THE EFFECT OF DATE OF SEEDING ON PLANT DEVELOPMENT AND WINTER SURVIVAL OF FALL SEEDED GRASSES AND LEGUMES

by

HAROLD EVERETT TOWER

B. S., Montana State College, 1928

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1932

TABLE OF CONTENTS

INTRODUCTION

The seeding of small-seeded grasses and legumes in the fall of the year, is a desirable practice throughout much of the humid, tame-pasture region of the middle west. (1), (2), (4), (5), (8). Compared to seeding in the spring of the year, fall seeding in this region is preferred for several reasons. First, weather conditions during the fall are usually more favorable to the establishment of stands than they are in the spring of the year. Spring plantings are often seriously injured because the plants do not have time to develop sufficiently to enable them to withstand the dry, hot periods of the summer. Second, weeds, which are often very troublesome in spring plantings, are quite well controlled when fall seeding is practiced, providing good stands are secured. Third, fall seeding affords opportunity to grow a small grain crop during the spring, and then, if weather conditions are favorable, to properly prepare the ground and seed it to grass or legumes in the early fall of the same year. Fourth, plantings made in the fall will produce considerably more growth the following year than will spring plantings.

However, certain risks also accompany fall seeding so much plantings are not always successful. Dry and hot weather during August and early September is not uncommon and may cause considerable damage to early plantings. For this reason, delayed seeding to avoid the drought period is advisable. If seeding is delayed until too late in the fall, however, there is danger of the plants winterkilling. The best time to seed, then, from the standpoint of the establishing of stands, would be as late in the fall as possible --to avoid the drought period--yet early enough to afford the plants sufficient time to develop to a stage where they can survive the winter. Just how late in the fall the seeding of different grasses and legumes may be done, with assurance that the plants will not winterkill, is not definitely known.

The purpose of this study was to obtain information as to the best time of seeding. The work was conducted with two principal objects in view: first, to obtain quantitative data on the relative plant development of certain adapted grasses and legumes, sown at successive intervals in the fall of the year, and second, to determine the relation of the plant development to winter survival.

Inasmuch as plant growth is mainly dependent upon soil and weather conditions, careful observations of these were made during the growth period.

It is realized that the results of one year cannot be considered as conclusive. However, they should indicate what might be expected in years when similar conditions prevail.

REVIEW OF LITERATURE

It appears that few studies have been made for the purpose of obtaining definite information on the relation of root development to winter survival of fall sown crops. Keim and Beadle (4) have reported on work which was conducted at Lincoln, Nebraska, during the fall of 1925, to determine the relation of time of seeding different grasses and legumes in the fall of the year to their root development and winter survival. Seven different dates of plantings, during the period from August 1 to October 26, of brome grass, timothy, Kentucky blue grass, alfalfa, sweet clover and red clover, were included in their study. They found that successively less above-ground and below-ground growth was made with increased lateness of planting. Winter survival was found to be closely correlated with fall root development so only those plantings which had vigorous root systems were able to survive. Later seedings of grasses were found to be more successful in surviving the winter than were similar seedings of legumes, even though the legumes made a deeper root growth.

Janssen (3) conducted studies at Wisconsin on the effect of date of seeding winter wheat on plant development and its relation to winter hardiness. He found that root development was greatest for the earliest date of seeding and less for each succeeding planting. Winter hardiness was found to follow in decreasing order the plantings of September 28, September 4, October 3, October 17, and August 15. He noted that winterkilling in most instances, was due to the plants being raised out of the soil where they died of desiccation.

It is unlikely that the results of such studies of winter wheat serve as a very reliable index of the response of perennial grasses and legumes.

MATERIALS AND METHODS

The experimental data herein reported were obtained at Manhattan, Kansas, during the fall, winter and spring seasons of the period from September 8, 1931 to April 30, 1932. The study included three grasses--namely, meadow fescue (Festuca elatior), orchard grass (Dactylis glomerata), and Kentucky blue grass (Poa pratensis); and three legumes--namely, common alfalfa (Medicago sativa), biennial white sweet clover (Melilotus alba), and white clover (Trifolium repens). The seed of both the grasses and legumes was obtained from seed dealers and growers in Kansas and was representative of a good grade of commercial seed. Germination and purity tests were made at the seed laboratory at the Kansas State College. These data are given in table 1.

Table 1. Germination and Purity Tests*

Grass or legume	Per cent Purity	Germination	Hard Seeds
Meadow fescue	99	90	
Orchard grass	88	92	
Kentucky blue grass	80	80	
Alfalfa	97	83	12
Sweet clover	99	89	
White clover	98	90	

Experimental plots, fifteen feet long and six feet wide were laid out on an area of uniform land on the Agronomy Farm. The soil type is classified as a silt loam. The land had not previously produced a crop in 1931 and was in excellent condition for the seeding of small seeded grasses and legumes.

Each grass and legume was sown in a single plot on each of five different dates. Seeding was accomplished by broadcasting the seed on the surface of the ground, and then raking the ground lightly with a hand rake. The plots were rolled with a hand roller immediately after seeding to afford more favorable conditions for quick germination. Table 2 presents data of dates of seeding, rates of seeding and dates of emergence.

*Courtesy of Seed Laboratory, Kansas State College.

