 2 and 11, 1957, the second was between June 24 and July 27, 1957, and the third was conducted between July 1 and August 9, 1957.

Seed Color

On the first day of each experiment, all inverted capsules were removed from a number of leafy spurge plants and each plant was marked with a colored tag. The plants were examined daily and when the capsules were inverted over the cyathia the date was recorded. Those cyathia in which the ovary was not exposed were removed to insure that all capsules were the same age. Since more cyathia and female flowers developed on the tagged plants, it was necessary to check these plants daily. When new bracts opened, the new cyathia were removed so that they would not be mistaken for those already under observation. However, it was possible to leave capsules of two or three different ages on some plants without losing accuracy.

On large plants that developed numerous sets of bracts, it was

possible to let a new age group of capsules develop every 6 or 7 days. Since one age group was a week older than the next group, there was no difficulty in distinguishing one group from the other. This system reduced the number of cyathia that needed to be removed, and increased the number of capsules that could be observed from the same number of plants.

In the June 2 - 31 experiment the age of the capsules at harvest was 1 - 29 days, and in the June 24 - July 27 experiment it was 3 - 27 days. Two methods of harvesting were used. One method consisted of mowing the plants and placing them in separate paper bags. The capsules would dry and burst open. The seeds from each plant were placed in separate envelopes. The other method was easier and faster and allowed for observation of more than one age of capsules on the same plant. Individual capsules were removed at the age desired and those from the same plant were placed in a packet.

The seeds in each packet were separated according to color and counted. Seeds of each color from each plant were germinated separately.

Preliminary germination tests had indicated that all seeds germinated best in two per cent KNO_3 solution under alternating temperature of 20°C. and 30°C. Mottled seeds germinated best under at least 10 days of alternating light and darkness, gray seeds germinated best under dark conditions, brown seeds germinated under both conditions and 10 days of light did not inhibit the germination of the gray seeds. Therefore, all seeds in these experiments were germinated in a germinator under alternating temperature of 30°C. for 8 hours and 20°C. for 16 hours. For the first 10 days, they were given light while under the warmer tem-

perature. After that they were placed in the dark.

Results of the first experiment (June 2 - 31, 1957) are shown in APPENDIX TABLE I and Figure 10. Figure 11 shows the stage of development of seed and capsules at 7, 10 and 15 days after the capsules had inverted.

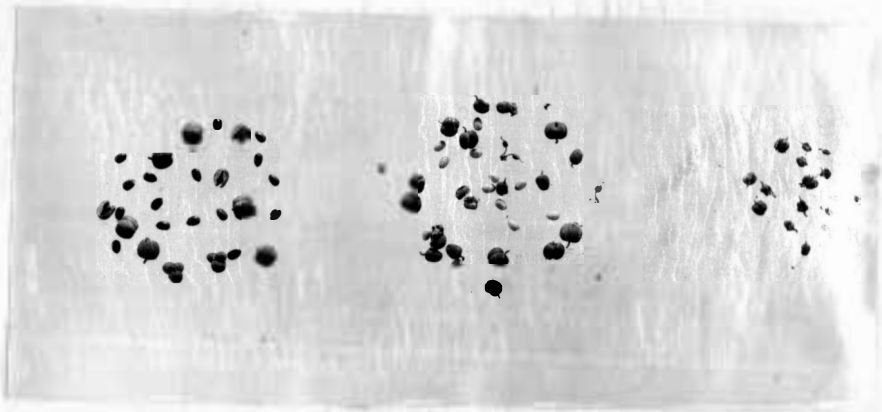

Figure 11. Capsules and Seeds Obtained in First Experiment 15 Days after Capsules Inverted (left) 10 Days after Inversion (center) and 7 Days after Inversion (right).

The ovaries and the capsules began to enlarge at about 8 days after the capsules had inverted. The seeds were shrivelled in size, and yellow in color. Seeds from capsules that were one day older were more rigid. Many of them were not shrivelled and were slightly brighter yellow in color. One of the yellow seeds had brown ends. The capsules appeared to be fully developed by the tenth day and a few more of the yellow seeds had brown tips. However, the majority of the seeds were yellow.

Eleven days after the capsules had inverted seeds that were yellow, yellow with brown tips, yellow-striped, orange-brown or reddish-

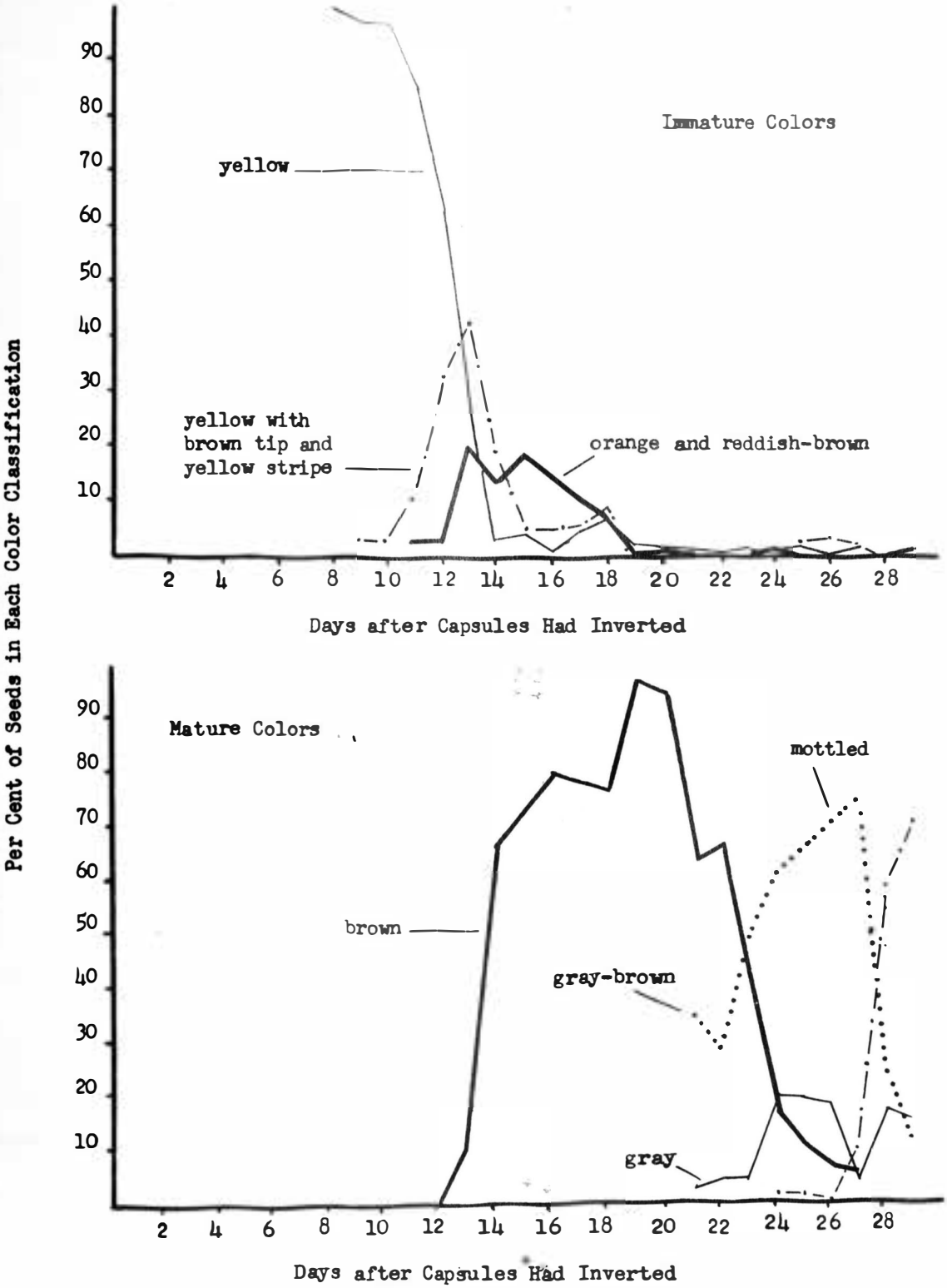

Figure 10. Relationship Between Seed Color and Capsule Age at Time of Harvest (June 2 - 31, 1957).

brown were observed. Two days later brown seeds were present. Brown was the predominant color between the fourteenth and the twenty-third day after the capsules inverted. On the twenty-first day many gray-brown and a few gray seeds were present. On the twenty-third day gray-brown seeds were predominant. Mottled seeds were present on the twenty-fourth day, and they became the majority on the twenty-eighth day. The capsules had not started to dehisce by the time they were harvested, although some of the capsules were 29 days old.

