A STUDY OF ALFALFA SEEDING TIME IN RELATION TO CROP ESTABLISHMENT

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A STUDY OF ALFALFA SEEDING TIME IN RELATION TO CROP ESTABLISHMENT

by

JOHN EDWARD FRITH

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INTRODUCTION

The real core of the rotation on any farm in Michigan is its sod crops, especially the legumes which produce high quality roughage, aid in erosion control and maintenance of soil organic matter.

Alfalfa, in the last few decades, has become Michigan's most valuable and dependable hay and pasture legume. With the increased emphasis in recent years on "grassland" farming its use may even become more important. U.S. Census (27) figures show that the alfalfa acreage, cut for hay, in Michigan has grown from 6,553 acres in 1910 to 524,657 acres in 1930, and 1,179,987 acres in 1945.

One of the main problems in alfalfa production is the establishment of successful seedings. Each section of the world has environmental factors, climate, soil and crop relationships peculiar to that area. Within limits, soil can be tailored to fit a crop; but as yet man has not materially changed the climate. Therefore, the purpose of this experiment is to study the relationship of seeding time to alfalfa establishment under East Lansing, Michigan conditions.

REVIEW OF LITERATURE

Many studies have been made concerning the effect of the rate of planting, the depth of planting, method of seeding, the pH of the soil, the fertility levels of the soil, clipping or grazing in the year of seeding, low temperature, ice, and adapted varieties of seed on establishment and/or maintenance of alfalfa stands. However, little work has been done on the effect of the time of seeding on stand establishment.

One of the earliest references to the time of seeding is in the Bible; Ecclesiastes 11:6, (2), "In the morning sow thy seed, and in the evening withhold not thy hand; for thou knowest not whether shall prosper, either this or that, or whether they both shall be alike good."

Two other Biblical references (2), which blanket the whole subject, are The Parable of the Sower, Mark 4:3-8, and Genesis 8:22, "While the earth remaineth, seed time and harvest, cold and heat, summer and winter, and day and night shall not cease."

Thatcher et al (25) and Willard (30) of Ohio found that the stand count was a better measure of surety of a method of seeding than was the yield of hay in the first year after seeding. It has the further advantage of giving significant data without carrying experiments through to a hay crop.

"Alfalfa in Michigan" (1) and Sewell (24) recommend a good seed bed, about 7 inches deep, firm to the depth of the furrow slice.

Moore (19) Murphy and Arny (20) found that ¼ to ½ inch deep plantings gave optimum emergence of alfalfa.

Rate of seeding recommendations range from 5 to 8 pounds per acre by Dexter (7) to 10 to 12 pounds per acre in the Ohio "Handbook of Experiments in Agronomy" (22).

Musbach and King (21) in their study conclude that the temperature conditions and the distribution as well as the overall amount of rainfall must be considered in interpreting one or two years seeding data.

Milton (18), of Wales, found that the amount of rain subsequent to any sowing played as important a part in effecting soil germination as did the temperature.

Relationships were:

High temperature and low rain--poor germination;

High temperature and adequate rain--best germination.

Given the same temperature for two periods, the one with the most rain will give the best germination.

Dunn (8) working with Smooth Vetch and Sweet Clover, found that while freezing weather softens hard seed, especially in moist soil, the seeds which have absorbed enough water to swell were either injured or killed by freezing. He also found that the permeable seeds produce radicles at temperatures slightly above freezing.

Coffman (5), in Kentucky, found that though alfalfa germinated to a limited degree at 32 to 34°F. it was very weak. Good germination and strong seedlings started at about 40°F.

Sellshop and Salmon (23) found frost and freezing caused more severe injury on wet than dry ground.

Sellshop and Salmon (23) and Tysdal and Pieters (26) found that young

plants were more sensitive than older ones.

Midgley (17) in work with alfalfa and dodder found that in alternate freezing and thawing, above 23°F. the first freeze was the most effective in increasing permeability of hard seed. He also found that continued moisture for about two months, without freezing, was as effective in reducing hard seed as alternate freezing and thawing.

Liggatt (15) and (16), of Alberta, found that during the first growing season hard seeds had only 50% of the agricultural value of the permeable but in the long haul were equal. Additional germination after the winter was entirely due to hard seeds.

Harrington (10) found that impermeable seeds go through the winter in a frozen condition and germinate 50 to 60% the following spring.