Table 2. Rates and Dates of Seeding and Dates of Emergency

Grass or legume	Rate of seeding-lbs. per acre	Emergence dates of different dates of seeding				
		Sept. 8	Sept. 18	Sept. 28	Oct. 8	Oct. 23
Meadow fescue	18.0	9-22	9-23	10-4	10-17	11- 6
Orchard grass	15.0	9-23	9-23	10-5	10-19	11- 8
Kentucky blue grass	18.0	9-28	9-28	10-7	10-20	11-10
Alfalfa	15.0	9-22	9-23	10-2	10-14	11- 4
Sweet clover	15.0	9-23	9-24	10-4	10-15	11- 6
White clover	18.0	9-23	9-24	10-4	10-15	11-10

Soil moisture and temperature data were obtained at weekly intervals during the fall growth period. Moisture samples were taken in each of the six-inch layers of soil from the surface to a depth of three feet. Calculations for the percentage of moisture were made on the basis of dry weight. Soil temperature readings, at depths of three, six and nine inches, were taken weekly at approximately 9 a.m. The daily maximum and minimum air temperatures and precipitation were obtained from the records of the United States Weather Bureau. These latter data were recorded at Manhattan.

The direct method of root examination described by Weaver (9) was used in this study. The data on fall root growth were obtained during the first week in December. Because of disagreeably cold weather at this time, it was found advisable to modify the method slightly. The procedure was as follows: a trench was dug between the ends of adjoining plots to a depth slightly greater than the deepest roots. The soil was then carefully worked away from the roots of a number of representative plants bordering on the wall of the trench. Maximum depth of penetration, lateral extent, degree of branching at different depths, as well as the position of the roots in the soil were observed in this way. Blocks of soil, to a depth of approximately twelve inches, and sufficiently large to contain a number of representative plants, were then removed and taken to the greenhouse, where detailed data on the number of main roots, diameter of roots and number of rhizomes per plant were obtained.

Fall measurements of top growth consisted of height of plants and number of tillers per plant in the case of the grasses, and number of leaves per plant in the case of the legumes.

Winterkilling data were obtained by making stand-counts, on meter quadrats, both in the fall and in the spring of the year.

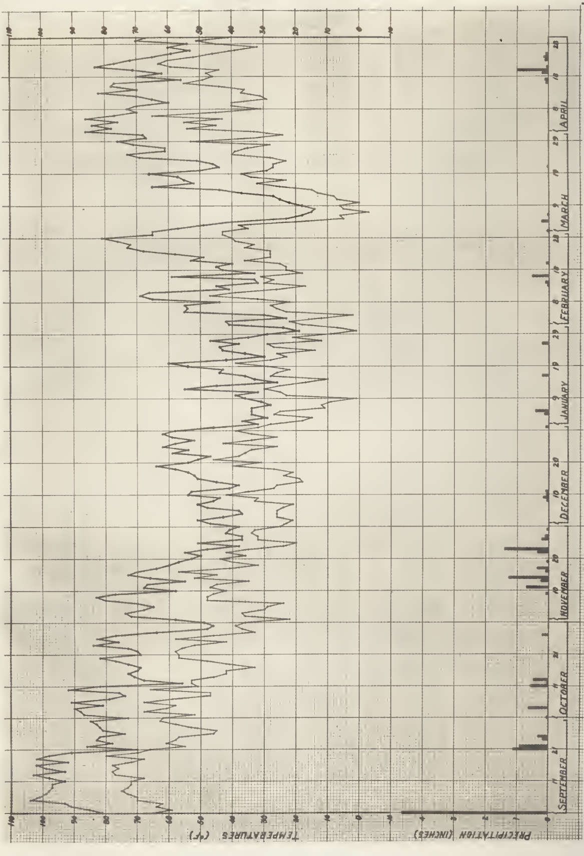
WEATHER CONDITIONS

Since temperature and moisture are important factors which influence the germination of seeds, growth of plants and degree of winterkilling, a review of the weather conditions throughout the duration of the experiment will be given. In attempting to show these factors of environment and their relation to plant response, it was found convenient to treat them in monthly periods.

Maximum and minimum daily temperatures, in degrees Fahrenheit, and daily precipitation for the period from September 1, 1931 to April 30, 1932 are represented graphically in plate 1. Soil temperature data are given in table 3 and represented graphically in figure 1. Soil moisture data are shown in table 4.

Plate I. Graph showing maximum and minimum daily temperatures, in degrees Fahrenheit, and daily precipitation for the period from September 1, 1931 to April 30, 1932; upper line, maximum temperatures; lower line, minimum temperatures; black columns, precipitation in inches.

Plate I



TEMPERATURES (°F)
PRECIPITATION (INCHES)
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL

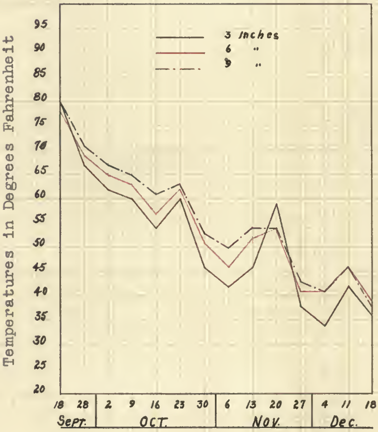


Fig. 1. Graph showing soil temperatures, in degrees Fahrenheit, at depths of 3, 6, and 9 inches, taken at weekly intervals during the growth period.