The germination percentages of seeds grouped according to age are given in APPENDIX TABLE I and similar data for seeds grouped according to color are shown in TABLE XXVIII. Only three viable seeds were obtained from capsules that were harvested less than 19 days after inversion. In 16-day old capsules, 3 of 475 brown seeds were viable. In 19- and 20-day old capsules, 10 - 13 per cent of the brown seeds were viable. On the twenty-first day, germination was 4 of 4 gray, 55 of 89 gray-brown, and 29 of 168 brown seeds; and the germination percentage was about the same for all capsules that were older when harvested. None of the yellow, orange-brown, red or reddish-brown seeds were viable even though some were obtained from capsules that had inverted 29 days before being harvested.

Results of the second experiment (June 24 - July 27, 1957) are shown in APPENDIX TABLE II and Figure 12.

Shrivelled yellow seeds were present on the seventh day. The majority of seeds on the ninth day were yellow, although reddish-brown, orange and yellow seeds were observed. Brown seeds appeared on the tenth, gray-brown and gray on the fifteenth and mottled on the eighteenth

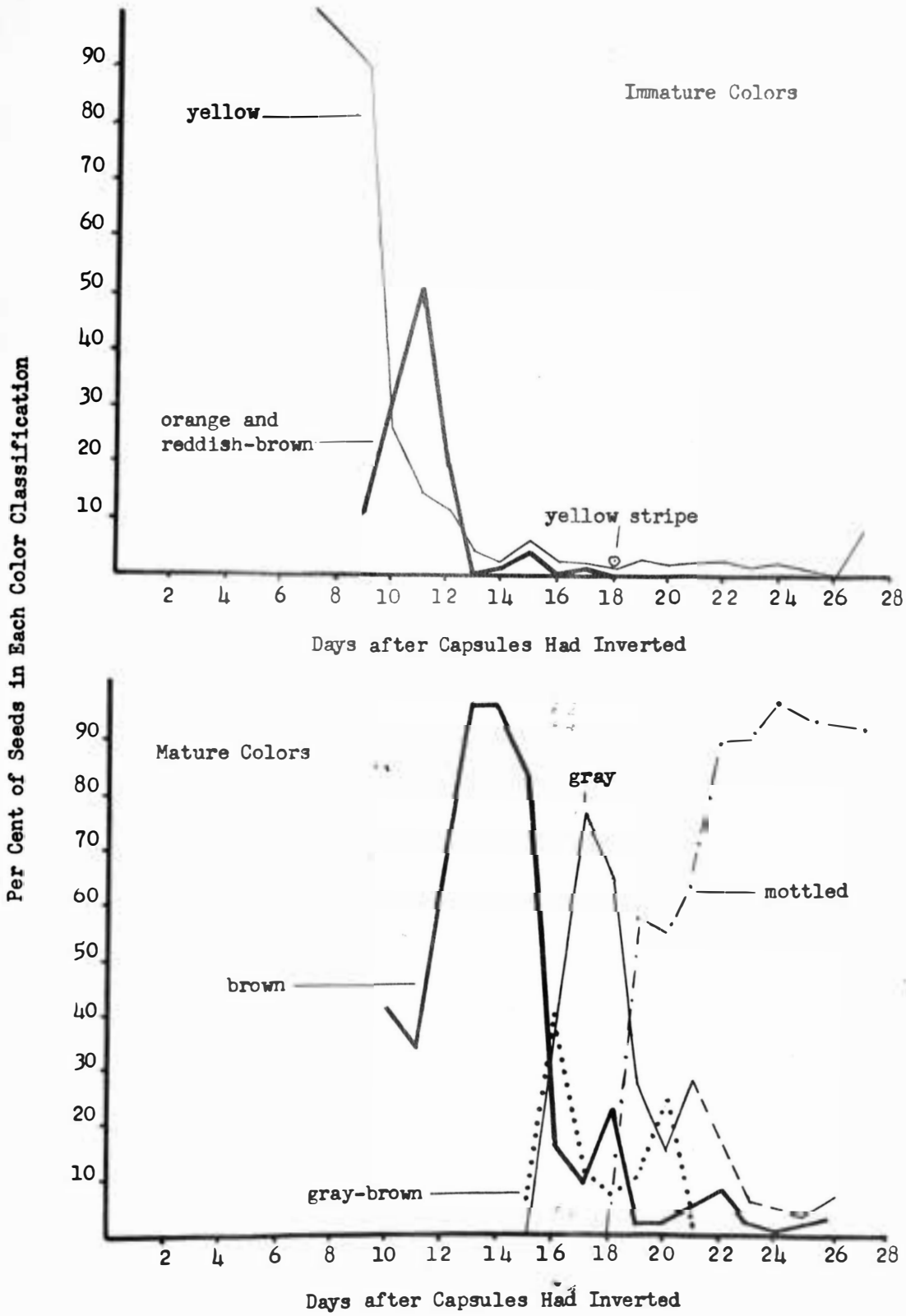

Figure 12. Relationship Between Seed Color and Capsule Age at Time of Harvest (June 24 - July 27, 1957).

TABLE XXVIII. NUMBER AND GERMINATION PERCENTAGE OF LEAFY SPURGE SEEDS GROUPED BY COLOR IN TWO EXPERIMENTS (JUNE 2 - 31, AND JUNE 24 - JULY 27, 1957).

Seed color	Total number of seeds		Germination percentage	
	June 2-31	June 24-July 27	June 2-31	June 24-July 27
Mottled	87	582	79.3	66.5
Gray	269	344	82.2	72.4
Gray-brown	1175	133	59.8	63.2
Brown	2178	446	7.5	24.0
Reddish-brown	155	44	0.0	0.0
Red	4	-	0.0	0.0
Orange-brown	112	10	0.0	0.0
Yellow stripe	117	4	0.0	0.0
Yellow/br. tip	200	2	0.0	0.0
Yellow	961	49	0.0	0.0
White	12	5	0.0	0.0
Shrivelled yellow	97	26	0.0	0.0
Shrivelled white	9	1	0.0	0.0

day after the capsules had inverted. Brown seeds reached the majority on the tenth, gray-brown on the sixteenth, gray on the seventeenth and mottled on the nineteenth day after inversion. Some of the capsules had dehisced on the twenty-sixth and twenty-seventh day in this experiment.

The viability data of the various age groups are presented in APPENDIX TABLE II, and the number and per cent of viable seeds in each color group are given in TABLE XXVIII. The youngest seeds to germinate were from capsules harvested on the thirteenth day after they had inverted. These were brown seeds and 11 of 1250 germinated. On the fifteenth day after the capsules had inverted, the gray germinated 1 of 1, the gray-brown 3 of 5 and the brown 54 of 84 seeds. Eighteen days after the capsules had inverted the germination of the harvested seeds was: 3 of 3 mottled, 85 of 122 gray, 12 of 13 gray-brown and 21 of 43 brown seeds. No yellow, orange-brown, red or reddish brown seeds germinated even though some were obtained from capsules that had inverted 27 days before harvest.

