A STUDY OF THE DEVELOPMENT OF THE SUBTERRANEAN SYSTEM OF THE JOHNSON GRASS PLANT

by

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INTRODUCTION

The relative meaning of the word "weed" as defined by Bailey (1) is "a plant growing where it is not wanted." He gives another definition which puts the term on an absolute basis, that is, "a weed is a wild plant which has a habit of intruding where it is not wanted." A weed may be classified as to the duration of its life cycle annual, biennial or perennial. An annual is one which completes its life cycle in one growing season while a biennial requires two growing seasons to complete its life cycle. A perennial is a plant which lives for a period of three years or more. Perennials may be subdivided into simple, bulbous and creeping. A creeping perennial is one which spreads by stolons, rhizomes or lateral roots. Gates (6) reported Johnson grass[1] (Sorghum halepense) to be an annual or perennial grass reproducing by seeds and large rhizomes.

The control of weeds is rapidly increasing in importance throughout all agricultural areas and is becoming a part of our over all conservation program. Weeds interfere in many ways with man's efforts to grow useful plants, especially in reducing the productive capacity of agricultural lands. It has long been recognized that weeds take a heavy toll annually in crop production. There are many factors which have contributed to the problem, two of which are the lack of understanding of the seriousness of weeds and carelessness. Until quite recently

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[1] Johnson grass (Sorghum halepense) will be referred to hereafter as Johnson grass.

this loss was considered inevitable and very little was done to reduce the heavy toll weeds were taking. The introduction of herbicides and farm mechanization have brought encouragement and hope that our most widespread and destructive weeds may soon be brought under control.

Two of the fundamental steps which should be used in planning measures for the control of a plant are an understanding of its growth habits and a knowledge of its life cycle. In the study which has been conducted, an attempt has been made to learn more about the Johnson grass plant especially the development of its root system from a seedling to maturity and through the dormant period to resumption of growth the following season.

REVIEW OF LITERATURE

The underground stems or rootstocks of Johnson grass have been classified by Cates and Spillman (3) as primary, secondary and tertiary. Primary rootstocks included all of those which were alive in the ground at the beginning of the growing season in the spring. The rootstocks which developed from the primaries, came to the surface and formed new crowns, giving rise to new plants, were designated as secondaries. Tertiary rootstocks were those which developed later in the season from the crown of the new plant. They considered the primaries used up all of their strength in producing secondaries and vegetative growth above ground with enough deterioration taking place by fall that they would not live through the second winter. The secondary and tertiary rootstocks were classified as primary rootstocks at the beginning of the growing season following the one in which they were formed. In other words, there was a new mass of rootstocks formed in one growing season which gave rise to the next year's growth and then decayed.

The formation of tertiary rootstocks from the crown of the plant was found by Cates and Spillman (3) to take place about the time it began to bloom. The extent to which these organs developed depended upon the length of time the plant was allowed to stand after blossoming, soil in which it was growing and the length of time the plants had been in a sod formation. The tertiary rootstocks increased in size and extended to a greater depth if the plants were allowed to remain standing after blooming. They penetrated to a greater depth in a light soil than

in a heavy soil. Plants growing in a thick heavy sod which had not been disturbed for several years did not have an underground root system that was as extensive as a plant growing in an old sod which had been plowed in the spring.

Cates and Spillman (3) made their observations on plants which were produced from rhizomes and did not conduct a study of the development of the root system from plants which had been started from seed. Since the main source of new infestations is from seed which has been carried by irrigation water, by overflow from flooding streams or by impure crop seed it is desirable to know more about the development of plants from this source.

A greenhouse study was conducted by Sturkie (7) in order to determine the time of rootstock development of seedlings. He found that no rootstocks appeared until the heads were showing. The progressive development of the rootstocks was associated with the development of the seed, and most rapid growth being at the time the seed matured. The dry weight of the rootstocks was used as a measure of growth. Plants used in this experiment were grown in two gallon pots, therefore, the depth of penetration and the area of concentration of the rhizomes could not be determined.

Elder (4) states that seedlings, grown under field conditions in Oklahoma, did not develop rhizomes or underground stems until the plant reached the boot stage of development. The most rapid and extensive development of rhizomes occurred during the heading and maturing stages.

According to Vinall and Crosby (8) Johnson grass is more easily destroyed if the rootstocks are concentrated near the surface of the soil and are more subject to winter killing. Cates and Spillman (3) have indicated there is a possibility that rootstocks deteriorate less during a dry winter season than one in which there is ample moisture in the soil.

In the study conducted by Barnett (2), during the winter of 1936-'37, it was found that the maximum depth of frost penetration in a compact soil which had no surface protection was approximately 22 inches. He also found the frost penetration to be only 3¼ inches in a soil that was protected by a 3 inch layer of settled wheat straw.

JOHNSON GRASS AS A WEED

Johnson grass, a native of the coastal countries of the Mediterranean region, was introduced into the United States many years ago. Bailey (1) indicated that it was brought to this country from Turkey during the early 1830's. Until the weedy character of this plant was realized, it spread rapidly and was considered an excellent hay grass for the South. It is being used as a forage crop in some of the Southern states, however, in most localities it is regarded as a weedy grass. The reason for this is that it spreads both by seed and vigorous root-stocks, and once it becomes established it is difficult to eradicate from cultivated fields.