Table 3. Air and Soil Temperatures, in Degrees Fahrenheit, Taken at Approximately 9 a.m., at Weekly Intervals During the Growth Period

Soil temperatures Depth	Sept. 18	Sept. 28	Oct. 2	Oct. 9	Oct. 16	Oct. 23	Oct. 30	Nov. 6	Nov. 13	Nov. 20	Nov. 27	Dec. 4	Dec. 11	Dec. 18
3 inches	80	67	62	60	54	60	46	42	46	59	38	34	42	36
6 inches	78	69	65	63	57	62	51	46	52	54	41	41	46	39
9 inches	80	71	67	65	61	63	53	50	54	54	43	41	46	38
Air temperature	91	64	72	66	56	64	42	44	44	46	38	29	39	40

Table 4. Soil Moisture Data in Per cent, as Determined from Samples Pulled at Weekly Intervals During the Fall of 1931

Depth	Sept. 18	Sept. 28	Oct. 2	Oct. 9	Oct. 16	Oct. 23	Oct. 30	Nov. 6	Nov. 13	Nov. 20	Nov. 27
0- 6	14.87	21.53	18.45	16.55	20.80	17.12	17.45	16.33	20.30	22.40	23.23
6-12	18.74	22.51	17.80	18.72	21.41	19.63	19.87	18.80	20.24	21.72	22.43
12-18	19.26	21.59	21.55	19.12	20.42	19.61	18.98	18.95	20.00	19.52	21.32
18-24	19.05	21.10	19.17	19.32	19.28	19.31	18.96	18.24	19.05	20.39	21.27
24-30	18.60	18.90	18.97	18.91	18.34	18.53	18.05	17.44	17.71	19.27	21.09
30-36	18.11	17.94	18.09	18.13	17.27	17.96	17.04	17.79	17.66	18.95	21.39

Monthly Weather Conditions

September. The weather for the first three weeks of September was characterized by high temperatures and, after the first, almost complete absence of rainfall. Maximum daily temperatures above 100°F. were recorded on the 5th, 6th, 13th, 17th and 18th. There were twelve days during the period in which maximum temperatures exceeded 95°F. Rains during the last ten days of the month resulted in cooler temperatures for this period. Although total precipitation for the month was above normal it was distributed so unevenly that the period from September 5 to September 20 was very dry.

The first three plantings were made during this month. The first of these was made on September 8 during the dry, hot weather. Germination did not take place and with the continued drought it was deemed advisable to water the plantings artificially to afford conditions favorable for germination. On September 19, water equivalent to .5 inch of rainfall was applied. This, together with rains a few days later, resulted in final germination and fair stands.

The second seeding was made on September 18. The rains of 1.13, .92, .18, and .33 inches which occurred on the 21st, 22nd, 24th and 25th respectively, gave the seeds a good start. As shown in table 2, this seeding emerged nearly as soon as the September 8 seeding.

The third seeding was made on September 28. Both soil temperature and moisture were favorable to quick germination so good stands resulted.

<u>October.</u> Temperature and soil moisture conditions throughout most of October were favorable to plant growth. Rainfall was slightly less than normal, but was well distributed over the month. Temperatures were above normal and no frosts occurred.

The fourth and fifth seedings were made on October 8 and 23, respectively. The seeding on October 8 was followed by rains of .58, .05, and .48 inches on the 11th, 12th and 13th, respectively. These rains assured good stands. Since soil temperatures were lower than they were during September, germination and emergence were slower.

The fifth planting was made on October 23. Soil moisture conditions were favorable for germination, but temperatures were so low that germination and emergence were very slow. Final stands were good. Little growth was made by this set of plantings.

<u>November.</u> November was a very wet month with total precipitation amounting to 5.12 inches. Rain or snow were recorded on twelve of the last twenty-two days of the month. Temperatures during the first half of the month were favorable to some plant growth. Little visible growth occurred after the 20th. Minimum temperatures dropped below freezing on several occasions during the last week of the month which

resulted in freezing-injury to the last seeding of legumes. Snow fell on the 22nd and 23rd but it remained for only a few days.

December. Mild temperatures prevailed during the entire month. Alternate freezing and thawing of the ground during the first two weeks of the month caused considerable damage to the last seeding, particularly to the legumes. Temperatures during the last half of the month were very mild for this time of the year, with below freezing temperatures recorded on only three occasions. Precipitation amounted to .53 inch.

January. Temperatures during January were seasonable. A minimum of 1°F. was recorded on the 9th and 30th, and a maximum of 60°F. was recorded on the 20th. Precipitation was about normal. Light rains accompanied by below freezing temperatures occurred on two occasions. Five inches of snow fell but it did not last. As maximum daily temperatures ranged above freezing and minimum daily temperatures below freezing, considerable soil heaving occurred.

February. Temperatures during most of February were very mild and were unseasonably high during the latter part of the month. A minimum of 2°F. was recorded on the 4th and a maximum of 81°F. was recorded on the 28th. Precipitation totalled .83 inch.

March. Temperatures during the first two weeks of March were the coldest experienced during the entire winter.

Minimum temperatures dropped to near or below zero on several occasions. The minimum temperature for the winter, $-3^{o}F.$, was recorded on the 7th. This cold period following the warm weather of the latter part of February was the critical period of the winter so far as winterkilling was concerned.

Precipitation during March totalled only .40 inch. Strong winds occurred frequently during the latter part of the month, and caused a rapid drying of the surface soil.