Effect of 2,4-D on Seed Viability

All capsules were removed from a patch of leafy spurge plants and each plant marked with a colored tag. The plants were observed daily and the date that the capsule inverted over the cyathia was recorded for the period July 1 to August 9, 1957. Capsules that inverted later were removed. Several capsules the same age were allowed to develop on one plant and capsules of more than one age group were also allowed to develop on the same plant. Part of the patch was sprayed with one-half pound acid equivalent per acre of a butoxyethanol ester of 2,4-D on July 22, 1957, when the capsules were at all ages between 3 days before inversion and 18 days after inversion. The remainder of the patch was not sprayed.

The capsules were removed just before dehiscence and placed in coin envelopes. Capsules from each plant were kept separately. The seeds from each packet were separated according to color and counted. Seeds of each color from each plant were germinated separately on two per cent KNO_3 impregnated blotters in a germinator under 8 hours of light at 30°C. and 16 hours of dark at 20°C. for 10 days and at the same temperatures without light for 14 days. At this time germination was low for the mottled seeds so they were exposed to light for 21 days.

APPENDIX TABLE III presents the data for the 2,4-D treated patch and APPENDIX TABLE IV shows the results from the untreated patch. Figure 13 shows the relationship between seed color and age of capsules at spraying time for treated and untreated leafy spurge plants. In Figure 14, capsules and seeds from treated and untreated plants are shown.

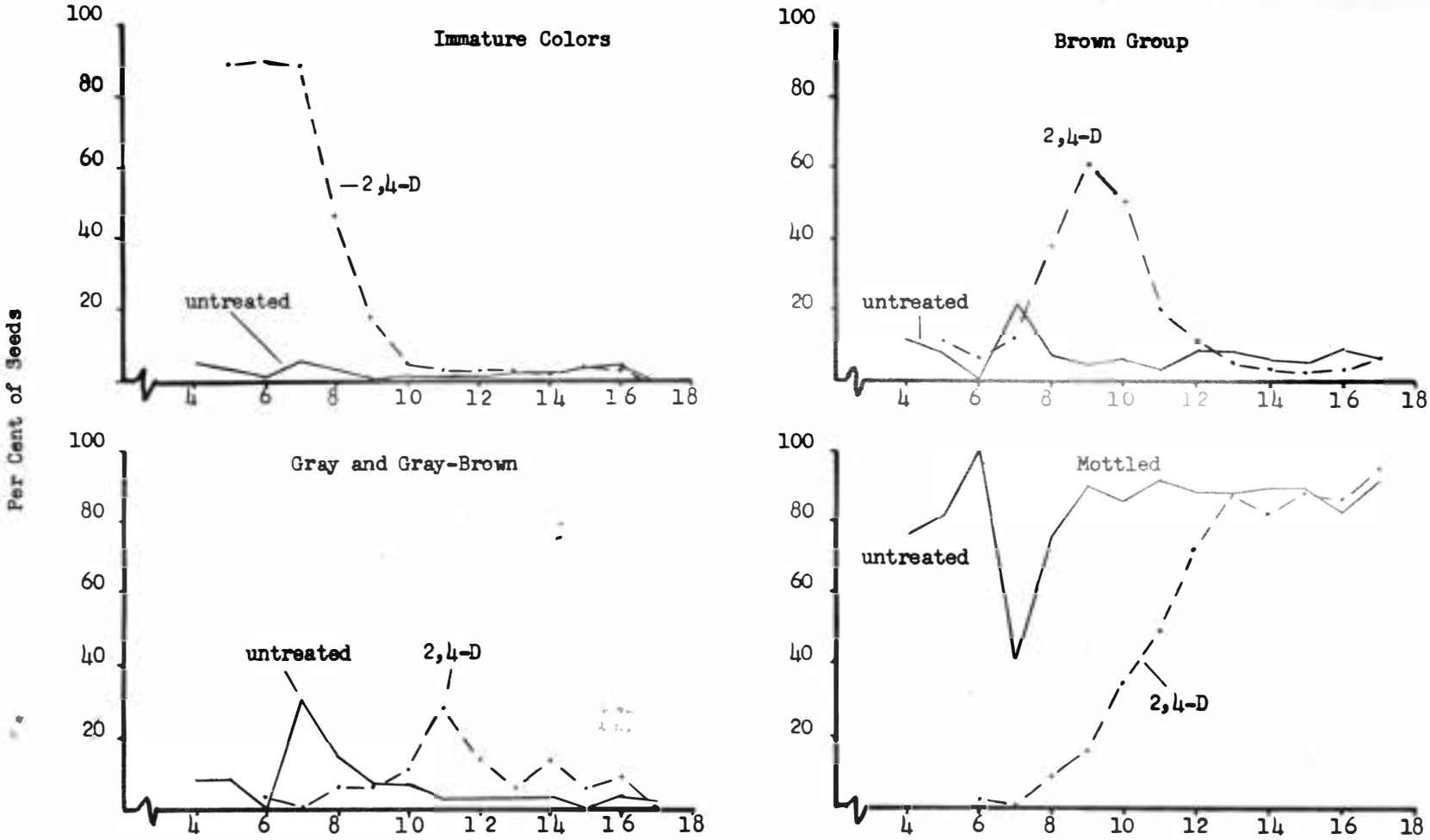

Figure 13. Relationship Between Seed Color and Age of Capsules at Spraying Time.

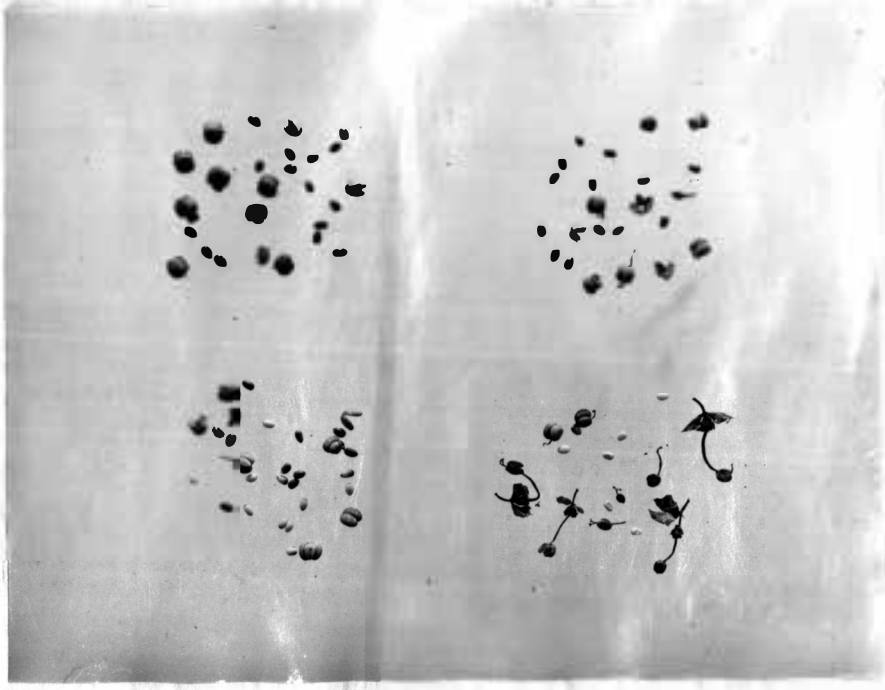

Figure 14. Capsules and Seeds of Untreated Leafy Spurge (upper left hand corner); Leafy Spurge Treated with 2,4-D 9 Days after Capsules Inverted (upper right hand), 8 Days after Inversion (lower left hand), and 6 Days after Inversion (lower right hand).. They Were Harvested 15, 18, 18 and 20 Days after Inversion, Respectively.

In this experiment a new seed color was observed. It was dark gray with reddish tinge or dark brown with reddish tinge, and was called dark gray-brown with reddish tinge.