Hellowell (12) found that interspersing of short rainy periods with rapid drying of a soil surface and dry weather are fatal to germinating seeds and young seedlings.

The literature on time of planting, coming from widely different climatic conditions, is in considerable disagreement.

Kiesselbach and Anderson (14), of Nebraska, found that seeding alone was most dependable. Best seeding time was either spring or early fall if condition were favorable for prompt germination and continued fall growth. Seeding after September 1 increased the danger of winter killing.

Brooks (3), in Massachusetts, reports that late summer sowing on carefully prepared seedbeds are the least risky.

Hansen (9) found in 8 years work that under irrigation in Montana fall seeding in oat stubble out-produced spring seedings.

In Idaho work (13) broadcasting without a nurse crop proved best.

With proper tillage, seedings up to July gave satisfactory stands. Fall seedings or seedings on snow or honey-combed soil gave poor stands.

Cox and Megee (6) state that for summer seedings, seedbeds must be weed free before planting. They found that seedings after mid August were more apt to winter kill in the northern states.

Haynes (11), in Ohio work concluded that the high freezing risk of March seedings could be avoided by broadcasting half of the seeding early and drilling the remainder later.

Hollowell's (12) studies with low hop clover in Missouri, North Carolina and Kentucky show that even in the favorable years December, January and February seedings produced good stands, but spring growth was unsatisfactory. September and October Seedings gave the best results.

EXPERIMENTAL PROCEDURE

Preliminary work on this experiment was begun in July 1948. Two lots of certified Grimm alfalfa seed were secured. One with a very low percentage of hard seed, with 79% quick germination and 10% hard seed, was secured from Montana. The other, with 48% quick germination and 51% hard seed, was secured through the Michigan Crop Improvement Association.

The seedbed was prepared in the normal manner by plowing, dragging and cultipacking. Seedings were made directly on the seedbed without fertilizers or any additional seedbed preparation except that weeds were hoed off on the plots to be planted the day the plantings were made. During the winter months, the ice and snow was removed before planting. Except on the frozen ground, seed was raked lightly with a garden rake to cover it..

Seed, after inoculation, was planted on duplicate six by six foot plots at the rate of ten pounds per acre every two weeks beginning August 14, 1948 and ending July 30, 1949. Seeding was done by mixing the seed with sand and distributing it as evenly as possible with a large salt shaker using a criss-cross pattern.

At the time of planting a counted package of 200 seeds of the same lot was buried in each plot, to be dug up at later dates and examined. These seeds were placed in a water permeable celophane tube in a paraffin impregnated cardboard tube with its ends plugged with cotton, so that moixture could get to the seed and yet the seed could be recovered. Seed packets were dug up on November 6, 1948, March 15, 1949 and October 29, 1949 for examination. Because of poor technique and planning, samples one to six were only estimated since they appeared in solid-moldy masses. The other samples were checked for the number germinated in the field, the number of seeds molded and the number not molded. Germination on these were run in the germinator both for quick and total germination.

Stand counts of plants per square foot were taken by means of a one square foot counting ring on November 2, 1948, August 24-27, 1949, November 5-9, 1949 and May 26-31, 1950.

At the same time the November 1949 stand counts were taken, height measurements were made to the nearest inch and comparative photographs of representative plants were taken.

Soil analysis was run in the soils laboratory with the results of pH ranging from 6.9 to 7.8. Soil type had previously been determined by a Soils Department survey to be Conover Loam.

Daily soil moisture and soil temperature readings (at the depth of 1 inch) for the duration of the experiment were taken from Hydrologic Survey data on an alfalfa sod which was on slightly lighter soil with a northern exposure.

Rain-fall and air temperature data was obtained from the East Lansing U.S. Weather Bureau Station reports.

To obtain additional data on the effect of late winter and early spring conditions in planting, beginning January 15, 1948, 100 alfalfa seeds were planted in duplicate 6 inch clay pots and placed out of doors for 4 weeks and 6 weeks respectively. Plantings were continued through April 23, 1948. At the end of 4 weeks one culture was brought into the green-house. At the end of 6 weeks the duplicate culture was brought in. Observations, stand counts and pictures were made on the plantings through those of March 26, 1948.