April. The dry period of March continued throughout the first two weeks of April. As a result, little growth was made by any of the plantings during this period. Many plants which were severely injured but not killed by the late freeze died during this dry period. This was especially true of sweet clover plants whose taproot had been broken by heaving of the soil, and of plants of the later seedings of Kentucky blue grass which did not have a very deep, root system.

The drought period was broken on April 16 and moisture conditions were favorable during the remainder of the month. As temperatures were warm, growth was rapid during this time.

Summary of Weather Conditions

With the exception of the first three weeks of September, weather conditions during the fall of 1931 were very favorable for the germination and growth of fall sown grasses and legumes. Mean monthly temperatures during the fall were in all cases above normal. Precipitation was sufficient for crop needs after September 20, and was considerably above normal for November. Killing frosts did not occur until late in November, which afforded the plants a long growth period and an opportunity to build up resistance to freezing injury by exposure to gradually lowering temperatures.

Temperatures during December, January and February were relatively mild. They were unseasonably high during the latter part of February. The coldest weather of the winter was experienced during the first two weeks of March. Winterkilling was severe during this period. Temperatures during the latter part of March and throughout April were seasonable. The period from March 15 to April 15 was dry and windy and resulted in retarding spring growth. Moisture conditions were favorable for plant growth after April 15.

Table 5 gives the monthly summaries of important weather data.

Table 5. Monthly Summaries of Temperatures and Precipitation Data, with Deviations from the Mean, for the Months of September 1931 to April 1932, Inclusive

Month	Temperature (°F.) Max.	Min.	Mean	Deviation from mean	Precipitation (inches) 1931-1932	Deviation from mean
September	104	45	78.4	+ 8.2	7.21	+ 3.82
October	92	33	62.9	+ 4.7	2.04	- 0.25
November	83	20	48.2	+ 4.4	5.12	+ 3.63
December	64	18	40.4	+ 9.0	0.53	- 0.33
January	60	1	28.5	+ 0.0	1.03	+ 0.26
February	81	2	39.9	+ 7.4	0.83	- 0.36
March	76	-3	35.8	- 8.1	0.40	- 1.10
April	86	29	58.0	- 4.0	1.91	- 0.72

EXPERIMENTAL RESULTS

Fall Growth

Measurements of fall growth, both above-and below-ground, were obtained during the first week in December. After this date there was no noticeable growth of any of the plantings. Since the type of top growth and root systems of the grasses is different from that of the legumes the same data were not obtained, in the measurement of their development. For this reason it is desirable to consider the results of the grasses and legumes separately.

Top Growth of Grasses. Table 6 shows the height of top growth and number of tillers per plant for each of the five successive seedings of grasses. These data show that there was a progressive decrease in both the height of top growth and number of tillers per plant from the early to the late seedings. There was no measurable difference in the amount of top growth between the first two seedings; this was to be expected since they emerged on or about the same date.

Meadow fescue made the greatest top growth and Kentucky blue grass the least of the three grasses studied.

Table 6. Data Obtained During the First Week in December on the Height of Top Growth and Number of Tillers per Plant of the Five Successive Seedings of Grasses made During the Fall of 1931

Grass	Date of seeding	Height (inches)	Number of tillers per plant
Meadow fescue	September 8	3.5	5
	September 18	3.5	5
	September 28	2.5	3
	October 8	2.0	2
	October 23	1.0	0
Orchard grass	September 8	2.5	4
	September 18	2.5	4
	September 28	2.0	3
	October 8	1.5	1
	October 23	1.0	0
Kentucky blue grass	September 8	2.0	3
	September 18	2.0	3
	September 28	1.5	1
	October 8	0.7	1
	October 23	0.5	0

Root Development of Grasses. Quantitative data on the root development of the grasses is given in table 7. The manner in which these data were obtained has previously been discussed under the heading of "Materials and Methods."

An examination of the data in table 7 shows that root development, as measured by the number of roots originating from the base of the crown, maximum and working depth of penetration, and lateral extent, was greatest for the earliest seeding and was successively less for each later seeding. Only slight differences in root growth were noted between the first two seedings. As will be shown later this was also true of the legumes. These differences could have easily been due to chance error in obtaining the data, but since in most cases the differences are in favor of greater root growth for the earlier seeding some actual differences may have existed. The application of water to the September 8 seeding to favor germination, may have initiated root growth sooner than was indicated by emergence. However, as will be seen later, the differences in root development between these two plantings were so slight, that no measurable difference of resistance to winter injury were noted.

It is seen that in all cases a close relationship exists between the number of roots per plant, depth of penetration and lateral extent. By comparing the data in table 6 with that in table 7 it is also seen that a close

Table 7. Data Obtained During the First Week in December on the Root Development of the Five Successive Seedings of Grasses Made During the Fall of 1931

Crop	Date of seeding	Number per plant		Extent of roots (inches)		
					Depth of penetration	
		Roots	Rhizomes	Lateral	Maximum	Working
Meadow fescue	September 8	23	--	6.5	21.0	12
	September 18	23	--	7.0	20.0	11
	September 28	18	--	5.0	15.0	8
	October 8	8	--	3.5	8.0	5
	October 23	3	--	2.0	3.5	--
Orchard grass	September 8	20	--	6.0	18.0	12
	September 18	19	--	6.0	16.0	11
	September 28	16	--	4.5	14.0	8
	October 8	9	--	2.5	8.0	4
	October 23	3	--	2.0	3.0	--
Kentucky blue grass	September 8	12	4	4.5	13.0	7
	September 18	13	3	4.5	12.0	8
	September 28	11	2	3.5	8.0	4
	October 8	7	0	2.0	4.0	--
	October 23	3	0	0.5	1.5	--

relationship exists between the amount of top growth and root growth which was made during the fall. Thus, these data indicate that time of seeding in the fall, has no influence in modifying either the type of root growth or the proportion of top growth to root growth made in the fall.