Only two seeds were produced when leafy spurge was sprayed 4 days or less after the capsules had inverted. These two seeds were white with brown tips, even though the capsules had been inverted from 15 to 21 days before harvest.

Capsules, that had been inverted 6 days and more when sprayed, produced some mottled seeds. However, the majority of seeds were white in capsules that had been inverted 5, 6 or 7 days at the time of spray-

ing; and dark gray-brown with reddish tinge in capsules that had been inverted 8, 9 or 10 days. Most seeds were mottled in capsules that inverted 11 or more days before spraying and in capsules that were not sprayed.

On the 2,4-D treated leafy spurge, some capsules started to dehisce on the ninth to the twenty-fifth day after they had inverted; whereas, untreated capsules did not start to dehisce until the nineteenth to the twenty-fourth day (APPENDIX TABLES III and IV).

The germination percentage of the seeds grouped according to color is given for treated and untreated plants in TABLE XXIX. Similar data for seed grouped according to time of spraying are given in TABLE XXX, and APPENDIX TABLES III and IV. Mottled seeds had the highest germination percentage in the seed from both the treated and the untreated

TABLE XXIX. GERMINATION PERCENTAGE OF LEAFY SPURGE SEEDS, GROUPED ACCORDING TO COLOR, FROM SPRAYED AND UNSPRAYED LEAFY SPURGE PLANTS.

Seed color	Total number of seeds		Germination percentage	
	Treated	Untreated	Treated	Untreated
Mottled	2287	1621	40.0	61.0
Gray	412	85	10.4	58.8
Gray-brown	75	3	4.0	33.3
Dark gray-brown with reddish tinge*	1047	125	2.1	9.6
Reddish-brown	34	2	0.0	0.0
Orange-brown	19	0	0.0	0.0
Yellow or white stripe	113	5	0.0	0.0
Yellow or white with brown tips	31	0	0.0	0.0
Yellow	130	16	0.0	0.0
White	490	15	0.0	0.0
Shrivelled yellow or white	98	3	0.0	0.0
Total	4736	1875	20.7	56.0

* Includes dark gray-brown with reddish tinge, dark brown and brown.

plants. Seeds from untreated plants had a higher germination percentage than seeds from treated plants. The youngest seeds to germinate from treated plants were those from capsules that were 6 days old when sprayed (TABLE XXX and APPENDIX TABLE III). However, less than 10 per cent were viable from capsules that had been inverted less than 10 days at time of treatment.

TABLE XXX. GERMINATION PERCENTAGE OF LEAFY SPURGE SEEDS GROUPED ACCORDING TO THE NUMBER OF DAYS CAPSULES HAD BEEN INVERTED AT THE TIME OF SPRAYING.

Days	Total number of seeds		Germination percentage	
	Treated	Untreated	Treated	Untreated
-3	*	**	*	**
-2	*	**	*	**
-1	*	**	*	**
0	*	**	*	**
1	*	**	*	**
2	*	**	*	**
3	2	**	0.0	**
4	*	63	*	63.5
5	28	39	0.0	53.8
6	67	22	3.0	31.8
7	504	52	1.0	50.0
8	390	89	4.4	52.8
9	614	57	9.4	84.1
10	409	291	26.4	47.8
11	687	168	23.7	63.1
12	545	365	37.1	63.6
13	576	162	27.6	54.9
14	285	145	32.3	50.3
15	342	243	20.5	41.6
16	234	64	37.2	34.4
17 and 18	53	115	35.8	87.0
Total	4,736	1,875	20.7	56.0

* No seed developed.
** Harvesting started on the fourth day.

Bulk-Harvested Seeds

Bulk quantities of seed were harvested for seed-weight and germination studies. The seeds were obtained by stripping all the capsules from the plants. Capsules were allowed to dry and the seeds were separated as to color. Two hundred each of brown, gray and mottled seeds were harvested in June, 1957, and 2000 gray and 1800 mottled seeds were harvested in August, 1957. These seeds were separated into 100-seed lots, and each lot was weighed and germinated.

The weight and germination percentage are presented in TABLE XXXI. Mottled seeds weighed more than gray seeds and gray seeds weighed

TABLE XXXI. THE WEIGHT AND GERMINATION OF LEAFY SPURGE SEEDS BY COLOR WHEN HARVESTED AT TWO DIFFERENT DATES.

Seed color	Harvest date	Number of seeds	Weight in mg/100 seeds	Germination percentage
Mottled	June	200	301.5	82.0
Mottled	August	1800	288.6	82.8
Gray	June	200	254.5	86.0
Gray	August	2000	269.2	89.5
Brown	June	200	182.0	25.0

more than brown seeds. Mottled seeds that were harvested in August weighed less than those harvested in June. The germination percentage of gray seeds was slightly higher than that of mottled seeds and was considerably higher for both gray and mottled than for brown seeds.

Discussion

Several different colors of seeds were observed. They corresponded with the maturity of the seed. As the seed increased in age, the

color of the seeds changed from yellow to yellow with brown tips. The brown then moved in from both ends until a narrow yellow band was present. These seeds were called yellow stripe. The stripes changed to orange giving the seeds an orange-brown appearance. As the orange became darker, the seeds appeared reddish-brown and later brown. They changed from brown to gray. First, a gray line developed along one side of the seeds. This gradually became larger until the seeds were gray-brown in color. The seeds then lost their brown tint and were gray. Tiny brown spots then began to appear on the seeds giving them a slightly mottled gray appearance. The brown spots gradually increased until the seeds were distinctly mottled. In some instances shades of green appeared between gray and mottled. Some of the seeds were much more darkly mottled than others.

This sequence of colors was observed in capsules harvested at a known age and was further supported by seed-weight and germination data. Several lots of brown, gray and mottled seeds were weighed. Brown seeds were the lightest, and mottled seeds were the heaviest, with gray seeds being intermediate. It is reasonable to expect seeds to become heavier as they mature. The yellow, yellow with brown tips, yellow stripe, orange-brown, red and reddish-brown seeds did not germinate because they were immature and were incapable of germinating. However, brown, gray-brown, gray and mottled seeds were viable. Brown seeds were present 3 or 4 days before they were viable. The gray-brown, gray and mottled seeds were viable the same day that they appeared. Also their germination percentage was approximately three times higher than that of the brown seeds.

This sequence of seed color is similar to that observed by Hanson

and Rudd (11), but does not agree with that reported by Bakke (1), and Selleck and Coupland (23). Hanson and Rudd mentioned that the purplish-brown seeds with very little gray tinge were less mature than the light gray tinged with purple. They also mentioned that there were light gray mottled with purplish-brown seeds present. They did not indicate the maturity of the mottled seeds.

Bakke (1) and Selleck and Coupland (23) reported that brown seeds weighed more than the gray seeds. The former stated that more brown seeds germinated, but the latter found no significant difference in germination between seeds of these two colors. If the seeds they called brown were the same as the mottled seeds in this study, the results reported here would be in close agreement with the results they reported.

In combining the results from the first and second experiments, it was found that yellow was the most prevalent color between the seventh and the tenth day after the capsules had inverted. Between the ninth and the thirteenth day, the yellow with brown tips, yellow stripe, orange-brown, red and reddish-brown colors were the most common. Brown was predominant from the tenth to the fifteenth in the second experiment and from the fourteenth until the twenty-second in the first. Gray-brown was predominant only on the sixteenth day in the second experiment; while in the first, it prevailed from the twenty-third until the twenty-seventh. Gray prevailed the seventeenth and the eighteenth days in the second experiment; although, in the first experiment, gray was never the predominant color. However, gray was common from the twenty-fourth until the twenty-ninth day. Mottled was the most mature color

observed. Its period was from the nineteenth through the twenty-seventh day after the capsules had inverted in the second experiment. In the first experiment, mottled was predominant only on the last 2 days of harvest, the twenty-eighth and the twenty-ninth.