EXPERIMENTAL RESULTS

Weather and Ground Conditions

The fall of 1948 was dry with only .11 inch rain in August after the 15th and less than half normal rain-fall in September and October. Along with this dryness the last half of August was 7° above normal and September averaged 4° above normal. Early October was cold with light frosts on the 4th, 5th, 14th and 17th. The first killing frost was on the 18th. Late October was warm. The November temperature with a mean of 42.9°, was the highest on record. The rain-fall was average.

The winter of 1948-1949 was quite open with temperatures averaging from 2 to 6°F. above normal and with snow-fall averaging about 5 inches per

month below normal.

March 1949 was approximately normal with the usual up and down fluctuations of temperature with a low (10°) on the 1st and a high (71°) on the 29th.

April was of average temperature for the season but three quarters of the rain-fall came from the 14th through the 18th and left the first and last parts of the month dry. Light frosts occurred on the 10th, 17th and 28th. The last snow of the winter occurred on the 17th of the month.

May started hot and dry with a record high for so early in the season. On May 6th the temperature was 89°F. Three quarters of the monthly rain-fall occurred on the 18th and 19th. A heavy frost came on May 11th and light frosts came on the 26th and 29th.

Early June continued warm and dry, with the last light frost of the season occurring on June 8th.

Late June and July were warm with adequate rain-fall.

August 1949, though normal in temperature, was the second driest since 1934.

September continued dry with slightly below normal temperatures. First frosts of the season came on September 24th and 29th.

October 1949 was one of the warmest on record with the 9th, 10th and 11th all going over 80°F. The dry spell was broken on the 3rd. A killing frost came on the 25th and the first trace of snow on the 31st.

November precipitation and temperature averages were near normal. However, November 20th was below normal and a record low of -5.1°F. was set on the 26th. There was a snow-fall of 7.8 inches on Thanksgiving Day.

Though December 1949 and January 1950 were both warmer and wetter than normal, snow-fall was below normal. Only 29 days of December and January averaged below freezing temperatures with a December high of 62° and a January record high of 65°F.

February was variable, starting warm and ending cold. It had more snow than any other month of the winter.

March had normal rain-fall with the last snow on the 27th and slightly below normal temperature ranging from a minimum of 3° to a maximum of 50° in a variable fashion. The average was 28.2°F.

April 1950 was one of the coldest and wettest on record.

May was average in temperature and below normal in rain-fall which was scattered.

The monthly summary of rain-fall, table I, shows that both the fall and spring of the year the seedings were made in, August 1948-July 1949, were below normal in amount of rain-fall.

Table I. RAIN-FALL BY MONTH

Month	Year	Amount of precipitation in Inches		
		Total	Above average	Below average
August	1948	1.86"		.96"
September		1.62		1.29
October		1.01		1.46
November		2.49	.01	
December		2.23	.16	
January	1949	3.48	1.66	
February		2.47	.57	
March		2.61	.26	
April		1.87		.71
May		2.35		1.07
June		4.89	1.38	
July		4.78	1.68	
August		1.61		1.21
September		1.91		1.00
October		2.35		.12
November		1.60		.88
December		4.70	2.63	
January	1950	3.61	1.79	
February		3.34	1.44	
March		2.39	.04	
April		4.53	1.95	
May		1.96		1.46

As shown in table II the first killing frost in the fall of 1948 came one week later than the average; the one in the spring of 1949 came on May 11th, 9 days later; and the fall 1949 first killing frost was two weeks later than average.

Though table II from weather reports (29) and field observations show considerable glazing in the winter months, only twice was it found necessary to use a shovel or pick to remove ice or crusted snow from the plots in order to make a seeding on the scheduled day. Those were February 1, 1949, snow, and February 12, ice.

Soil moisture, soil temperature and air temperature are the three most important climatic factors affecting seeding time of alfalfa. Bi-weekly averages of these are shown in Graph I for the period beginning with August 1948 and extending through May 1950. The ground being frozen from March 1 to 26, 1948 and from the middle of January to the middle of April, 1950 made the ground moisture percentage figures for those periods unobtainable.

WINTER CULTURES

Seedings of 100 alfalfa seeds were made during the winter in 6 inch clay pots and immediately put outdoors for 4 and 6 weeks respectively before bringing back into the green-house. Lot I contained the high percentage of hard seed and Lot II the low percentage of hard seed. As shown in Table III, the winter plantings made out-doors did not germinate until late February. Plantings made as late as March 26 were frosted.