Figures 2, 3, and 4 show diagramatically the relative root development of the five successive seedings of meadow fescue, orchard grass and Kentucky blue grass, respectively. It is noted that only a few of the roots extend to the maximum depth of penetration; the majority extend only to the working level.

Meadow fescue and orchard grass were very similar in their root habits. Plants of both of these grasses developed a large number of coarse, vigorous appearing roots. The root growth of Kentucky blue grass was less extensive and much finer in character than that of either of the other two grasses. The first three plantings of Kentucky blue grass had developed underground rootstocks. These data agree well with results reported by Weaver (9) in studies conducted at Lincoln, Nebraska.

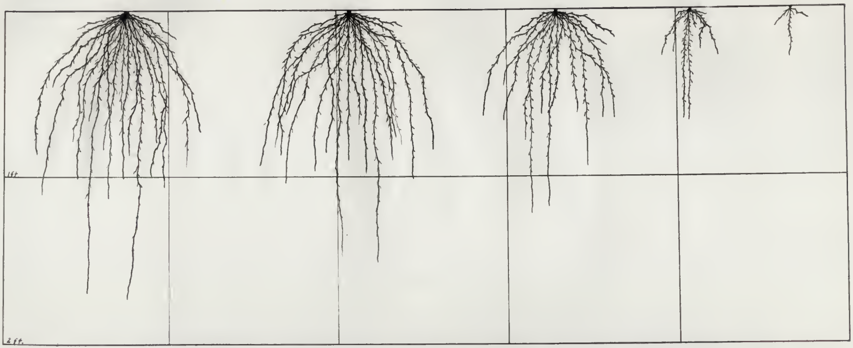


Fig. 2. Relative root development of meadow fescue seedings as measured during the first week in December; from left to right, seedings of September 8, September 18, September 28, October 8 and October 23, respectively.

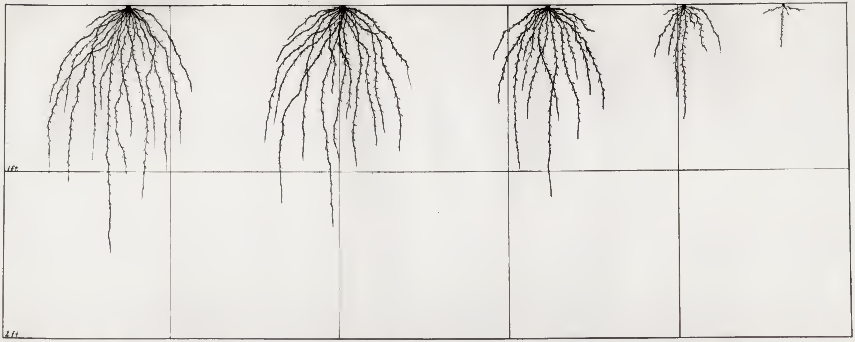


Fig. 3. Relative root development of orchard grass seedings as measured during the first week in December; from left to right, seedings of September 8, September 18, September 28, October 8 and October 23, respectively.

Fig. 4. Relative root development of Kentucky blue grass seedings, as measured during the first week in December; from left to right, seedings of September 8, September 18, September 28, October 8 and October 23, respectively.

<u>Top Growth of Legumes.</u> Top growth of the legumes was measured by counting the number of leaves per plant. This data was considered a more accurate measurement of the top growth than was height of plant, since the legumes, especially white clover, made a very prostrate top growth. Data on the number of leaves per plant for each of the different seedings is given in table 8. It is seen that the earlier seedings made a much greater top growth than did the later seedings. Alfalfa developed more leaves per plant than did similar seedings of white clover and sweet clover; the latter two clovers had nearly equal numbers.

<u>Root Development of Legumes.</u> Data on the root development of the legumes consisted of measurements of depth of penetration, lateral extent and diameter of the taproot. These data as measured during the first of December, are given in table 8. The relative root development of the different seedings of alfalfa, sweet clover and white clover are shown in figures 5, 6, and 7 respectively.

In all cases it is seen that the maximum depth of penetration and lateral extent of the roots and the diameter of the taproot became less with increased lateness of planting. There is a direct relationship between the age of plants and the extent of their root systems. As with the grasses, seeding at a later date had no influence in modifying the root habits but resulted in only a less extensive root system.

Table 8. Data Obtained During the First Week in December on the Above-Ground and Below-Ground Growth of the Five Successive Seedings of Legumes Made During the Fall of 1931

Crop	Date of seeding	No. of leaves per plant	Depth of penetration (inches)	Lateral spread (inches)	Diameter of taproot (M.M.) Crown	3"	6"
Alfalfa	September 8	18	40.0	9.0	2.0	0.8	0.5
	September 18	18	35.0	7.0	1.9	0.8	0.5
	September 28	7	28.0	5.0	1.0	0.5	0.5
	October 8	4	15.0	4.0	0.8	0.4	0.4
	October 23	1	5.5	1.0	0.7	0.4	---
Sweet clover	September 8	10	36.0	6.0	2.7	1.0	0.5
	September 18	8	36.0	5.0	2.7	0.6	0.6
	September 28	5	15.0	3.5	1.3	0.5	0.4
	October 8	3	9.0	2.0	1.1	0.5	0.4
	October 23	1	4.5	0.5	0.7	0.4	---
White clover	September 8	11	25.0	4.0	1.3	0.4	0.3
	September 18	11	22.0	3.5	1.3	0.4	0.4
	September 28	7	13.0	2.5	0.9	0.4	0.4
	October 8	3	7.0	1.0	0.5	---	---
	October 23	1	3.0	0.5	0.4	---	---

Fig. 5. Relative root development of alfalfa seedings as measured during the first week in December; from left to right, seedings of September 8, September 18, September 28, October 8 and October 23, respectively.