The reason for the various colors found in leafy spurge seeds is mainly due to differences in age. There will be seeds of different colors on the same plant. On any plant new inflorescences are being produced continually for some period of time. Each pedicel of the umbel produces a single inflorescence. At the point of attachment below the cyathium, two opposite bracts begin to appear. The pedicel elongates, the bracts open and the female flower appears and is fertilized. This process may be repeated several times. As a result, there are seeds of several different ages on the same plant. The development of the inflorescences in this manner has also been observed by Selleck and Coupland (23, 24) and Bakke (1).

Several of the immature colors were found throughout the two experiments, even when most of the seeds were mature. Age of capsule did not appear to be a factor. In some cases, seeds from certain capsules were immature; and in other cases, one seed in a capsule would be effected and the others would be mottled. It is postulated that this was a physiological reaction. It is possible that the plant was under stress for nutrients or water. The first capsules to start development or the first seeds in a capsule would demand so much of the nutrients that those that were only slightly younger would be at a disadvantage. They would mature more slowly and be of a different physiological age even though they were of the same chronological age as mottled seeds.

White and partially white seeds are similar to the yellow seeds in maturity, but for some reason they are white. Since these seeds usually appear during the later stages of maturity, it is believed that they stopped development at an earlier stage. Then these seeds would never later become viable, even if the capsule did not dehisce.

When the dark gray-brown with reddish tinge seeds were first observed among those harvested from the 2,4-D experiment, it was thought that the chemical had caused discoloration. However, untreated seeds of the same color were also observed. Genetic variation does not appear to be a factor because this color was not observed in two previous experiments conducted on the same patch of leafy spurge. This leaves the possibility that the drier and warmer conditions in the latter part of July and August hastened maturity. This may have caused a grouping of the colors giving a new color that takes the place of the brown seeds described in the two earlier experiments.

In the spraying experiment from the treated plots, there was a large number of immature seeds. Based on color, 19.3 per cent were immature compared with 2.1 per cent for the untreated. This, and the low germination percentage of the treated, indicated that 2,4-D had an effect on the seed. These immature seeds would not have matured because the capsules were cracked down one side at the time of harvest. The cracking indicates that the capsules were almost ready to dehisce.

SUMMARY AND CONCLUSIONS

The purpose of this study was to obtain preliminary data about the reproduction of leafy spurge (Euphorbia esula L.) by studying the development of seeds and some factors affecting the dormancy or activity of root buds.

In the vegetative bud studies, four experiments were conducted. In one experiment leafy spurge roots were exhumed at weekly intervals and transplanted in greenhouse pots to secure an indication of the effect of natural environment on root bud activity. In two experiments transplants were exposed to different temperatures and photoperiods to learn the effect of these factors on root bud development. In a fourth experiment, auxin and antiauxin were applied in various concentrations to the cut surface of decapitated leafy spurge shoots to determine the effects of these hormones on the development of axillary buds above-ground and root buds.

In the leafy spurge seed maturation study, two experiments were conducted to determine the relationship between seed color and maturity by harvesting seeds from capsules of known age. Seed color were correlated with seed-weight, ability to germinate and age of capsules. A third experiment was conducted to determine the latest date that an application of 2,4-D would prevent the production of viable seeds.

The following conclusions can be drawn:

1. Natural dormancy exists in leafy spurge; it is brought about by short days and cool temperatures. It appears that a killing frost is

instrumental in causing complete dormancy. Expressions of dormancy are: root buds that fail to elongate or emerged shoots that have thick leaves and short internodes.

2. Low temperatures cause natural after-ripening, hence the breaking of dormancy.

3. In general, root buds develop and grow under conditions of short days. Temperature regulates the rate of growth. The cool temperatures produce a hardening-off effect and are very instrumental in flower initiation. Root buds subjected to cool temperatures produce shoots that flower much quicker than root buds under warm temperature conditions.

4. Results in this experiment on the effect of auxin and anti-auxin on the root bud development in leafy spurge are indefinite. In general, trans-cinnamic acid promotes growth of the axillary buds and inhibits the development of the root buds. Indole-3-acetic acid suppresses the growth of root buds and for a short time suppresses axillary buds.

5. For further work leafy spurge seedlings should be used instead of exhumed roots. Roots are too variable; one cannot determine age or other factors that may mask the results. The only criterion for root selection is uniform size. Seeds from the same patch would help eliminate some of the genetical variation. The seedlings obtained should be approximately the same age if they are germinated at the same time. The use of seedlings also enables the research worker to have control

over the temperature and photoperiod prior to and during the actual experiment.

6. Variation in leafy spurge seed color is due to differences in age of seed. As the seed increases in age, color changes from yellow to yellow with brown tips, to brown ends with a narrow yellow band, to brown with an orange band and to a reddish-brown seed, followed in order by brown, gray-brown, gray and finally mottled.

7. The rapidness of change in seed color depends upon several environmental factors, such as rainfall, humidity and temperature. Optimum rainfall, high humidity or low temperature tend to delay development. Therefore, seeds from plants grown under optimum conditions have more time to mature and have greater seed weight.

8. Yellow, yellow stripe, orange-brown and reddish-brown seeds are nonviable. Brown, gray-brown, gray and mottled seeds are capable of germinating.

9. If leafy spurge is to be mowed to prevent the production of viable seeds, mowing must be done before seeds have turned brown. This is 10 to 13 days after the capsules have inverted. The exact number of days varies with variation in growing conditions.

10. An application of one-half pound of butoxyethanol ester of 2,4-D does not prevent the production of viable seed if spraying is delayed more than 5 days after the capsules have inverted.

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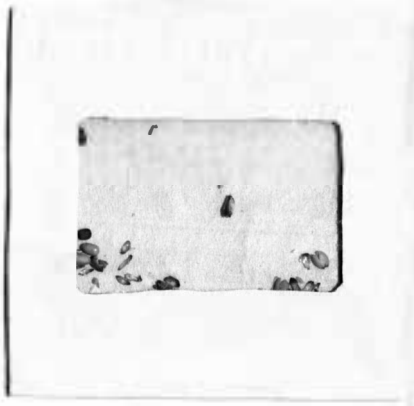
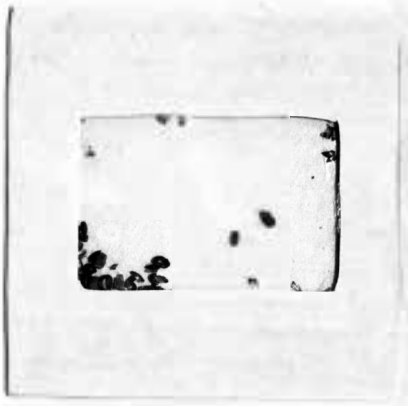
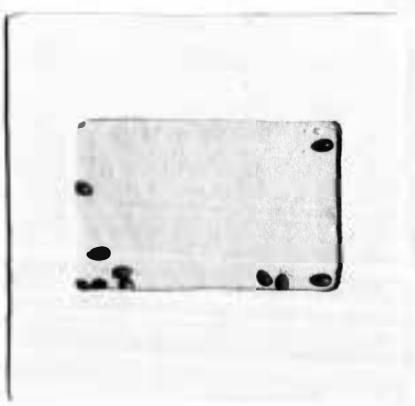
APPENDIX



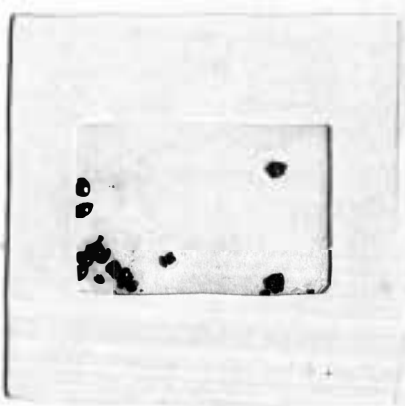
Immature



Brown



Gray-brown and gray



Mottled

Figure 1. Leafy Spruge Seeds.