Table II. DATES OF FROST AND ICE ON GROUND
From Weather Reports and Field Observations

Date		Condition
October	4, 1948	Light frost
	5	Light frost
	14	Heavy frost
	17	Light frost with trace of snow
	18	Killing frost
December	14	Glazed
	15	Glazed
January	15, 1949	Glazed and frozen ground
	17	Glazed
	18	Glazed
	23	Glazed
	25	Glazed
February	1	Snow crusted
	12	Glazed (used pick before seeding)
	14	Glazed
	21	Glazed
	22	Glazed
March	2	Glazed
	9	Glazed
	26	Frost out 1 inch
April	9	Frost out
	10	Light frost
	17	Light frost
	28	Light frost
May	11	Heavy frost
	26	Light frost
	28	Light frost
	29	Light frost
June	8	Light frost
September	24	Light frost
	29	Light frost
October	25	Killing frost
November	26	Glazed
	27	Glazed
December	6	Glazed
	7	Glazed
	10	Glazed
	22	Glazed
January	4, 1950	Glazed
	15	Glazed
	23	Glazed
	24	Glazed
February	13	Glazed
	14	Glazed
	21	Glazed
April	10	Glazed

GRAPH NUMBER I

WEEKLY AVERAGES OF GROUND and AIR TEMPERATURES
and GROUND MOISTURE , AUGUST 1948 - MAY 1950

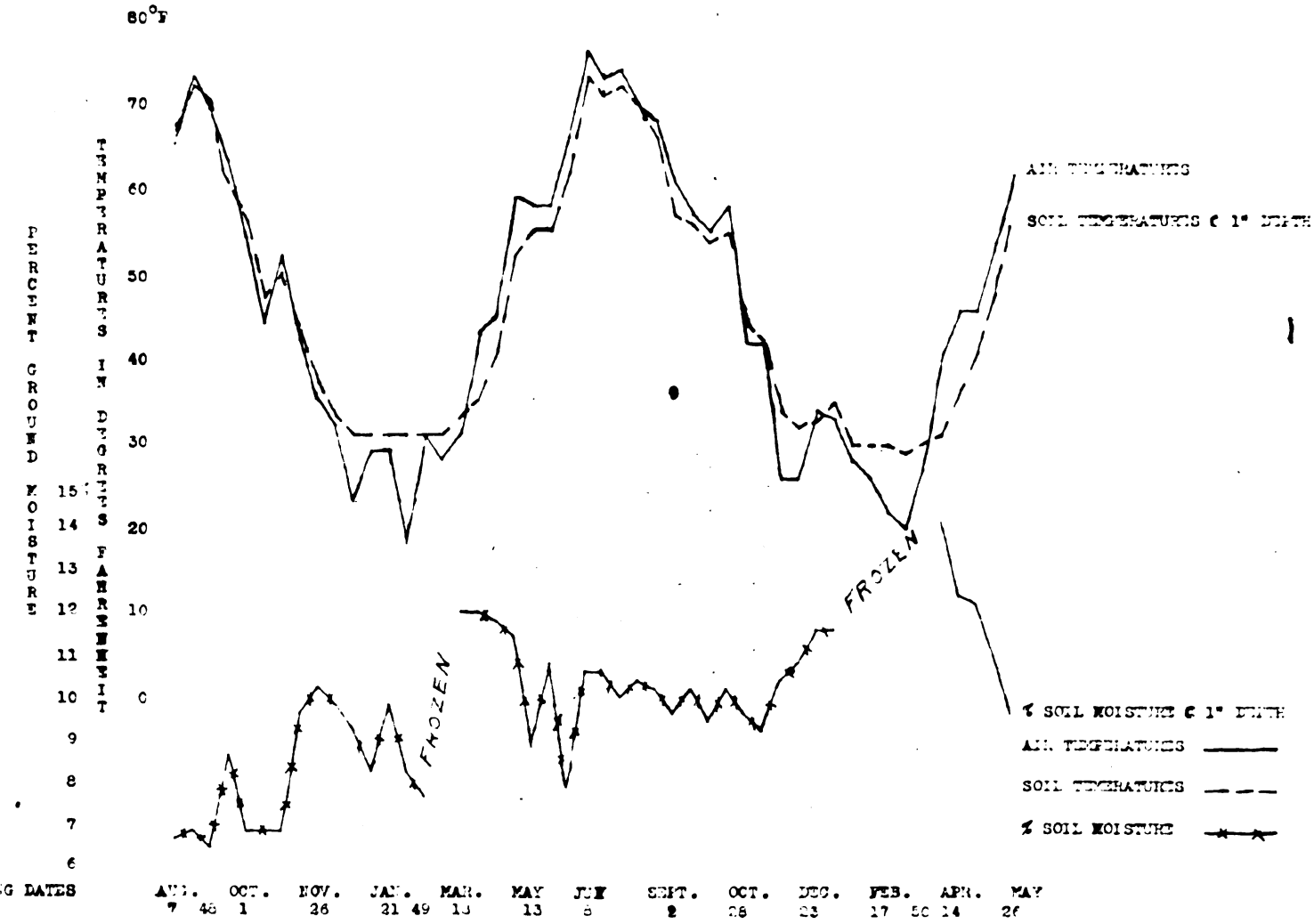


Table III. POT SEEDINGS OF 100 SEEDS

Date Planted	Lot	Date Into Greenhouse	Number Seedling Plants Starting Outdoors	Indoors	Total	Comment
Jan. 15	I	Feb. 12		75	75	
		Feb. 26		54	54	
	II	Feb. 12		47	47	
		Feb. 26		21	21	
Feb. 1	I	Feb. 26		60	60	
		Mar. 12		58	58	
	II	Feb. 26		49	49	
		Mar. 12		52	52	
Feb. 12	I	Mar. 12		38	38	
		Mar. 26		66	66	
	II	Mar. 12		47	47	
		Mar. 26		47	47	
Feb. 26	I	Mar. 26		39	39	Uneven size, damping off
		Apr. 9	35	6	41	Frosted and killed 35
	II	Mar. 26		51	51	Even size, no damping off
		Apr. 9	32	1	53	Frosted and killed 32
Mar. 12	I	Apr. 9	37	2	39	Frosted and killed 33
		Apr. 23	41	2	43	Frosted and killed 41
	II	Apr. 9	23	15	38	Frosted and killed 9
		Apr. 23	26	1	27	Frosted and killed 26

To show the results of the winter seedings being left out in the winter temperatures for varying lengths of time, pictures were taken of the cultures, and those from two representative planting dates Figures 1 and 2, comparing the effect on both Lot I and Lot II, were used.

FIGURE I WINTER ALFALFA CULTURES

Lot Number	I	I	II	II
Date Planted - January 15, 1949				
