University of Alberta Library

0 1620 3448506 8

For Reference

NOT TO BE TAKEN FROM THIS ROOM

METHODS OF MEASURING GROWTH RATE IN ALFALFA

Warren E. Smith

Department of Plant Science

University of Alberta

Ex LIBRIS
UNIVERSITATIS
ALBERTAENSIS

Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

<https://archive.org/details/methodsofmeasuri00smit>

U N I V E R S I T Y O F A L B E R T A

FACULTY OF AGRICULTURE

The undersigned hereby certify that they have read and recommend to the Committee on Graduate Studies for acceptance a thesis on "Methods of measuring growth rate in alfalfa", submitted by Warren E. Smith, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

PROFESSOR

PROFESSOR

PROFESSOR

METHODS OF MEASURING GROWTH RATE IN ALFALFA

Warren E. Smith
Department of Plant Science

A THESIS

submitted to the University of Alberta
in partial fulfilment of the
requirements for the degree of

MASTER OF SCIENCE

Edmonton, Alberta

April, 1947

TABLE OF CONTENTS

	<u>Page</u>
Introduction	1
Literature review	2
Growth characteristics of alfalfa	9
Field experiment	11
Materials	11
Experimental methods	12
Methods of measuring plant characters	13
Experimental results	14
Discussion	17
Greenhouse experiment	18
Materials	18
Methods	19
Experimental results	20
Discussion	25
General discussion	26
Summary	29
Acknowledgements	31
References	31

TABLE OF CONTENTS

Page

1	Introduction
2	Objectives
3	Scope of the study
4	Significance
5	Methodology
6	Results
7	Discussion
8	Conclusion
9	References
10	Appendix
11	Index
12	Summary
13	Abstract
14	Introduction
15	Objectives
16	Scope of the study
17	Significance
18	Methodology
19	Results
20	Discussion
21	Conclusion
22	References
23	Appendix
24	Index
25	Summary
26	Abstract
27	Introduction
28	Objectives
29	Scope of the study
30	Significance
31	Methodology
32	Results
33	Discussion
34	Conclusion
35	References
36	Appendix
37	Index
38	Summary
39	Abstract
40	Introduction
41	Objectives
42	Scope of the study
43	Significance
44	Methodology
45	Results
46	Discussion
47	Conclusion
48	References
49	Appendix
50	Index
51	Summary
52	Abstract
53	Introduction
54	Objectives
55	Scope of the study
56	Significance
57	Methodology
58	Results
59	Discussion
60	Conclusion
61	References
62	Appendix
63	Index
64	Summary
65	Abstract
66	Introduction
67	Objectives
68	Scope of the study
69	Significance
70	Methodology
71	Results
72	Discussion
73	Conclusion
74	References
75	Appendix
76	Index
77	Summary
78	Abstract
79	Introduction
80	Objectives
81	Scope of the study
82	Significance
83	Methodology
84	Results
85	Discussion
86	Conclusion
87	References
88	Appendix
89	Index
90	Summary
91	Abstract
92	Introduction
93	Objectives
94	Scope of the study
95	Significance
96	Methodology
97	Results
98	Discussion
99	Conclusion
100	References

METHODS OF MEASURING GROWTH RATE IN ALFALFA

W. E. Smith

INTRODUCTION

Many workers have reported that alfalfa, like several other cross-breeding plants, exhibits reduced vigor of growth when inbred but maintains its vigor regularly under conditions of cross-pollination. Usually loss of vigor in alfalfa following inbreeding has been studied by comparison of inbred and open-pollinated plants with respect to yield of fodder at the "haying" stage of growth and with respect to seed yield. Comparisons of this kind have been made from field-plot yields obtained at one stage of growth only, viz. the early flowering or "haying" stage. It would seem desirable that loss of vigor due to inbreeding in alfalfa should be studied by much more refined methods involving careful measurements of growth rate at various stages of the plant's development before reliable generalizations can confidently be made. One of the difficulties in this procedure is the choice of the best criterion of growth rate in alfalfa. It was with the object of determining this best criterion that this investigation was undertaken. The criteria were conceived to involve methods of measurement and stages of plant development at which growth was measured. Several procedures

1881-82

1881-82

The following is a list of the lands which have been surveyed and classified by the General Land Office during the year 1881-82. The lands are classified into three classes, namely, lands which are surveyed and classified by the General Land Office, lands which are surveyed and classified by the State Land Office, and lands which are surveyed and classified by the local land office. The following is a list of the lands which have been surveyed and classified by the General Land Office during the year 1881-82.

were adopted for purposes of comparison with each other and particularly with that of weighing the growth at different developmental stages, which is probably the best criterion, but which is not practical because of the necessity of removing the aerial parts of the plant for each measurement reading, which disrupts the continuity of the growth of the plant.

It was decided to study growth measurements in terms of radicle elongation, stem number, stem length, node number in the stem, and weight of aerial growth after a specified interval of time.

LITERATURE REVIEW

In the study of growth it is desirable to give some quantitative expression to the amount of growth which is accomplished by a plant or a group of plants during a given period of time. The principal measures which have been employed for this purpose, as outlined by Meyer and Anderson (13) are: (1) increase in the length of stem, root, or other organs of the plant; (2) increase in the area of leaves; (3) increase in diameter of stem (or other organs); (4) increase in volume; (5) dry weight increment; and (6) fresh weight increment.

If increase in length is taken as the measure,

Livingston (11) and Maximov (12) suggest that the simplest equipment for this study is a millimeter rule. A horizontal microscope or an auxanometer--a self-registering apparatus--may be used for finer and more accurate measurements of growth. If the growth of certain organs is used instead of that of the whole plant, they (11, 12) describe a method of marking the growing organs by means of India ink applied with a fine brush. These marks are made at definite distances from one another, and the increase in distance is measured at certain time intervals. This makes it possible to obtain a precise measurement of the changes in length of each portion during the experiment, and to ascertain the dimensions of the entire growing zone, since only in this region does the distance between the marks increase.