TABLE I. DATA FROM THE FIRST SEED MATURATION EXPERIMENT FROM JUNE 2 - JUNE 31, 1957.

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
1	1	11	--	--	--	--
2	6	40	--	--	--	--
3	2	56	--	--	--	--
4	11	209	--	--	--	--
5	9	134	--	--	--	--
6	5	58	--	--	--	--
7	9	140	--	--	--	--
8	21	241				
	(3)		Shrivelled yellow	10	0	100.0
9	9	122				
	(1)		Yellow/br. tip	1	0	2.7
	(5)		Yellow	24	0	64.9
	(4)		Shrivelled yellow	12	0	32.4
Total				37	0	100.0
10	29	375				
	(2)		Yellow/br. tip	12	0	3.4
	(26)		Yellow	321	0	91.4
	(7)		Shrivelled yellow	18	0	5.1
Total				351	0	99.9
11	26	437				
	(1)		Reddish-brown	7	0	1.4
	(1)		Red	3	0	0.6
	(1)		Orange-brown	3	0	0.6
	(4)		Yellow stripe	10	0	2.0
	(8)		Yellow/br. tip	45	0	9.1
	(25)		Yellow	403	0	81.6
	(8)		Shrivelled yellow	23	0	4.7
Total				494	0	100.0
12	19	314				
	(1)		Brown	1	0	0.4
	(2)		Reddish-brown	5	0	2.1
	(1)		Red	1	0	0.4
	(7)		Yellow stripe	24	0	10.0
	(11)		Yellow/br. tip	55	0	22.9
	(17)		Yellow	151	0	62.9
	(2)		Shrivelled yellow	3	0	1.2
Total				240	0	99.9

TABLE I. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
13	13	99				
	(3)		Brown	9	0	10.3
	(2)		Reddish-brown	4	0	4.6
	(6)		Orange-brown	14	0	16.1
	(2)		Yellow stripe	7	0	8.0
	(9)		Yellow/br. tip	30	0	34.5
	(7)		Yellow	20	0	23.0
	(2)		Shrivelled yellow	3	0	3.5
Total				87	0	100.0
14	22	240				
	(13)		Brown	164	0	66.1
	(6)		Reddish-brown	12	0	4.8
	(6)		Orange-brown	19	0	7.7
	(10)		Yellow stripe	23	0	9.3
	(8)		Yellow/br. tip	23	0	9.3
	(3)		Yellow	7	0	2.8
Total				248	0	100.0
15	27	297				
	(26)		Brown	286	0	73.3
	(13)		Reddish-brown	51	0	13.1
	(9)		Orange-brown	19	0	4.9
	(5)		Yellow stripe	11	0	2.8
	(7)		Yellow/br. tip	9	0	2.3
	(3)		Yellow	5	0	1.3
	(1)		White	2	0	0.5
	(4)		Shrivelled yellow	7	0	1.8
Total				390	0	100.0
16	22	397				
	(21)		Brown	475	3	78.9
	(15)		Reddish-brown	45	0	7.5
	(14)		Orange-brown	39	0	6.5
	(8)		Yellow stripe	15	0	2.5
	(6)		Yellow/br. tip	12	0	2.0
	(4)		Yellow	6	0	0.9
	(5)		Shrivelled yellow	10	0	1.7
Total				602	3	100.0

TABLE I. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
17	13	141				
	(12)		Brown	199	0	78.3
	(7)		Reddish-brown	20	0	7.9
	(6)		Orange-brown	6	0	2.4
	(7)		Yellow stripe	10	0	3.9
	(4)		Yellow/br. tip	6	0	2.4
	(3)		Yellow	6	0	2.4
	(2)		White	2	0	0.8
	(4)		Shrivelled yellow	5	0	2.0
Total				254	0	100.1
18	15	66				
	(11)		Brown	84	0	76.4
	(4)		Reddish-brown	5	0	4.5
	(2)		Orange-brown	3	0	2.7
	(3)		Yellow stripe	7	0	6.4
	(1)		Yellow/br. tip	3	0	2.7
	(3)		Yellow	7	0	6.4
	(1)		White	1	0	0.9
Total				110	0	100.0
19	11	*				
	(10)		Brown	110	14	97.3
	(1)		Reddish-brown	1	0	0.9
	(1)		Yellow	1	0	0.9
	(1)		Shrivelled yellow	1	0	0.9
Total				113	14	100.0
20	18	*				
	(17)		Brown	156	15	95.1
	(1)		Orange-brown	2	0	1.2
	(1)		Yellow stripe	1	0	0.6
	(1)		Yellow/br. tip	1	0	0.6
	(3)		Yellow	3	0	1.8
	(1)		Shrivelled yellow	1	0	0.6
Total				164	15	99.9

* The number of capsules were not counted because they had dehisced while drying in the paper sacks.

TABLE I. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
21	12	*				
	(1)		Gray	4	4	1.5
	(4)		Gray-brown	89	55	33.6
	(11)		Brown	168	29	63.4
	(1)		Yellow	1	0	0.4
	(1)		White	1	0	0.4
	(2)		Shrivelled white	2	0	0.8
Total				265	88	100.1
22	10	*				
	(2)		Gray	14	9	4.3
	(5)		Gray-brown	90	52	27.7
	(9)		Brown	215	27	66.2
	(1)		Reddish-brown	1	0	0.3
	(1)		Yellow stripe	1	0	0.3
	(1)		Yellow	1	0	0.3
	(1)		Shrivelled yellow	1	0	0.3
	(1)		Shrivelled white	2	0	0.6
Total				325	88	100.0
23	13	*				
	(2)		Gray	12	9	3.5
	(10)		Gray-brown	172	78	50.0
	(8)		Brown	154	35	44.8
	(1)		Yellow/br. tip	1	0	0.3
	(2)		Yellow	2	0	0.6
	(1)		White	1	0	0.3
	(2)		Shrivelled white	2	0	0.6
Total				344	112	100.1
24	27	*				
	(1)		Mottled	4	2	0.6
	(7)		Gray	128	111	19.3
	(25)		Gray-brown	408	261	61.4
	(17)		Brown	109	31	16.4
	(2)		Reddish-brown	2	0	0.3
	(3)		Orange-brown	5	0	0.8
	(1)		Yellow/br. tip	1	0	0.2
	(3)		Yellow	3	0	0.4
	(2)		Shrivelled yellow	2	0	0.3
	(2)		Shrivelled white	2	0	0.3
Total				664	405	100.0

TABLE I. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
25	22	*				
	(1)		Mottled	3	3	0.9
	(7)		Gray	68	59	19.3
	(20)		Gray-brown	231	129	65.6
	(11)		Brown	35	8	9.9
	(2)		Reddish-brown	2	0	0.6
	(2)		Yellow stripe	2	0	0.6
	(1)		Yellow/br. tip	1	0	0.3
	(1)		White/br. tip	5	0	1.4
	(3)		White	3	0	0.9
	(1)		Shrivelled yellow	1	0	0.3
	(1)		Shrivelled white	1	0	0.3
Total				352	199	100.1
26	10	*				
	--		Mottled	--	--	
	(4)		Gray	21	16	18.4
	(9)		Gray-brown	81	63	71.0
	(2)		Brown	7	0	6.1
	(1)		Orange-brown	1	0	0.9
	(2)		Yellow stripe	4	0	3.5
Total				114	79	99.9
27	13	*				
	(2)		Mottled	13	11	11.4
	(1)		Gray	5	4	4.4
	(11)		Gray-brown	85	51	74.6
	(2)		Brown	6	1	5.3
	(1)		Yellow stripe	1	0	0.9
	(1)		White/br. tip	2	0	1.8
	(1)		White	2	0	1.8
Total				114	67	100.2
28	12	*				
	(7)		Mottled	35	28	59.3
	(2)		Gray	10	5	16.9
	(5)		Gray-brown	14	10	23.7
Total				59	43	99.9

TABLE I. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
29	8	*				
	(4)		Mottled	32	25	69.6
	(3)		Gray	7	4	15.2
	(2)		Gray-brown	5	4	10.9
	(1)		Orange-brown	1	0	2.2
	(1)		Yellow stripe	1	0	2.2
Total				46	33	100.1

TABLE II. DATA FROM THE SECOND SEED MATURATION EXPERIMENT FROM JUNE 24 - JULY 27, 1957.