Left Outdoors	4 weeks	6 weeks	4 weeks	6 weeks
Viable Plants	75%	54%	47%	21%

Lot I - High % Hard Seed Lot II - Low % Hard Seed

FIGURE II WINTER ALFALFA CULTURES

Lot Number	I	II	I	II
Date Planted - February 26, 1949				
Left Outdoors	4 weeks	4 weeks	6 weeks	6 weeks
Viable Plants	39	51	6	1
Number Frosted and killed	0	0	35	32

Figures I and Figure II show quite definitely that plantings left outdoors for the shorter time, 4 weeks, in the winter temperatures gave a higher final stand count, in most cases, than those left out for 6 weeks.

BURIED SEED PACKETS

Not much useful information was obtained from the buried seed packets. The first three plantings were only estimated as they were solid masses of mold. September 25th and October 29th plantings had good ground germination and the germination of those put in the germinator brought them up to about 75% total germination. October 9th was the last moldy one. October 23rd plantings, Lot I -13, Lot II -6, germinated in the ground and both had a total germination of over 80%. November through January 15th plantings neither germinated in the ground in the packets or in the germinator over 4%. January 29th Lot I germinated 85% in the ground and 1% in the germinator and Lot II 23% identifiable in the ground, with a mass of disintegrated material also in the tube, and 1% in the germinator. Plantings from February on were useless as the tubes were full of dirt and angleworms and in many cases the tubes had broken down.

STAND COUNTS AND FIELD OBSERVATIONS

Four stand counts were taken:

The first, on November 2, 1948, was of plantings through October 23, with August and both September plantings giving good counts. August 28th gave the highest count in both seed lots. The September 25th planting was just in the cotyledon stage.

The second count, in August 1949, was through the May 21st planting. Lot I seedings gave counts of 10 plants per square foot or better on August 14th and 28th, February 26, and April 9th through May 21st. Lot II seedings gave counts of 10 or better on August 28th, and April 23rd

through May 21st. Only the August 14th seeding gave a higher count for Lot II.