A photographic method for measuring and recording morphological and physical characters has been described by Pack (14). With the camera data for innumerable exact measurements and characters which may be used for future reference can be easily and quickly recorded. The photographic method possesses the advantage of permitting measurements of any degree of precision without the growing organ being touched, all disturbances of its normal development thus being eliminated.

However, the photographic method requires the use of controlled light, which may be impossible or undesirable.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

and in the same category. The only thing in a
different category is the one in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

lighting (11) and (12) are also in the same
category. The only thing in a different
category is the one in the same category.

Staniland (17) describes an apparatus which will yield similar information without the necessity of using controlled light. By the use of this apparatus accurate scale drawings can be made of plants for the study of growth changes; the investigator can make his drawings at suitable intervals of time, thus securing an accurate and permanent record of the development of the plant. It consists simply of a peep-hole punched through a piece of tin, and a piece of plain glass mounted in a frame. The glass is placed between the object to be drawn and the peep-hole so that by looking through the peep-hole the image of the object can be easily traced on the glass. It is a simple apparatus and has many useful applications.

Ipatjev (9), in his study of accurate morphological methods for measuring plant growth, suggested two methods. To one, the method of comparison of organs corresponding to one another, he gave the name "comparative ontogenetic method". For example, in a tomato plant the fifth real leaves which have attained their maximum development, ceased growing, and are liable to decay, are compared.

His second method, which may conveniently be called the "diagram method", consisted of tracing diagrammatically the progress of the plant's development. Here, the order of appearance of organs on a plant in the course of its development, is recorded. The differences in the expression of a

given organ are shown on the same graph, with the dates of their development.

It is often desirable to study the growth of roots and above-ground portions of the plant simultaneously. Goto (5), in his study of Halo Blight of oats, was able to do this by the use of glass-fronted tin cases, 22 x 12 x 1.75 inches in size. These were placed at an angle of 45 degrees in specially constructed frames. This allowed the roots to grow against the glass so that daily observations and measurements could be made of roots and above-ground parts.

Arndt (2) was able to study all parts of the cotton seedlings which were grown in the dark in agar medium in test tubes, and was able to make daily observations on all parts of the seedling.

The growing of excised roots in a culture medium has proved to be a good method for comparing growth rates of different plants. Whaley and Long (23) studied the behavior of excised roots of heterotic hybrids and their inbred parents in culture media. They found that, in all cultural media the excised roots of hybrids of corn grew better than inbreds.

The measure of total weight is probably the best criterion of growth. Tysdal et al (20), in their review of alfalfa breeding, concluded that forage yield under field conditions is possibly the best criterion of the productivity of alfalfa.

given organs were shown on the same graph, with the following
their development.

It is often desirable to study the growth of certain
and above-ground portions of the plant simultaneously. This
(2), in the study of the growth of roots, was able to do this
by the use of glass-enclosed thin tubes. 25 x 125 x 1.75 inches
in size. These were placed at an angle of 45 degrees to
speedily constructed T-tubes. This allowed the roots to
grow against the glass so that daily observation was possible.
Each tube is made of rubber and above-ground portion.

Figure (3) was also made. All tubes of this design
had openings which were closed in the back by a rubber stopper.
These, and was able to make daily observations on all parts
of the seedling.

The growth of excised roots in a culture medium.
has proved to be a good method for comparing growth rates of
different species. Lewis and Jones (1921) studied the behavior
of excised roots of *Lactuca scariola* and their lateral growth
in culture media. They found that, in all cultural media the
excised roots of *Lactuca* at first showed a rapid increase
The amount of total weight is usually the best

criterion of growth. Spedding et al (1921), in their review of
lateral branching, concluded that lateral growth under certain
conditions is possibly the best criterion of the productivity
of plants.

Paddick (15) found that he was able to explain the dynamics of hybrid vigor in corn through measurement of linear growth of seedling radicle and immature leaves at comparable positions on plants of the same age. He measured the extent as well as speed of development by the number of leaves produced at a given time. He concluded that whatever hybrid vigor was found to be, it was safe to assume that the answer would be closely connected with the development of the plant.

Many workers have studied the relationship of size of seed to the subsequent growth of the plant. The work of Sprague (16), Kempton and McLane (10), Evans and Johnson (3) indicates that large seed size has little if any permanent significance. It seems that the measurement of seed size alone would not be a suitable criterion of growth.

Veatch (2) investigated several characters of soybeans with regard to hybrid vigor. He found that hybrids, on the average, exceeded the higher parental average in the following characters: total yield, number of seeds per plant, number of pods per plant, plant weight, height, total stem and branch length, number of nodes per plant, and number of days between planting and flowering. All these measures were good criteria of added vigor exhibited by hybrids as compared with parents.

Internode number and length have been used by many workers as measures of growth rate in plants. Anderson and

Schregardus (1), in their study of growth, noted that plants may differ from each other, not only in number of internodes and their absolute dimensions, but also in the relative size of successive internodes and in the pattern of change of relative size.

When selection is desired for a certain character, it is often desirable to determine, if possible, what other characters of the plant are associated with it. Sometimes certain characters are inherited together. By selecting for one, it may then be possible to secure the others. This association of characters frequently presents difficulties. In alfalfa, Tysdal and Westober (19) noted that selection for increased forage production usually gave at the same time a coarser and more sparsely leaved plant of poorer quality.

Wexelson (22), in his studies of inbreeding and heterosis in red clover, used plant height, weight, stem number, and internode length to measure growth. He found that no effect of inbreeding on seed weight at the time of germination could be demonstrated. However, he noted that inbreeding effects were visible at an early stage of seedling growth, inbred seedlings being in general weaker than crossbreds. This effect might appear immediately after germination or at a somewhat later stage. He found that differences in vigor between inbred and crossbred families

were retained in vegetative propagation. In his correlation studies he presented data which showed that depression in weight was significantly correlated with depression in height and that number of stems and the depression in the latter were correlated with depression in internode length. He concluded that depression of plant weight by inbreeding was caused by a reduced plant height due to shorter internodes.