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
3	1	1	-----	---	---	---
4	3	19	-----	---	---	---
5	3	14	-----	---	---	---
6	6	57	-----	---	---	---
7	8	49				
	(4)		Shrivelled yellow	11	0	100.0
9	4	14				
	(1)		Reddish-brown	1	0	5.3
	(1)		Orange-brown	1	0	5.3
	(4)		Yellow	17	0	89.5
Total				19	0	100.1
10	7	23				
	(2)		Brown	11	0	40.7
	(3)		Reddish-brown	5	0	18.5
	(3)		Orange-brown	4	0	14.8
	(1)		Yellow	5	0	18.5
	(1)		Shrivelled yellow	2	0	7.4
Total				27	0	99.9
11	9	32				
	(4)		Brown	16	0	34.0
	(7)		Reddish-brown	19	0	40.4
	(3)		Orange-brown	5	0	10.6
	(3)		Yellow	7	0	14.9
Total				47	0	99.9
12	10	28				
	(8)		Brown	34	0	66.7
	(4)		Reddish-brown	11	0	21.6
	(4)		Yellow	6	0	11.8
Total				51	0	100.1
13	11	68				
	(11)		Brown	125	11	96.2
	(1)		Yellow	1	0	0.8
	(2)		Shrivelled yellow	4	0	3.1
Total				130	11	100.1

TABLE II. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
14	5	72				
	(5)		Brown	80	9	96.4
	(1)		Reddish-brown	1	0	1.2
	(2)		Shrivelled yellow	2	0	2.4
Total				83	9	100.0
15	9	*				
	(1)		Gray	1	1	1.0
	(2)		Gray-brown	5	3	5.0
	(9)		Brown	84	54	84.0
	(1)		Reddish-brown	4	0	4.0
	(2)		Yellow	5	0	5.0
	(1)		Shrivelled white	1	0	1.0
Total				100	58	100.0
16	15	*				
	(7)		Gray	50	37	37.3
	(12)		Gray-brown	54	22	40.3
	(7)		Brown	27	7	20.2
	(2)		White	3	0	2.2
Total				134	66	100.0
17	10	*				
	(8)		Gray	72	52	77.4
	(2)		Gray-brown	10	9	10.8
	(5)		Brown	8	3	8.6
	(1)		Reddish-brown	1	0	1.1
	(2)		Yellow	2	0	2.2
Total				93	64	100.1
18	13	*				
	(3)		Mottled	3	3	1.6
	(10)		Gray	122	85	65.2
	(1)		Gray-brown	13	12	7.0
	(8)		Brown	43	21	23.0
	(4)		Yellow stripe	4	0	2.1
	(2)		Shrivelled yellow	2	0	1.1
Total				187	121	100.0

* The number of capsules were not counted because they had dehisced while drying in paper sacks.

TABLE II. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
19	14	*				
	(8)		Mottled	99	61	57.9
	(9)		Gray	46	38	26.9
	(4)		Gray-brown	17	14	9.9
	(2)		Brown	4	0	2.3
	(2)		Yellow	3	0	1.8
	(1)		White	1	0	0.6
	(1)		Shrivelled yellow	1	0	0.6
Total				171	113	100.0
20	9	*				
	(5)		Mottled	73	49	55.3
	(3)		Gray	20	19	15.2
	(5)		Gray-brown	33	23	25.0
	(2)		Brown	3	0	2.3
	(2)		Yellow	3	0	2.3
Total				132	91	100.1
21	8	*				
	(8)		Mottled	42	26	64.6
	(4)		Gray	18	7	27.7
	(1)		Gray-brown	1	1	1.5
	(1)		Brown	3	1	4.6
	(1)		Shrivelled yellow	1	0	1.5
Total				65	35	99.9
22	10	*				
	(10)		Mottled	36	23	90.0
	(3)		Brown	3	1	7.5
	(1)		White	1	0	2.5
Total				40	24	100.0
23	21	*				
	(21)		Mottled	163	102	90.1
	(4)		Gray	11	8	6.1
	(3)		Brown	3	0	1.7
	(1)		Reddish-brown	1	0	0.6
	(1)		Yellow/br. tip	2	0	1.1
	(1)		Yellow	1	0	0.6
Total				181	110	100.2

TABLE II. (Continued)

Days after capsules have inverted	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds	Per cent of total number of seeds
24	9	*				
	(9)		Mottled	55	40	96.5
	(1)		Reddish-brown	1	0	1.8
	(1)		Shrivelled yellow	1	0	1.8
Total				57	40	100.1
25	14	*				
	(14)		Mottled	72	60	93.5
	(2)		Gray	2	2	2.6
	(2)		Brown	2	0	2.6
	(1)		Shrivelled yellow	1	0	1.3
Total				77	62	100.0
26	8	18				
	(8)		Mottled	28	20	93.3
	(2)		Gray	2	0	6.7
Total				30	20	100.0
27	4	*				
	(4)		Mottled	11	3	91.7
	(1)		Shrivelled yellow	1	0	8.3
Total				12	3	100.0

TABLE III. DATA FROM TREATED LEAFY SPURGE PLANTS IN SPRAYING EXPERIMENT JULY 1 - AUGUST 9, 1957.

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
-3	9,13	2	11	--	--	--
-2	14	3	32	--	--	--
-1	9,10,14,15	8	67	--	--	--
0	16,17	11	108	--	--	--
1	17,18	11	65	--	--	--
2	18	7	58	--	--	--
3	15,19-21	21	187			
	19	(1)	-	White/br. tip	2	0
4	16,19-21	13	97	--	--	--
5	16-21	24	112			
	19	(1)		Dk g br/r t*	3	0
	18	(4)		White	9	0
	17,18,19,21	(4)		Sh. white**	16	0
Total					28	0
6		19	94			
	20	(1)		Mottled	1	1
	20	(1)		Gray	2	1
	17,18	(2)		Dk g br/r t	4	0
	20	(1)		Reddish-brown	1	0
	20,21	(13)		White	50	0
	20	(5)		Sh. white	9	0
Total					67	2
7		42	346			
	19,23	(3)		Mottled	4	4
	17,21,23	(13)		Dk g br/r t	53	1
	18,19	(2)		Orange-brown	7	0
	18-21,23	(16)		Yellow stripe	42	0
	17-20	(9)		Yellow	45	0
	17-19,21,23	(25)		White	321	0
	19,20,23	(4)		Sh. yellow	17	0
	17,18,20	(4)		Sh. white	15	0
Total					504	5

* Dk g br/r t refers to dark gray-brown with reddish tinge.
** Sh. refers to shrivelled.