The third count, in November 1949, gave counts for Lot I of 10 or better on all seedings between February 26th and August 28th with the highest counts coming in April, early May and July. Lot II counts of 10 or over occurred between April 9th and July 30th except for the June 4th seeding.

The final count, shown in Table IV, in May 1950, gave Lot I counts of over 10 square foot on August 14th, April 9th, July 2nd and 16th and Lot II counts of over 10 per square foot on August 14th and April 9th.

Graphical presentation of these counts is given in Graph II.

On November 2, 1948, some of the October 9th planting was observed to be just coming through the soil.

On November 20th, an occasional sprout from the October 23rd planting could be seen.

At the time of the December 4th seeding, only the August and September 11th seedings looked satisfactory.

The ground did not begin to freeze in the plots until the 1st of January and was completely frozen the 15th of January. Frost in the soil had started to go out by the 26th of February, and was completely out by April 9th.

The first new plants, including the April 9th planting, were observed on April 23rd.

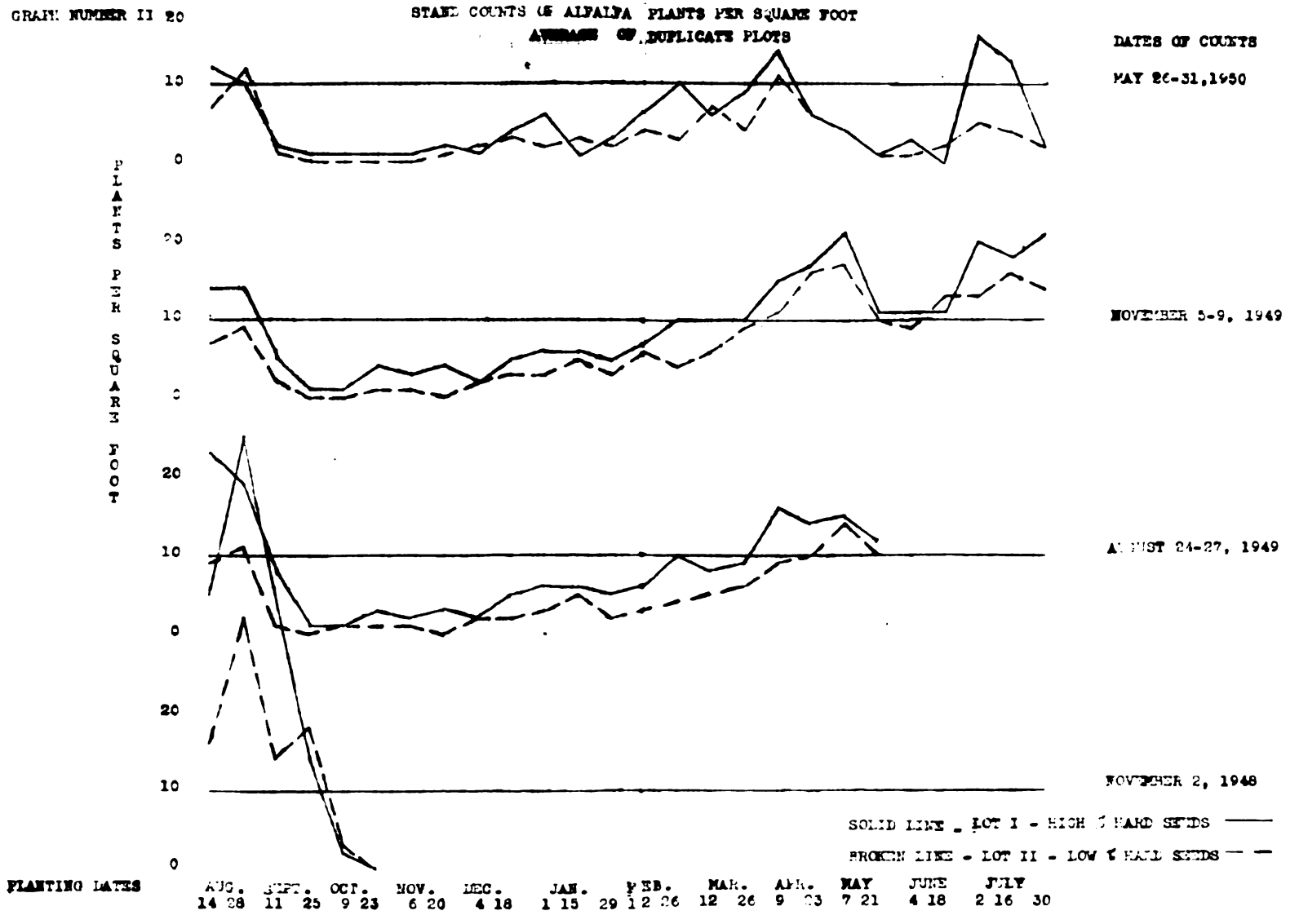
From May 21st on it was necessary to remove the weeds with a wheelhoe before making the planting.