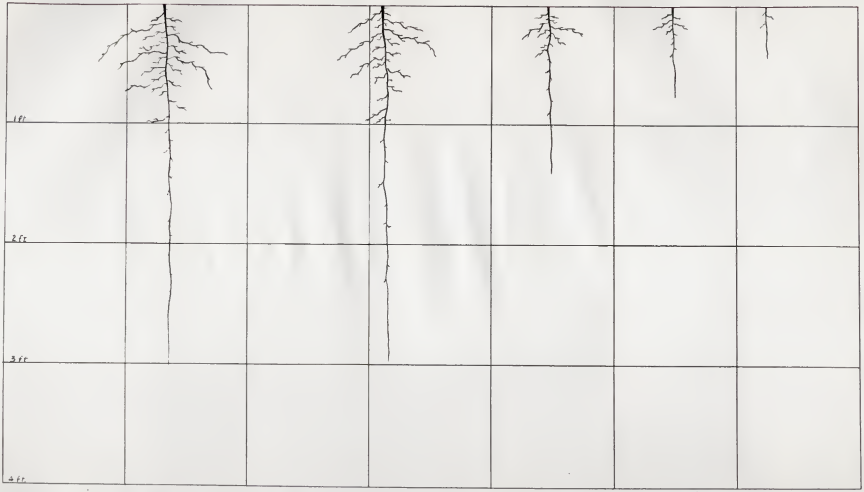


Fig. 6. Relative root development of sweet clover seedings as measured during the first week in December; from left to right, seedings of September 8, September 18, September 28, October 8 and October 23, respectively.

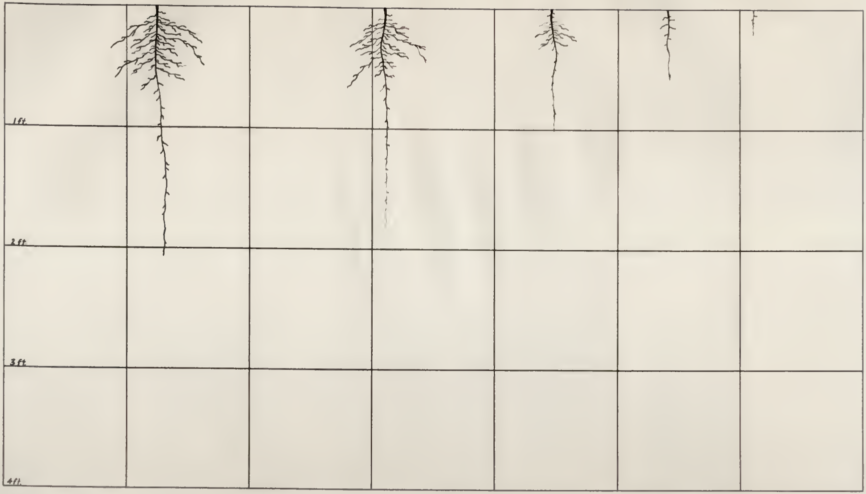


Fig. 7. Relative root development of white clover seedings as measured during the first week in December; from left to right, seedings of September 8, September 18, September 28, October 8 and October 23, respectively.

The relation of a top growth to root growth is also evident.

All seedings of alfalfa made a deeper root growth with more lateral extent than did similar seedings of sweet clover. White clover made a much less extensive root growth than did either of the other two legumes. As shown in figures 5, 6, and 7 lateral root development was limited largely to the upper one-third of the root system. White clover had a greater number, but shorter, lateral branches than did sweet clover or alfalfa. Sweet clover had the largest taproot and white clover the smallest. The diameters of the taproots varied greatly below three inches. They often became quite enlarged when passing through the looser soil pockets only to become small again upon entering a more compact layer of soil.

Winter Survival

Winter survival data, determined by stand-counts on meter quadrats both in the fall and spring, are given in table 9. The fall stand-counts were made during the second week of November. The spring stand-counts of the grasses were made on April 6 and 9, and those of the legumes on April 27.