TABLE III. (Continued)

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
8		32	235			
	18-20,22	(12)		Mottled	33	11
	18,19,22	(10)		Gray	20	3
	20	(1)		Gray-brown	6	1
	18-22	(24)		Dk g br/r t	149	2
	19,20	(4)		Reddish-brown	6	0
	18,20	(2)		Orange-brown	3	0
	18-20,22	(10)		Yellow stripe	38	0
	19	(1)		White stripe	1	0
	18-20	(4)		White/br. tip	13	0
	18-21	(10)		Yellow	51	0
	18-20,22	(11)		White	61	0
	19,20	(4)		Sh. white	9	0
Total					390	17
9		57	392			
	18,21,23,24	(22)		Mottled	95	44
	18-21	(16)		Gray	37	13
	18-23	(47)		Dk g br/r t	374	1
	18,19,23	(4)		Reddish-brown	5	0
	19-21	(5)		Orange-brown	8	0
	18-20,23	(18)		Y & w stripe*	25	0
	18-20	(6)		White/br. tip	8	0
	19-22	(12)		Yellow	27	0
	19-21,23	(14)		White	32	0
	18,20,21	(3)		Sh. y & w**	3	0
Total					614	58
10		29	257			
	19-21	(18)		Mottled	143	84
	19,20	(14)		Gray	44	16
	19,20,23,24	(27)		Dk g br/r t	206	8
	19	(3)		Reddish-brown	4	0
	20	(2)		Y & w stripe	2	0
	19	(1)		White/br. tip	1	0
	20,21	(2)		Yellow	3	0
	19	(3)		White	3	0
	19,20	(3)		Sh. y & w	3	0
Total					409	108

* Y & w stripe refers to yellow and white stripe.
** Sh. y & w refers to shrivelled yellow and white.

TABLE III. (Continued)

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
11		11	376			
	19,20,21,23	(30)		Mottled	339	157
	19,20,21	(19)		Gray	182	1
	19	(1)		Gray-brown	4	0
	19,21,23	(19)		Dk g br/r t	144	5
	19,20	(3)		Reddish-brown	5	0
	23	(1)		Yellow stripe	2	0
	20	(3)		White	4	0
	19,20	(5)		Sh. white	7	0
Total					687	163
12		24	300			
	19-22	(22)		Mottled	391	196
	20,21,22	(14)		Gray	78	2
	20,21,22,24	(14)		Dk g br/r t	61	4
	21	(1)		Reddish-brown	1	0
	20,21	(3)		White/br. tip	4	0
	20,21	(4)		White	5	0
	19,20,21	(3)		Sh. white	5	0
Total					545	202
13		27	315			
	20,21,22	(27)		Mottled	498	156
	21,22	(12)		Gray	34	3
	21,22,23	(14)		Dk g br/r t	28	0
	20	(1)		Reddish-brown	1	0
	21	(1)		Orange-brown	1	0
	22	(3)		White stripe	3	0
		(1)		White/br. tip	2	0
	21,22	(2)		White	3	0
	20,21,22	(4)		Sh. white	6	0
Total					576	159

TABLE III. (Continued)

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
14		14	167			
	21,22,23	(14)		Mottled	233	88
	21,22	(4)		Gray	7	3
	21	(4)		Gray-brown	32	1
	21,22,23	(6)		Dk g br/r t	8	0
	21	(1)		Reddish-brown	1	0
	21	(1)		Yellow/br. tip	1	0
	21	(1)		Yellow	2	0
	21	(1)		Sh. yellow	1	0
Total					285	92
15		13	195			
	22	(13)		Mottled	300	69
	22	(2)		Gray	3	0
	22	(6)		Gray-brown	17	0
	22	(5)		Dk g br/r t	8	1
	22	(4)		Reddish-brown	8	0
	22	(1)		Yellow	2	0
	22	(1)		White	1	0
	22	(3)		Sh. y & w	3	0
Total					342	70
16		21	146			
	23	(20)		Mottled	200	85
	23	(4)		Gray	5	1
	23	(4)		Gray-brown	16	1
	23	(5)		Dk g br/r t	6	0
	23	(2)		Reddish-brown	2	0
	23	(1)		White	1	0
	23	(3)		Sh. white	4	0
Total					234	87
17&18		7	33			
	24,25	(7)		Mottled	50	19
	24,25	(2)		Dk g br/r t	3	0
Total					53	19

TABLE IV. DATA FROM NONTREATED LEAFY SPURGE PLANTS IN SPRAYING EXPERIMENT JULY 1 - AUGUST 9, 1957.

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
4		5	51			
	20,21	(5)		Mottled	48	35
	20,21	(2)		Gray	5	4
	20,21	(4)		Dk g br/r t*	5	0
	21	(1)		Dark brown	2	1
	21	(1)		Yellow	3	0
Total					63	40
5		3	22			
	21,23	(3)		Mottled	32	18
	21,23	(2)		Gray	3	3
	21	(2)		Dark brown	3	0
	21	(1)		White	1	0
Total					39	21
6		3	11			
	22	(3)		Mottled	22	7
Total					22	7
7		4	25			
	22,23	(2)		Mottled	22	14
	19,21	(2)		Gray	16	11
	19	(1)		Dk g br/r t	4	1
	19,21,23	(3)		Dark brown	7	0
	19	(1)		Yellow	1	0
	23	(1)		White	2	0
Total					52	26
8		6	55			
	22,24	(6)		Mottled	67	46
	22	(1)		Gray	13	0
	22,24	(3)		Brown	6	1
	22	(1)		White	3	0
Total					89	47
9		6	11			
	20,23	(6)		Mottled	51	46
	20,23	(2)		Gray	2	1
	(23)	(1)		Gray-brown	2	1
	(20)	(2)		Dk g br/r t	2	0
Total					57	48

* Dk g br/r t refers to dark gray-brown with reddish tinge.

TABLE IV. (Continued)

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
10		13	142			
	21,22	(13)		Mottled	250	121
	21	(5)		Gray	21	16
	21	(3)		Dk g br/r t	6	1
	21	(2)		Dark brown	7	1
	21	(2)		Yellow	4	0
	21	(2)		White	2	0
	21	(1)		Sh. yellow**	1	0
Total					291	139
11		8	93			
	20,22	(7)		Mottled	155	101
	22	(4)		Gray	5	4
	22	(4)		Dk g br/r t	5	1
	22	(1)		Reddish-brown	1	0
	22	(1)		Yellow	1	0
	22	(1)		Sh. yellow	1	0
Total					168	106
12		7	103			
	20,21	(7)		Mottled	321	226
	21	(1)		Gray	10	5
	20,21	(5)		Dk g br/r t	22	1
	20	(1)		Brown	2	0
	20	(1)		Dark brown	5	0
	20	(1)		White stripe	1	0
	20,21	(1)		White	3	0
	21	(1)		Sh. yellow	1	0
Total					365	232
13		9	82			
	21,22	(9)		Mottled	143	84
	21	(2)		Gray	4	3
	21	(3)		Dk g br/r t	6	1
	21	(1)		Brown	4	1
	21	(2)		Dark brown	3	0
	21	(1)		White stripe	1	0
	21	(1)		White	1	0
Total					162	89

** Sh. refers to shrivelled.

TABLE IV. (Continued)

Days after capsules inverted spraying occurred	Days after capsules inverted harvesting occurred	Number of plants	Number of capsules	Color of seeds	Number of seeds	Number of viable seeds
14		7	77			
	21,22,23	(7)		Mottled	129	70
	21	(2)		Gray	3	1
	21	(1)		Gray-brown	1	0
	21	(2)		Brown	8	2
	21,22	(2)		Dark brown	1	0
	21,22	(2)		White stripe	2	0
	21	(1)		Yellow	1	0
Total					145	73
15		6	123			
	22,23	(6)		Mottled	221	100
	21	(3)		Dk g br/r t	8	1
	21	(1)		Brown	4	0
	22	(1)		Reddish-brown	1	0
	21	(1)		Yellow	5	0
	21	(1)		White	3	0
	21	(1)		Sh. yellow	1	0
Total					243	101
16		4	36			
	22,23	(4)		Mottled	53	21
	22	(1)		Gray	2	1
	23	(1)		Brown	6	0
	23	(1)		Reddish-brown	2	0
	23	(1)		Yellow	1	0
Total					64	22
17&18		7	71			
	23,24	(7)		Mottled	107	99
	23	(1)		Gray	1	1
	23,24	(3)		Dark gray	3	0
	23	(2)		Brown	4	0
Total					115	100