Table IV FINAL STAND COUNT

Average of Duplicate Plots
May 26-31, 1950

Date of Planting	Lot Number	Plants per Square Foot
August 14, 1948	I	12
	II	7
28	I	10
	II	12
September 11	I	2
	II	1
25	I	1
	II	0
October 9	I	1
	II	¼
23	I	1
	II	¼
November 6	I	1
	II	¼
20	I	2
	II	1
December 4	I	1
	II	2
18	I	4
	II	3
January 1, 1949	I	6
	II	2
15	I	1
	II	3
29	I	3
	II	2
February 12	I	4
	II	4
26	I	10
	II	4
March 12	I	6
	II	7
26	I	9
	II	4
April 9	I	14
	II	11
23	I	6
	II	6
May 7	I	4
	II	4
21	I	1
June 4	II	1
	I	3
	II	1
18	I	¼
	II	2
July 2	I	16
	II	5
16	I	13
	II	4
30	I	2

*Lot I--
High % Hard seed
Lot II
Low % Hard seed


GRAIN NUMBER II
STAND COUNTS OF ALFALFA PLANTS PER SQUARE FOOT
AVERAGE OF DUPLICATE PLOTS
PLANTS PER SQUARE FOOT
20
10
0
20
10
0
20
10
0
20
10
0
DATES OF COUNTS
MAY 26-31,1950
NOVEMBER 5-9, 1949
AUGUST 24-27, 1949
NOVEMBER 2, 1948
SOLID LINE - LOT I - HIGH % HARD SEEDS
BROKEN LINE - LOT II - LOW % HARD SEEDS
PLANTING DATES
AUG. 14 28
SEPT. 11 25
OCT. 9 23
NOV. 6 20
DEC. 4 18
JAN. 1 15 29
FEB. 12 26
MAR. 12 26
APR. 9 23
MAY 7 21
JUNE 4 18
JULY 2 16 30

DISCUSSION

The stand count, plants per square foot, was used as a final measure of crop establishment. Even though there can be some variation in stand with no significant change in yield (30), the stand count shows which time or times of seeding are most apt to give satisfactory stands without carrying the crop through to maturity. It also, by being repeated at intervals, gives changes in stand.

Seeding too late in the fall gives unsatisfactory stands. Either the alfalfa plant does not get enough growth to build up an ample food reserve and is winter killed, or it is so small and tender that it is killed by the fall frosts.

The winter being open, and slightly above average temperature, probably resulted in swelling and sprouting of seed sown in the late fall and winter and early spring, thus causing them to be killed in the next cold snap.

Early summer seedings ran into rather heavy weed competition. Summer seedings would have a better chance of getting established if the seedbed was prepared shortly before seeding rather than the fall before.

Height measurements taken on summer and early fall seedings in the same year a seeding is made would be of value in determining desirable height for winter survival. However, as taken in this experiment, in the second fall, the value is much less because the late summer and early fall seedings have already survived one winter. The rest have had nearly a full season to get established.

CONCLUSIONS

1. Seed lots having a high percentage of hard seed give as good or better stand under central Michigan conditions as do those with an extremely low percentage of hard seed, particularly in the late June and July seedings, and the very early spring seedings.

2. Early summer seedings were unsatisfactory due to water deficiencies and weed competition.

3. According to the data of this experiment, the first two weeks of April and the period of July and August give the best chance for good alfalfa establishment.

BIBLIOGRAPHY

1. Alfalfa in Michigan. Mich. Agr. Exp. Sta. Cir. Bul. 154, 1936.

2. The Bible.

3. Brooks, W.P., Alfalfa. Mass. Sta. Bul. 154, 1914.

4. Bouyoucos, G.J. and Mick, A. H., An Electrical Resistance Method for Continuous Measurement of Soil Moisture Under Field Conditions. Mich. Agr. Exp. Sta. Tech. Bul. 172, 1940.