In 1914 Freeman (4) studied correlations between various characters in alfalfa and among others found positive correlations indicating that nitrogen content was associated with percentage of leaves; and green weight with both the average number of stems and the average height. He found negative correlations indicating that a greater forage yield was associated with a smaller percentage of leaves, a greater height, a smaller number of stems, and a greater average height. He found no significant correlation between thickness of stand and percentage of leaves.

Hackborth and Ufer (7), in their study of growth characters in alfalfa found a high positive correlation between forage yield and height and also a positive correlation between height of stem, length of internode and coarseness of stem. Thus, a high-yielding plant was tall and upright but of low quality because it had long internodes, was sparsely leaved, and had thick woody stems. He also found a positive though slight correlation between forage production and seed production.

were retained in vegetative propagation. In the comparison studies he presented data which showed that increased in weight was significantly correlated with duration in water and that number of stems and the percentage in the latter were correlated with duration in water. The correlation of weight and duration of 41 in water in the latter was caused by a general trend being due to similar responses. In 1954, however, (4) and (5) correlation between vegetative propagation in alfalfa and among other four positive correlations (1) and (2) were observed and also significant correlation of height and weight with root and average number of stems and the average height. In 1955, negative correlations between height and average height were associated with a smaller percentage of stems, a greater height, a smaller number of stems, and a greater average height. No trend in significant correlation between height and average height and percentage of stems was observed. In 1956, however, the correlation in alfalfa found a high positive correlation between average height and height and also a positive correlation between average height of stem, length of internode and average height of stem. Thus, a high-yielding plant was tall and upright but at low height because of low internode length and average height, and also (1956) stems. In 1957, a positive correlation between height and average height was observed.

GROWTH CHARACTERISTICS OF ALFALFA

The alfalfa plant is a long-lived perennial, its average length of life being from five to seven years depending upon environmental conditions. It develops annually from a crown, new shoots, or stems, which normally flower and set seed. Hayward (8) and Stewart (18) have reported on the structure and development of the plant. Their observations would suggest five specific phases in the life cycle of alfalfa:

- (1) syngamy to mature seed
- (2) germination to seedling (first true leaves)
- (3) seedling to flowering
- (4) flower to mature seed
- (5) second and each subsequent year's growth
 - (a) origin of secondary stems to flowering
 - (b) flowering to mature seed.

This study is concerned with the growth rate in the second and third phases.

The second phase represents the first independent growth of the young plant. In germination, the primary root emerges near the hilum and penetrates the soil rapidly, forming a slender, unbranched tap root. The seedling is epigeal and oval cotyledons are raised above the ground as the hypocotyl elongates and straightens. The first epicotyledonary

leaf blade is simple and obcordate or orbicular with a very slender petiole, while the second, third, and subsequent leaves are trifoliate.

At the beginning of phase three the seedling axis is slender with a short first internode, but the second internode may elongate considerably as the plant develops. There are buds in the axils of the cotyledons as well as in the axil of each trifoliate leaf, and these develop coincidentally with the growth of the primary axis to originate the so-called crown. Usually, there are three and sometimes four branches in addition to the primary axis which form this characteristic crown. When four develop the fourth arises from the axillary bud of the first trifoliate leaf, following the development of the other three from the cotyledonary buds and that of the unifoliate leaf. In the case of vigorous growing plants, additional branches may arise from adventitious buds which occur near the bases of the axillary branches. The first one usually develops between the branches arising from the buds in the axils of the cotyledons. In older plants several buds may develop each from any point in the periphery of the crown, as designated by Stewart (18) to include the perennial portion of the stems of the plant.

Alfalfa has an indeterminate growth habit. In this typical "open" growth system added vigor is expressed in the production of greater linear growth and numbers, rather

Journal of the American Medical Association

than in increase in actual size of primary organs such as leaves, stems, flowers, and seeds.

FIELD EXPERIMENT

The first of two studies on growth rate was made in the field in the summer of 1946.

Materials

The seed used for this experiment was obtained from open-pollinated and seventh-generation selfed strains. The open-pollinated strains are designated by their common varietal names and the selfed strains by the numbers under which they were recorded at the University of Alberta.

It should be pointed out that the selfed strains were not derived from the open-pollinated strains used, therefore a greater variety of material is represented than would have been the case if both selfed and open-pollinated strains had come from common origins.

The two groups, self- and open-pollinated strains, were used in order to obtain the widest possible variation in growth rates, it being presumed that the self-pollinated strains would grow less rapidly.

When in flower is covered with numerous small, white, tubular flowers, the leaves, stems, flowers, and seeds.

PLANT CHARACTERISTICS

The plant is a small, erect, annual herb, growing to a height of 1-2 feet. It is covered with numerous small, white, tubular flowers, the leaves, stems, flowers, and seeds.

PLANT CHARACTERISTICS

The plant is a small, erect, annual herb, growing to a height of 1-2 feet. It is covered with numerous small, white, tubular flowers, the leaves, stems, flowers, and seeds.

The plant is a small, erect, annual herb, growing to a height of 1-2 feet. It is covered with numerous small, white, tubular flowers, the leaves, stems, flowers, and seeds.

The plant is a small, erect, annual herb, growing to a height of 1-2 feet. It is covered with numerous small, white, tubular flowers, the leaves, stems, flowers, and seeds.

Experimental Methods

Five open-pollinated and five selfed strains were used. The seeds were first scarified in concentrated sulphuric acid for 18 minutes, then thoroughly washed with tap water and dried. They were soaked in petri dishes between damp filter paper on June 4, 1946, at 60°F. for 24 hours. Then they were planted on summerfallowed land on June 5, 1946, at the rate of three seeds per hill, each hill being regarded as an experimental unit or plot. The hills were check-rowed two feet apart each way and arranged in the usual random manner into two 10 x 10 adjacent Latin squares. This provided ten replicates for each strain in each Latin square.

Thirty-seven days after planting the hills were thinned to one plant each. Several hills, however, had failed to produce plants.

On September 9th and 10th, 1946, all plants were cut just above the crown and weighed.

In order to study radicle elongation and to correlate data thus obtained with weights of field-grown plants, seeds of the same experimental strains were planted in upright glass-faced cases in the greenhouse. These cases were so designed as to allow visual examination of the root at intervals throughout its early development. By stacking these cases in close contact side by side the glass faces,

and consequently the alfalfa roots, were maintained in a state of darkness necessary for normal growth.