An examination of the data in table 9 shows that winterkilling was severe. From a practical standpoint not even the earliest seedings of alfalfa and sweet clover survived to an extent that would have justified leaving the

Table 9. Winter Survival Data As Determined from Stand-counts Made During November, 1931, and Again During April, 1932

Grass or legume	Date of seeding	Number of plants: November 1931	Number of plants: April 1932	Per cent survival
Meadow fescue	September 8	489	398	81.39
	September 18	896	847	94.53
	September 28	736	676	91.85
	October 8	797	29	3.65
	October 23	906	0	.00
Orchard grass	September 8	924	631	68.29
	September 18	1178	620	52.63
	September 28	1494	700	46.85
	October 8	1367	0	.00
	October 23	1223	0	.00
Kentucky blue grass	September 8	3534	2554	72.27
	September 18	3607	2328	64.54
	September 28	3662	2224	60.75
	October 8	2848	659	23.14
	October 23	3378	11	.33
Alfalfa	September 8	455	8	1.76
	September 18	554	14	2.53
	September 28	710	3	.42
	October 8	606	0	.00
	October 23	584	0	.00
Sweet clover	September 8	575	46	8.0
	September 18	626	107	17.09
	September 28	621	0	.00
	October 8	794	0	.00
	October 23	1047	0	.00
White clover	September 8	2328	1850	79.47
	September 18	2075	1084	52.46
	September 28	2229	170	7.63
	October 8	2560	0	.00
	October 23	2258	0	.00

stands in the spring. The few plants of alfalfa and sweet clover which did survive were very weak and made very little growth the following spring. White clover showed a greater resistance to winter injury than did either alfalfa or sweet clover. Survival percentages of white clover for the September 8 and September 18 seedings were 79 and 52, respectively. Only a few of the white clover plants of the September 28 seeding survived.

It is noted that the grasses were much more successful in resisting winter injury than were the legumes. Fair to good stands of all three grasses remained in the spring from the first three seedings. With the exception of the October 8 seeding of Kentucky blue grass the later seedings of all the grasses were largely killed. The data in table 9 would indicate that meadow fescue was more resistant to winter injury than either orchard grass or Kentucky blue grass. There is some question as to whether this is a true indication of the comparative resistance to winter injury of meadow fescue and Kentucky blue grass. It is believed that the stands of Kentucky blue grass may have been reduced from causes other than winterkilling. The fall stands of Kentucky blue grass were very thick and it is possible that a certain amount of this reduction in stands may have been due to competition among plants. The fact that Kentucky blue grass showed a fair survival for the October 8 seeding, as compared to almost complete killing for meadow fescue, would tend to indicate that Kentucky blue grass was more resistant to winter injury than meadow fescue. Also, the fact that Kentucky blue grass showed the least visible signs of winter injury as based upon the appearance of the top growth in the spring, would further substantiate this belief.

It should be stated that winter injury was not all due to one cause. According to Salmon (6), winterkilling of plants may be due to one or more of four causes: (1) heaving, (2) smothering, (3) physiological drought, and (4) low temperatures. In this study smothering was known not to have been a factor, physiological drought may have been, and heaving and low temperatures were known to have been important factors causing winterkilling. Frosts during late November and early December were responsible for killing the last seeding of legumes. Heaving of the soil during December, January and February caused considerable damage to the plants of the later seedings of both grasses and legumes, and also to the early seedings of sweet clover. A large number of the sweet clover plants of both the early and late seedings were lifted from the soil from two to three inches, with their taproots broken from five to seven inches below the crown. In spite of this, many of these plants remained alive until late in the spring and it is believed that many of them would have again established themselves had moisture conditions been more favorable.

The greatest amount of winterkilling was due to the late spring freeze which occurred during the first part of March. This sudden drop in temperature following the warm weather of February, during which time the plants apparently lost their hardiness, resulted in the death of many plants. The early seedings of alfalfa, which had previously shown less signs of injury than the other legumes, were, as shown in table 9, almost completely killed. The reason for alfalfa being injured more at this time than the other crops, perhaps lies in the fact that it responds so quickly to growing conditions and in doing so loses most of its resistance to freezing. Thus, Steinmetz (7) noted that alfalfa plants have no autonomous rest period and when brought into the greenhouse from the field during the non-growth period, came into active growth within three days. He noted that maximum cold resistance was reached during February and that this resistance was largely lost in March during the spring thaw.

The prolonged drought period in the spring was also a factor causing the death of many plants. This was especially true of the earlier seedings of sweet clover and the later seedings of Kentucky blue grass. Many of the plants in these seedings survived the freeze in March but died later because of unfavorable soil moisture conditions.

In consideration of all these factors of winterkilling, it is seen that there is a definite positive relationship between plant development and the ability of the plant to resist injury. The advantages of greater root growth are readily seen in opposing the forces of soil heaving. Greater root development is also an advantage to the plant in resisting drought in the spring. Whether or not the larger and older roots can actually withstand lower temperatures without injury is questionable. Thus, Weimer (10) found that there was little correlation between the freezing points of alfalfa roots and their different diameters. However, since the larger roots cool more slowly, due to their greater size and the usual accompaniment of a greater protective top growth, these critically low temperatures are not reached so soon and may even afford the plant time to build up its resistance.

The results indicate that there is a stage in the growth of the plant, closely associated with root development, which must be reached to enable the plant to survive a particular combination of adverse environmental conditions, to which it may be exposed during the winter. This stage of growth was not reached by any of the seedings of alfalfa or sweet clover, by only the first two seedings of white clover and by the first three seedings of the grasses.

Spring Growth

Because of the dry weather during March and the first two weeks of April little plant growth was made during this time. Measurements of top growth on April 14 and April 30 are given in Table 10. These data show that the earlier seedings made slightly more growth during the dry period. On April 30 there was no measurable difference in the top growth of the first three seedings. However, the growth of the October 8 seeding of Kentucky blue grass and the September 28 seeding of white clover were considerably less than their respective earlier seedings at this time.