5. Coffman, F. A., The Minimum Temperature of Germination of Seeds. Jour. Amer. Soc. Agron. 15:257-270, 1923.

6. Cox, J.F. and Megee, C.R., Alfalfa, p. 36-37, Wiley and Sons, New York, New York, 1928.

7. Dexter, S. T., What Makes Better Alfalfa. Mich. Ext. Fold. 61, 1943.

8. Dunn, L.E., Influence of Low Temperature Treatments on the Germination of Seeds of Sweet Clover and Smooth Vetch. Jour. Amer. Soc. Agron. 31:687-694, 1939.

9. Hansen, D., Work with Field Crops on Huntley Reclaimation Project Experiment Farm, U.S.D.A., B.P.I., Work Huntley Expt. Farm., 1917.

10. Harrington, G.T., Agricultural Value of Impermeable Seeds. Jour. Agri. Res. 6:761-796, 1916.

11. Haynes, J., Band Seeding--Key to Better Legume Stands. Successful Farming, 51:38, 39, 90, 1953.

12. Hollowell, E.A., The Establishment of Low Hop Clover, Trifolium Procumbens, as Affected by Time of Seeding and Growth of Associated Grasses. Jour. Amer. Soc. Agron. 30:589-598, 1938.

13. Field Crop Work in Idaho, 1923. Idaho Sta. Bul. 133, 1924.

14. Kiesselbach, T.A. and Anderson, A., Alfalfa in Nebraska. Neb. Agr. Exp. Sta. Bul., 222, 1927.

15. Liggatt, C.W., The Agricultural Value of Hard Seeds of Alfalfa and Sweet Clover Under Alberta Conditions. Sci. Agri. 8:243-366, 1927.

16. Liggatt, C.W., The Agricultural Value of Hard Seeds of Sweet Clover in Alberta. Sci. Agri. 9:683, 1929.

17. Midgley, A.R., Effect of Alternate Freezing and Thawing on the Impermeability of Alfalfa and Dodder Seeds. Jour. Amer. Soc. Agron. 18: 1087-1089. 1926.

18. Milton, W.E.J., An Investigation into the Soil Germination and Yield of Certain Crucifers, Clover, Italian Rye-Grass and Chicory Sown at Three-Weekly Intervals from May to November, 1925. The Jour. of Agri. 4:222-242, 1928.

19. Moore, R.P., Seedling Emergence of Small Seeded Legumes and Grasses. Jour. Amer. Soc. Agron. 35:370-381. 1943.

20. Murphy, R.P. and Arny, A.C., The Emergence of Grass and Legumes Planted at Various Depths in Five Soil Types. Jour. Amer. Soc. Agron. 31:17-28, 1939.

21. Musbach, F.L. and King. M.L., The Weather as a Factor in Crop Production. Jour. Amer. Soc. Agron. 16:381-383, 1924.

22. Handbook of Experiments in Agronomy. Ohio Exp. Sta. Spec. Cir. 53. 1938.

23. Sellshop, J.P.E. and Salmon, S.C., The Influence of Chilling Above the Freezing Point on Certain Crops. Jour. Agr. Res. 37:315-338, 1928.

24. Sewell, M.C., Tillage--A Review of the Literature. Jour. Agr. Res. 11:269-290, 1919.

25. Thatcher, L.E., Willard, C.J. and Lewis, R.D., Better Methods of Seeding Meadows. Ohio Agri. Exp. Sta. Bul. 588, 1937.

26. Tysdal. H.M. and Pieters. A.J., Cold Resistance of Three Species of Lespedeza Compared to that of Alfalfa, Red Clover and Crown Vetch. Jour. Amer. Soc. Agron. 26:923-928, 1934.

27. U.S. Census, 1945 and 1950.

28. U.S.D.A., S.C.S. in Cooperation with Michigan Agr. Exp. Sta. Michigan Hydrologic Research Project.

29. U.S. Weather Bureau, East Lansing, Michigan Station.

30. Willard, C.J., The Correlation Between Stand and Yield of Alfalfa and Sweet Clover. Jour. Agr. Res. 43:461-464, 1931.

ROOM USE ONLY