Statistical reduction of data obtained in this investigation follows the methods outlined by Goulden (6).

Methods of Measuring Plant Characters

The stem heights of plants in the field were measured in centimeters from the cotyledonary node to the top of the longest stem. These measurements were taken twice, at the time of thinning (thirty-seven days after planting) and at the time of cutting. The fully opened flower clusters on the whole plant also were counted at this time. Each plant was weighed immediately after it was cut. The stems counted at this time included those arising in the axils of the cotyledons at the first node of the primary axis, and those from the node of the first trifoliate leaf. In the greenhouse the radicle was measured in millimeters from the point of emergence from the seed to the extreme tip seven days after planting.

Experimental Results

TABLE I

Mean radicle length at seven days

Open-pollinated			Selfed		
Strain	Number of seedlings	Radicle mean (mm.)	Strain	Number of seedlings	Radicle mean (mm.)
Ranger	19	57	5-31	19	33
Vega	16	52	1-48	21	39
Ferax	22	49	4-8	20	45
Argentine	19	52	3-48	19	42
Kansas	23	45	3-24	18	42
Means		51.2 [±] 1.3			40.6 [±] 1.6

The difference between radicle lengths in the two groups is highly significant.

The variability within strains grown in replication has been computed by the total variance, variance between strains, and variance within strains. From the latter are calculated standard errors of the means.

The weighted means of the measured characters for open-pollinated and selfed strains are tested for significant difference by comparing the difference between their means with the standard error of the difference and applying the "T" test. There are significant differences between the fol-

Experimental Results

Table I

Mean results in terms of error

Group	Non-estimated		Estimated	
	Number of subjects	Mean error	Number of subjects	Mean error
Group 1	10	1.5	10	1.5
Group 2	10	1.5	10	1.5
Group 3	10	1.5	10	1.5
Group 4	10	1.5	10	1.5
Group 5	10	1.5	10	1.5
Group 6	10	1.5	10	1.5
Group 7	10	1.5	10	1.5
Group 8	10	1.5	10	1.5
Group 9	10	1.5	10	1.5
Group 10	10	1.5	10	1.5
Group 11	10	1.5	10	1.5
Group 12	10	1.5	10	1.5
Group 13	10	1.5	10	1.5
Group 14	10	1.5	10	1.5
Group 15	10	1.5	10	1.5
Group 16	10	1.5	10	1.5
Group 17	10	1.5	10	1.5
Group 18	10	1.5	10	1.5
Group 19	10	1.5	10	1.5
Group 20	10	1.5	10	1.5
Group 21	10	1.5	10	1.5
Group 22	10	1.5	10	1.5
Group 23	10	1.5	10	1.5
Group 24	10	1.5	10	1.5
Group 25	10	1.5	10	1.5
Group 26	10	1.5	10	1.5
Group 27	10	1.5	10	1.5
Group 28	10	1.5	10	1.5
Group 29	10	1.5	10	1.5
Group 30	10	1.5	10	1.5
Group 31	10	1.5	10	1.5
Group 32	10	1.5	10	1.5
Group 33	10	1.5	10	1.5
Group 34	10	1.5	10	1.5
Group 35	10	1.5	10	1.5
Group 36	10	1.5	10	1.5
Group 37	10	1.5	10	1.5
Group 38	10	1.5	10	1.5
Group 39	10	1.5	10	1.5
Group 40	10	1.5	10	1.5
Group 41	10	1.5	10	1.5
Group 42	10	1.5	10	1.5
Group 43	10	1.5	10	1.5
Group 44	10	1.5	10	1.5
Group 45	10	1.5	10	1.5
Group 46	10	1.5	10	1.5
Group 47	10	1.5	10	1.5
Group 48	10	1.5	10	1.5
Group 49	10	1.5	10	1.5
Group 50	10	1.5	10	1.5
Group 51	10	1.5	10	1.5
Group 52	10	1.5	10	1.5
Group 53	10	1.5	10	1.5
Group 54	10	1.5	10	1.5
Group 55	10	1.5	10	1.5
Group 56	10	1.5	10	1.5
Group 57	10	1.5	10	1.5
Group 58	10	1.5	10	1.5
Group 59	10	1.5	10	1.5
Group 60	10	1.5	10	1.5
Group 61	10	1.5	10	1.5
Group 62	10	1.5	10	1.5
Group 63	10	1.5	10	1.5
Group 64	10	1.5	10	1.5
Group 65	10	1.5	10	1.5
Group 66	10	1.5	10	1.5
Group 67	10	1.5	10	1.5
Group 68	10	1.5	10	1.5
Group 69	10	1.5	10	1.5
Group 70	10	1.5	10	1.5
Group 71	10	1.5	10	1.5
Group 72	10	1.5	10	1.5
Group 73	10	1.5	10	1.5
Group 74	10	1.5	10	1.5
Group 75	10	1.5	10	1.5
Group 76	10	1.5	10	1.5
Group 77	10	1.5	10	1.5
Group 78	10	1.5	10	1.5
Group 79	10	1.5	10	1.5
Group 80	10	1.5	10	1.5
Group 81	10	1.5	10	1.5
Group 82	10	1.5	10	1.5
Group 83	10	1.5	10	1.5
Group 84	10	1.5	10	1.5
Group 85	10	1.5	10	1.5
Group 86	10	1.5	10	1.5
Group 87	10	1.5	10	1.5
Group 88	10	1.5	10	1.5
Group 89	10	1.5	10	1.5
Group 90	10	1.5	10	1.5
Group 91	10	1.5	10	1.5
Group 92	10	1.5	10	1.5
Group 93	10	1.5	10	1.5
Group 94	10	1.5	10	1.5
Group 95	10	1.5	10	1.5
Group 96	10	1.5	10	1.5
Group 97	10	1.5	10	1.5
Group 98	10	1.5	10	1.5
Group 99	10	1.5	10	1.5
Group 100	10	1.5	10	1.5

The difference between results in the two

groups is highly significant.