Table 10. Measurements of Root Depth on April 14 and Height of Top Growth on April 14 and 30, 1932

Grass or legume	Date of seeding	Height of tops (in.)		Maximum depth of roots (in.)
		April 14	April 30	
Meadow fescue	September 8	6.0	9.0	31
	September 18	6.0	9.0	31
	September 28	4.0	9.0	28
Orchard grass	September 8	6.0	13.0	28
	September 18	6.0	14.0	26
	September 28	5.0	12.0	19
Kentucky blue grass	September 8	2.5	7.5	19
	September 18	2.5	7.0	20
	September 28	2.0	7.0	17
	October 8	1.5	4.5	11
White clover	September 8	1.0	4.0	30
	September 18	1.0	4.0	32
	September 28	0.5	3.0	19
Sweet clover	September 8	1.0	3.0	41
Alfalfa	September 8	1.0	4.0	44

Measurements of root depth were made on April 14. These data are given in table 10. It is seen that considerable downward penetration of the roots occurred between the time the root examinations were made in early December and again on April 14. No data were obtained as to when this root growth was made.

SUMMARY

1. Fall seeding of small-seeded grasses and legumes is a desirable practice throughout the humid tame-pasture region of the middle west. Because early seedings are subject to injury from drought, seeding as late in the fall as can be done without danger of the plants being winterkilled is advisable.

2. The purpose of this study was to obtain quantitative data on the relative plant development of certain adapted grasses and legumes, sown at successive intervals in the fall and to determine the relation of the plant development to winter survival.

3. The study included three grasses--namely, meadow fescue (Festuca elatior), orchard grass (Dactylis glomerata), and Kentucky blue grass (Poa pratensis); and three legumes--namely, alfalfa (Medicago sativa), biennial white sweet clover (Melilotus alba) and white clover (Trifolium repens). Seedings were made on September 8, September 18, September 28, October 8 and October 23.

4. Weather conditions after September 20 were more favorable to the growth of fall sown grasses and legumes than they normally are during the fall of the year. The first killing frost did not occur until late in November, thus affording the seedings a long growth period.

5. Both top growth and root growth were found to be greatest for the earliest seedings and less for each succeeding seeding.

6. Date of seeding was found to have no influence in modifying the habits of the roots but resulted in only a less extensive root growth.

7. Meadow fescue made a slightly greater root growth than did orchard grass; otherwise the root growth of these two grasses was very similar. Kentucky blue grass made a much less extensive root growth which was finer in character than that of meadow fescue or orchard grass.

8. The roots of alfalfa were found to penetrate deeper and to have more lateral spread than plants of similar seedings of sweet clover. Sweet clover had larger taproots than alfalfa. White clover plants had smaller roots with less penetration and lateral spread than alfalfa or sweet clover.

9. Winterkilling was quite severe. Only a few plants of the earlier seedings of alfalfa and sweet clover survived while all of the plants of the later seedings were killed. The September 8 and September 18 seedings of white clover survived with fair stands; only a few plants survived from

the September 28 seeding while all plants of the October 8 and October 23 seeding were killed.

10. Only slight differences were noted in the survival of the first three seedings of each of the grasses which survived with fair stands. The fourth seeding of Kentucky blue grass showed a greater survival than did similar seedings of meadow fescue and orchard grass.

11. The results indicate a definite relationship between plant development and the ability of the plant to resist winter injury.

12. No significant differences in spring growth were noted for the first three seedings. Plants which survived from the later seedings made measurably less top growth in the spring.

ACKNOWLEDGMENT

The writer wishes to express his appreciation and acknowledge his indebtedness to Professor A. E. Aldous for planning and initiating the experiment and for many helpful suggestions and criticisms offered in the preparation of this thesis; to Jay Bentley and Donald Cornelius for assistance rendered in gathering the field data; to Dr. J. E. Ackert for suggestions in the preparation of this thesis; and to the Agronomy Department, Kansas State College, for the use of materials and equipment.

LITERATURE CITED

(1) Aldous, A. E. and Zanley, J. W.
1931. Tame Pastures in Kansas. Kan. Agr. Expt. Sta. Bul. 253: 1-39.

(2) Beeson, M. A., Daane, Adrian, and Johnson, D. R.
1921. Alfalfa Experiment. Okla. Agr. Expt. Sta. Bul. 138: 1-18.

(3) Janssen, G.
1929. Effect of Date of Seeding Winter Wheat on Plant Development and Its Relationship to Winter Hardiness. Jour. Amer. Soc. Agron. 21: 444-465.

(4) Keim, F. D. and Beadle, George W.
1927. Relation of Time of Seeding to Root Development and Winter Survival of Fall Seeded Grasses and Legumes. Ecology 8: 251-264.

(5) Kiesselbach, T. H.
1918. Forage Crops. Nebr. Agr. Expt. Sta. Bul. 169: 1-36.

(6) Salmon, S. C.
1917. Why Cereals Winterkill. Jour. Amer. Soc. Agron. 9: 353-380.

(7) Steinmetz, F. H.
1926. Winter Hardiness of Alfalfa Varieties. Minn. Agr. Expt. Sta. Tech. Bul. 38: 1-33.

(8) Throckmorton, R. I. and Salmon, S. C.
1927. Alfalfa Production in Kansas. Kan. Agr. Expt. Bul. 242: 1-42.

(9) Weaver, John E.
1926. Root Development of Field Crop. 290 pp., McGraw-Hill Book Company, Inc., New York.

(10) Weimer, L. J.
1929. Some Factors Involved in the Winter Killing of Alfalfa. Jour. Agr. Res. 39: 263-283.