The variability within each group is small.

This has been confirmed by the small variance, variance between subjects, and variance within subjects. The two latter are calculated (standard error of the mean).

The weighted mean of the subjects' responses for

non-estimated and estimated conditions was found to be significantly different by comparing the differences between their means with the standard error of the difference and applying the t-test. There are significant differences between the two

TABLE II

Means of character measurements of five open-pollinated and five selfed strains taken in the field during the summer of 1946

Strain	Number of plants	Mean number of			Height 37 dy. (cm.)	Height 109 dy. (cm.)	Green wt. (gm.)
		Stems	Nodes	Flower clusters			
<u>Open-pollinated</u>							
Ranger	15	4.7	15.9	6.3	6.00	52.1	61.8
Vega	17	5.8	15.3	16.8	6.28	55.6	87.9
Ferax	14	5.2	14.8	5.6	5.37	49.5	61.2
Argentine	13	4.5	18.0	2.6	5.08	59.2	73.7
Kansas	17	5.1	15.5	4.2	5.79	55.3	69.5
Means		5.0	15.8* ±0.5	7.4** ±0.9	5.74 ±0.83	54.3** ±1.1	71.3** ±4.1
<u>Selfed</u>							
5-31	14	5.4	12.9	1.2	3.30	34.7	27.7
1-48	15	4.5	14.1	2.9	3.80	35.2	30.9
4-8	15	4.5	13.5	3.6	4.22	39.7	42.1
3-48	14	5.9	14.0	0.4	3.94	38.2	42.4
3-24	15	5.1	14.3	1.7	4.45	38.3	27.3
Means		5.1	13.8 ±0.3	2.0 ±0.5	3.87 ±0.66	39.4 ±0.7	32.1 ±2.5

* Mean significantly higher to the 5% point

** Means significantly higher beyond the 1% point than the corresponding means for the self-pollinated strains.

lowing means: stem height at one hundred and nine days, number of nodes, number of flower clusters, and green weights, in all cases in favor of the open-pollinated strains. There is no significant difference between the means for number of stems.

TABLE 1

Index of commercial fishery catch of the main-
polished and live salted salmon
in the North Pacific Ocean, 1913

Year	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	3023	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	3039	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	3071	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	3135	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	3151	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	3183	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	3199	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	3215	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	3231	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244	3245	3246	3247	3248	3249	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	3260	3261	3262	3263	3264	3265	3266	3267	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	3278	3279	3280	3281	3282	3283	3284	3285	3286	3287
------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

There is no significant difference between the open-pollinated and selfed groups in height of stem at thirty-seven days ($P = 0.09$), but the heights of stems for the open-pollinated groups are consistently higher than those for the selfed group and, for this reason, it is considered that the difference is very likely real. It is probable that this difference could have been calculated as statistically significant if the measurement had been made at a later date.

TABLE III

Coefficients of correlation between character measurements; (1) radicle length at 7 days, (2) height at 37 days, (3) height at 109 days, (4) number of nodes, (5) weight

$$r_{5\ 4} = +0.738^*$$

$$r_{3\ 4} = +0.875^{**}$$

$$r_{5\ 3} = +0.892^{**}$$

$$r_{5\ 1} = +0.793^{**}$$

$$r_{3\ 2} = +0.892^{**}$$

* Significant beyond the 5% point

** Significant beyond the 1% point

Both height at 109 days and radicle length at seven days show a highly significant positive correlation with weight. The stem height measured at 37 days shows a highly significant positive correlation with height measured at 109 days. The stem height at 109 days and node number

 

are positively correlated with a high degree of significance.

Discussion

As a result of measurements taken in the greenhouse it is shown that, in the same length of time, the open-pollinated strains produced longer radicles than selfed strains. The measurements of characters in the field indicate that the open-pollinated strains exceeded the selfed strains in stem length, number of nodes, time of blooming, and final green weights.

The correlations calculated indicate that the measurements of radicle length at seven days, stem height at 37 days, stem height at 109 days, yield approximately the same relative information as final weighing on the variability in plant vigor of growth for the strains used.

From the data obtained and observations made in this experiment it seems that radicle length, stem height, number of nodes, number of open flower clusters, and final weight, may be good criteria by which to differentiate growth rate in open-pollinated and selfed strains of alfalfa.

GREENHOUSE EXPERIMENT

Since only one year's results were obtained from the field experiment, it was thought that, though greenhouse experimental results are not always fairly comparable with those obtained under field conditions, some additional valuable data on growth measurements might be obtained from a greenhouse experiment. It was also desirable to determine whether the results obtained in the field could be substantiated by similar measurements taken under greenhouse conditions.

Materials

Seeds from three of the five open-pollinated strains used in the field were employed here. These were Ranger, Ferax, and Kansas. Owing to a shortage of seed, different selfed strains from those used in the field had to be utilized. They were similar to those used in the field experiment in that they were produced under the same conditions, but were of different stock material. The seeds were from seventh generation selfed plants.

Methods

The studies on the methods of measuring growth in alfalfa were made in the greenhouse with a temperature range of 65° to 75°F. during the winter of 1946-47. The soil used in the pot cultures was a sterilized mixture consisting of one-fourth sand and three-fourths Edmonton black loam. No supplementary nutrients were added to the soil. The natural daily light period was increased to sixteen hours by means of artificial lighting.

The testa of seeds used was nicked with a razor blade and placed between damp filter paper in petri dishes at a temperature range of 65° to 75°F. for seventy-two hours. The germinated seeds were inoculated with root nodule bacteria (Rhizobium meliloti) isolated from nodules of alfalfa. The most vigorous germinated seeds were transplanted, three in a pot, on November 5th, to the previously prepared soil in ten-inch pots.

The pots were arranged so that they constituted a complete randomized block experimental design with four replications of six strains. Each strain "plot" consisted of six pots, thus making a total of 36 pots in each replicate.

Twenty-five days after planting, the seedlings in the pots were thinned to two plants per pot. The seedlings

taken from the pots were weighed and measured for stem length. The fully opened trifoliate leaves were also counted for each plant. The stems were measured from the cotyledonary node to the tips of the uppermost leaves when these were extended by gentle upward stroking.

On February 14th--that is, one hundred and one days after transplanting--plant heights were measured from the soil surface in the pot to the tip of the stem. Stems ten centimeters and over in height were the only ones measured. The nodes were counted on all measured stems.

All plants were cut just above the cotyledonary node and weighed individually in grams on February 17th, 104 days after transplanting.

Experimental Results

Before proceeding with the above-described experiment, a comparison was made of the weights of open-pollinated and the selfed seed in order to determine whether differences in subsequent growth rates might be related to differences in original seed weights.

TABLE IV

Weight of 100 seeds in grams used in the greenhouse
growth measurement studies

Open-pollinated		Selfed	
Strain	Weight in grams per 100 seeds	Strain	Weight in grams per 100 seeds
Kansas	0.18	21-7	0.24
Ferax	0.26	15-34	0.23
Ranger	0.18	3-32	0.22
Mean	0.21 ± 0.03	Mean	0.23 ± 0.01

There is no significant difference between the mean weight per 100 seeds of the open-pollinated and the selfed groups, and therefore any difference in later growth cannot be attributed to difference in initial seed weight. There is a greater variation in seed weight among the open-pollinated strains, as might be expected from the variability among different varieties.

TABLE IV

Weight of 100 seeds in grams (g) and 1000 seeds in kilograms (kg) for various varieties

Variety		Weight of 100 seeds (g)	
Weight of 100 seeds (g)	Weight of 1000 seeds (kg)	Weight of 100 seeds (g)	Weight of 1000 seeds (kg)
0.15	1.5	0.15	1.5
0.15	1.5	0.15	1.5
0.15	1.5	0.15	1.5
0.15 ± 0.02	1.5 ± 0.2	0.15 ± 0.02	1.5 ± 0.2

There is no significant difference between the mean weight of 100 seeds of the two varieties in the field trials, and therefore no difference in the mean weight of 1000 seeds in kilograms in the field trials. There is a significant difference in the mean weight of 1000 seeds in kilograms between the two varieties in the field trials, as might be expected from the above results.

TABLE V

Measurements on seedlings removed from pots
25 days after transplanting

Strain	Number	Weight per seedling (gm.)	Stem length (cm.)	Number of leaves
<u>Open-pollinated</u>				
Ferax	22	0.6	4.7	1.7
Kansas	21	0.6	5.4	1.7
Ranger	21	0.5	5.0	1.9
Mean			5.0 $\pm$ 1.6	
<u>Selfed</u>				
3-32	19	0.5	4.2	1.8
15-34	21	0.7	4.3	1.8
21-7	24	0.6	4.8	1.4
Mean			4.5 $\pm$ 1.4	

In this experiment the means and their standard errors were calculated for the measured characters for open-pollinated and selfed groups and the means tested for significance, in the same manner as described for Table II.

There is no significant difference between open-pollinated and selfed groups in any of the characters measured at this stage. However, the data suggest slightly greater stem length for the open-pollinated group.

Table 1

Summary of results of the experiment on the effect of the concentration of the solution on the rate of the reaction.

Concentration of the solution, %	Time, min.	Volume of gas, ml.	Rate of reaction, ml./min.
1.0	10	10	1.0
2.0	5	10	2.0
3.0	3.3	10	3.0
4.0	2.5	10	4.0
5.0	2.0	10	5.0
6.0	1.7	10	6.0
7.0	1.4	10	7.0
8.0	1.3	10	8.0
9.0	1.1	10	9.0
10.0	1.0	10	10.0

In this experiment the rate of the reaction was determined by the volume of gas evolved in a given time. The results show that the rate of the reaction increases with the concentration of the solution. The rate of the reaction is directly proportional to the concentration of the solution. The results of the experiment are summarized in Table 1.

TABLE VI

Means of character measurements of six strains of alfalfa taken in the greenhouse on plants 104 days old

Strain	Weight (gm.)	Length of longest stem (cm.)	Total length of stem per plant (cm.)	Av. length of stem per plant (cm.)	No. of stems over 10 cm.	No. of nodes per longest stem	Av. no. of nodes per stem
<u>Open-pollinated</u>							
Perax	2.9#	30.2	74.4	22.4	3.2	13.0	10.7
Kansas	3.3	34.4	97.1	28.3	3.5	12.9	10.8
Ranger	3.3	34.1	99.7	24.7	4.0	12.9	10.1
Means	3.2 ±0.7	32.9** ±1.0	90.4** ±3.2	25.5* ±0.7	3.6** ±0.1	12.9	10.5 ±0.4
<u>Self-pollinated</u>							
3-32	2.5	24.8	47.9	20.7	2.5	12.3	10.9
15-34	1.3	24.5	40.9	23.7	1.8	12.9	11.9
21-7	2.4	21.9	27.5	20.6	1.4	13.5	12.5
Means	2.1 ±0.8	23.6 ±0.7	38.7 ±2.4	21.6 ±0.6	1.8 ±0.1	12.9	11.6 ±0.7

Each value is the mean of four replicates.

* Mean significantly higher to the 5% point

** Means significantly higher beyond the 1% point than the corresponding means for the self-pollinated strains.

There is a highly significant difference between the following means: length of longest stem, total length of stem per plant, and number of stems ten centimeters and over, in all cases in favor of the open-pollinated group. There is a significant difference in average length of stems, the open-pollinated group producing the longest stems. The differences for weight and number of nodes per measured stem between the two groups are not significant.

TABLE VII

Coefficients of correlations of measured characters,
(1) weight, (2) mean length of stem, (3) mean number of stems over 10 centimeters, (4) total stem length, (5) length of longest stem,
taken on greenhouse plants 104 days old

$$r_{1\ 2} = .973^{**}$$

$$r_{1\ 3} = .970^{**}$$

$$r_{1\ 4} = .982^{**}$$

$$r_{1\ 5} = .980^{**}$$

** significant beyond the .1% point.

The correlation coefficients given above indicate highly significant positive correlations between weight and the following variables in Table VI: length of stem, number of stems over ten centimeters, total stem length per plant, and length of longest stem.

Most of the variability in plant weight could obviously be accounted for by its association with any one of the afore-named characters. These correlations indicate that by measuring any of these characters the same relative information could be obtained on growth rates as is obtained from plant weight.

Discussion

Examination of Table V suggests that, except for height of stem, there seems to be no difference between the open-pollinated and selfed strains at this early stage of growth, viz. 25 days. The data indicate that the open-pollinated strains may have the longer stems at this stage.

The final weights of open-pollinated and selfed strains (Table VI) are not shown to be statistically different, but the differences are so consistently in favor of the open-pollinated strains that it seems fairly safe to postulate that the difference is real.

There is a highly significant difference in stem lengths between the two groups (Table VI) but there is no difference in the average number of nodes per stem. This same relationship was observed on number of nodes per longest stem. It would seem that at this stage of growth increase in stem length may be due more to an increase in

...of the variability in plant weight ...
...usually be associated ... by the ...
...of the ...
...that by ...
...information ...
...from ...

Discussion

...of ...
...of ...
...open ...
...growth ...
...collected ...
...the ...
...remain ...
...there ...
...the open ...
...growth ...
...there is ...
...length ...
...distance ...
...same ...
...growth ...
...increase ...

internode length than to an increase in node number.

The data from this experiment indicate that growth measurements such as weight, total stem length, length of longest stem, average length of stem, and average number of stems over ten centimeters in length, are all good criteria of growth in alfalfa under greenhouse conditions.

Correlations between weight and the above-mentioned measured characters are highly significant. It seems that any of these measures will demonstrate the same relative information on growth rates. Under greenhouse conditions stem length appears to be the best indicator of growth-rate differences which exists between open-pollinated and selfed strains of alfalfa.

GENERAL DISCUSSION

The weight of forage produced has been used as the principal criterion of growth and vigor in alfalfa; consequently, final plant weight was used as one of the measures of growth in these experiments. In experiments reported herein other measurements were made and correlated with weight to test their comparative value as growth measures. Green weights were used as it was desired to get a standard of size increase. There was greater variability in green weights in plants

grown under field conditions than in those grown under greenhouse conditions. Plant weight was positively correlated with length of stem, number of stems, number of nodes, and length of radicle. These correlations indicate that criteria other than weight measures could be used for studies of growth rates in alfalfa.

In these studies the earliest difference noted between the open and selfed strains was that of the linear growth of the radicle of seven-day-old seedlings. This character was easily measured and seems to be a reliable index of existing differences in potential growth rates. There was no significant difference in the weights of seeds used, but it may be possible that there would have been a difference in seed weights if all lots had been produced under similar conditions.

The plant height, as measured by stem length, was a good criterion of growth in alfalfa. Measurements of this character demonstrated that existing differences in growth rates of alfalfa plants could be established at an early stage. The differences in growth rate between inbred and open-pollinated strains were shown at the time of final weighing in both field and greenhouse experiments. The total length of stems produced per plant, as measured in the greenhouse, indicated that open-pollinated strains produced more aerial growth than selfed strains. Plant height is

growth rates of the seedlings in the first year after sowing
were similar. The seedlings were negatively correlated
with height at 1 year, number of leaves, number of roots, and
length of roots. There is a positive correlation between
other than height which could be used as a basis of selection
for the future.

In the first year the seedlings of the first year

showed the same pattern of growth as the seedlings of the first

year of the first year of the first year.

There was a significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

year. There was no significant difference in growth between the

first year of the first year and the first year of the first

positively correlated with weight, which indicates that heavier plants produced longer stems.

In alfalfa, leaves, lateral stems, buds, and flowers originate at the nodes. Therefore, it would be expected that as the number of nodes per plant increased so would the production of leaves, lateral stems, pods, and seeds.

In the field experiment the nodes, as counted on the longest stem, were more numerous for the open-pollinated strains, but this was not the case in the greenhouse. This discrepancy may be due to differences in stage of growth.

As a result of measurements taken in the field experiment and observations made in the greenhouse, it seems that the number of basal stems that plants were able to produce did not differ appreciably. However, when total length of stems produced was measured, it seemed that the more vigorous plants produced their basal stems earlier, and these grew longer in the same length of time. The total length of stems measured under greenhouse conditions indicated that open-pollinated plants had the greater total stem length.

The data on the earliness of flowering are meagre. Observations of this characteristic in the field indicated that open-pollinated strains were earlier blooming than the selfed strains, and it seems likely that they would consequently be earlier maturing.

The data from these experiments indicate that the

condition) correlated with weight, which indicated that

weight was a significant factor.

In addition, however, weight, height, and age were

included in the model. The results showed that weight was

the best predictor of success in the laboratory and that

weight, height, and age were also significant.

In the field experiment the results are similar to

the laboratory study, with weight being the best predictor

of success. The results also show that height and age were

also significant in the field experiment.

As a result of the laboratory study it was found

that weight was the best predictor of success. It was

also found that height and age were also significant.

However, the results of the field experiment

showed that weight was the best predictor of success.

The results also show that height and age were also

significant in the field experiment.

As a result of the laboratory study it was found

that weight was the best predictor of success. It was

also found that

height and age were also significant.

The results of the field experiment showed that weight

was the best predictor of success. The results also

showed that height and age were also significant.

As a result of the laboratory study it was found

that weight was the best predictor of success. It was

best criteria of growth rates for the alfalfa strains used were: green weights, plant height, total stem length, and radicle length.

SUMMARY

1. Alfalfa growth rate was measured in terms of radicle elongation, stem number, stem length, and node number, at specified time intervals, after placing the seeds under germination conditions, and these characters were correlated with weight of aerial growth.

2. The difference in growth rates between open-pollinated and selfed strains was measured in the greenhouse at the seedling stage by radicle elongation.

3. Early in the development of the plants there was a differential growth rate between open-pollinated and selfed strains, as shown by measurements of stem length in both the field and greenhouse experiments.

4. When the plants of the field experiment were harvested there were differences observed in length of longest stem, number of nodes, number of open flower clusters, and weight of plants, in favor of the open-pollinated group in all cases.

5. At the time plants were harvested in the greenhouse there were significant differences in length of longest stem, total length of stem, number of stems exceeding ten centimeters in length, between open-pollinated and selfed strains. This corroborates the evidence of superiority of the open-pollinated strains in the field experiment. There was no significant difference in weights between the open-pollinated and selfed strains, but it is considered that the difference is real and in favor of the open-pollinated groups. There was no inter-group difference in the number of nodes per measured stem.

6. Under conditions of these experiments, length of radicle, length of longest stem, total stem length, number of stems over ten centimeters, were the best criteria of growth rates for the strains of alfalfa used in this study.

7. From the high correlations between these growth characters and weight it would appear that any of these may be used as a substitute for weight of aerial parts in estimating the relative rates of growth of alfalfa plants.

ACKNOWLEDGEMENTS

The writer wishes to express his sincere gratitude to Dr. J. R. Fryer for assistance and guidance both during the course of the experimental work and in the preparation of the manuscript. Thanks are also expressed to Dr. A. G. McCalla for advice on the design of experiments and in the statistical reduction of the data.

REFERENCES

1. ANDERSON, E. and SCHREGARDUS, D. A method for recording and analyzing variations of internode pattern. Ann. Missouri Bot. Garden. 31:239-247. 1944.
2. ARNDT, C.H. Temperature-growth relations of the roots and hypocotyls of cotton seedlings. Pl. Physiol. 20:200-220. 1945.
3. EVANS, M. and JOHNSON, I.J. Comparative rates of growth of tetraploid and diploid sweet clover. Jour. Am. Soc. Agron. 37:867-875. 1945.
4. FREEMAN, G.F. Physiological correlations and climatic reactions in alfalfa breeding. Amer. Nat. 48:356-368. 1914.
5. GOTO, S. Studies on halo blight, a bacterial disease of oats. Unpublished Thesis, Univ. of Alta. 1943.
6. GOULDEN, C.H. Methods of Statistical Analysis. John Wiley and Sons, N. Y. 1939.
7. HACKBORTH, J. and UFER, M. "Züchterische beobachtungen an luzerneklonen. I. Einige züchterisch wichtige Korrelationkoeffizienten. Züchter 7:281-284. 1935.

REFERENCES

The author wishes to express his sincere appreciation to Dr. J. J. Edgar for assistance and guidance throughout the course of the experimental work and to the members of the committee. Thanks are also extended to Dr. J. J. Edgar for advice on the design of experiments and to the statistical section of the staff.

REFERENCES

1. ARNOLD, J. and COLEMAN, J. A. A study of the relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 1-14.
2. BROWN, J. J. The relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 15-24.
3. EVANS, M. and EVANS, J. J. The relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 25-34.
4. FISHMAN, J. W. The relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 35-44.
5. GOTO, S. The relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 45-54.
6. HARRIS, E. H. The relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 55-64.
7. JACKSON, J. and JACKSON, J. The relationship between the frequency of occurrence of a character and the frequency of occurrence of the character in the population. *Journal of the Royal Statistical Society*, 1934, 96, 65-74.

8. HAYWARD, H.E. The Structure of Economic Plants. Macmillan Co., N.Y. 309-337. 1938.
9. IPATJEV, A.N. Accurate morphological methods for studying varieties. Comptes Rendus (Doklady) de L'Academie des Sciences de L'URSS. 42:401-403. 1944.
10. KEMPTON, J.H. and McLANE, J.W. Hybrid vigor and weight of germ in seeds of maize. Jour. Agric. Res. 64: 65-80. 1942.
11. LIVINGSTON, B.E. Palladin's Plant Physiology. P. Blakiston's Son and Co. Philadelphia. 1918.
12. MAXIMOV, N.A. Plant Physiology. McGraw-Hill Book Co., Inc., N.Y. pp. 118-123. 1938.
13. MEYER, B.S. and ANDERSON, D.B. Plant Physiology. D. Van Norstrand Co., Inc., N.Y. 1946.
14. PACK, D.A. Photographic method for measuring and recording morphological and physical characters of plants. Phytopath. 14:433-435. 1924.
15. PADDICK, M.E. Vegetative development of inbred and hybrid maize. Iowa State College of Agric. Res. Bull. 331. 1944.
16. SPRAGUE, G.F. Hybrid vigor and growth rates in a maize cross and its reciprocal. Jour. Agric. Res. 53:819-830. 1936.
17. STANILAND, L.N. Simple laboratory and field apparatus for the production of accurate line drawings to scale. Ann. Appl. Biol. 33:170-177. 1946.
18. STEWART, G. Alfalfa-growing in the United States and Canada. Macmillan Co., N.Y. 46-57. 1926.
19. TYSDAL, H.M. and WESTOVER, H.L. Alfalfa improvement. U.S.D.A. Yearbook. pp. 1122-1153. 1937.
20. _____, KIESSELBACH, T.A. and WESTOVER, H.L. Alfalfa breeding. Univ. Neb. Ag. Exp. Sta. Res. Bull. 124. 1942.
21. VEATCH, C. Vigor in soybeans as affected by hybridity. Jour. Amer. Soc. Agron. 22:289-310. 1930.
22. WEXELSON, H. Studies on fertility, inbreeding, and heterosis in red clover. Vid. Akad. Skr. 1.M.-N. Kl. 1945. No. I.

1. LITVIN, L. I. The dynamics of economic life.
Moscow, 1955. 200-201. 1955.
2. LITVIN, L. I. Economic development of the USSR.
Moscow, 1955. 200-201. 1955.
3. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
4. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
5. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
6. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
7. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
8. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
9. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
10. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
11. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
12. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
13. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
14. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
15. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
16. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
17. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
18. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
19. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
20. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
21. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.
22. LITVIN, L. I. and others. The USSR in the world.
Moscow, 1955. 200-201. 1955.

23. WHALEY, W.G. and LONG, A. The behavior of excised roots of heterotic hybrids and their inbred parents in culture. Bull. Torrey Bot. Club. 71:267-275. 1944.

B29754