Although this plant originated in a warm climate, it has adapted itself to a wide range of conditions. Vinall and Crosby (8) stated that the thirty eighth parallel was approximately the northern limit for it to exhibit a perennial habit of growth and beyond this it is usually killed in cold winters. It appears that through natural selection this plant is developing rhizomes which can withstand colder winter temperatures. Serious infestations now exist along the streams and rivers of Ohio, Indiana, Illinois and Missouri as reported by Fuelleman (5) in 1950.

The acreage of land infested with this weed in Kansas is not as extensive as that of other weeds but it has become troublesome on some of the most productive land. It thrives best and is most persistent on the deep fertile soils found along rivers and streams. It has also become a serious pest

in the irrigated sections of the state.

The northward migration of this weedy grass was brought about by the use of impure crop seed and the natural development of winter hardiness. Many of the states have taken measures to prevent the introduction of Johnson grass seed by legislation which declares it a noxious weed. This prohibits agricultural seed containing Johnson grass from entering the state.

Provisions of the Kansas seed law pertaining to Johnson grass are as follows:

> Prohibited Weed Seeds. The statute prohibits the sale in Kansas of agricultural seed which contains any seed of field bindweed, hoary cress, Russian knapweed, or leafy spurge.
>
> Limited Weed Seeds. The presence of Johnson grass and dodder in seed sold for planting purposes is limited to not more than one seed of Johnson grass or dodder in ten grams of crop seed. This is equivalent to 45 such seeds to the pound of crop seed. Agricultural seed containing an excess of either of these weed seeds may be cleaned to remove the excess Johnson grass or dodder seeds or sold for processing purposes. Agricultural seed containing fewer than one of these weed seeds in ten grams may be sold when the label shows in addition to other requirements, the kind of weed seeds and rate of occurrence within this limitation.

Provisions of the Kansas noxious weed law pertaining to Johnson grass are as follows:

> Sec. 2-1314. Control and eradication of field bindweed, Russian knapweed, hoary cress and Johnson grass. It shall be the duty of person, associations of persons, the state highway commission, the boards of county commissioners, the township boards, school boards, drainage boards, the governing body of incorporate cities, railroad companies, and other transportation companies or corporations or their authorized agents and those supervising state-owned lands to control the spread of and to eradicate all weeds declared by legislative action to be noxious on all lands owned or supervised by them and to use such methods for that purpose and at such times as are approved and adopted by the state

> board of agriculture. The term noxious weeds shall mean field bindweed (Convolvulus arvensis), Russian knapweed (Centaurea picris), and hoary cress (Lepidium draba): Provided, That the term noxious weeds shall mean and include Johnson grass (Sorghum halepense) in those counties in which the county commissioners by resolution so declare. (L. 1937, ch. 1, § 1; L. 1945, ch. 3, § 1; March 20.)

The law also prohibits selling, bartering or giving away of livestock feed, screenings, nursery stock, plants, packing material, animal fertilizers and soil or sod which contains or is infested with noxious weed plant material or seeds. Livestock feed may be sold for consumption on the same farm where it has been grown or for processing only. Screenings may be sold if the viability of the noxious weed seed present has been destroyed. It is also unlawful to transport machinery and equipment into the state or from field to field which is not free from noxious weed seeds.

As of May 31, 1951, there are 32 counties in the state which have taken a forward step and by resolution declared Johnson grass as noxious (Fig. 1).

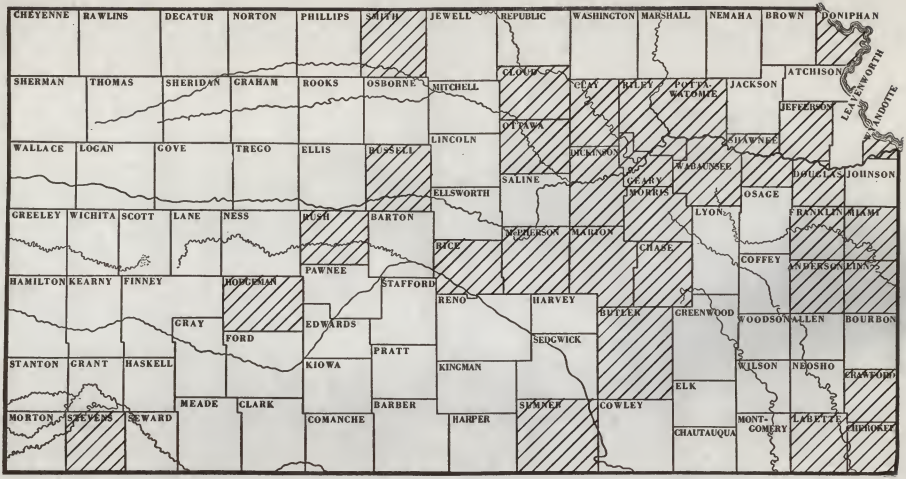

Fig. 1. Counties in Kansas which by resolution have declared Johnson grass to be a noxious weed, May 31, 1951.

MATERIALS AND METHODS

The site chosen for the planting was an area of uncultivated ground which contained a thick sod of annual weedy grasses. The soil was typical of the Geary silt loam found in this area. No layer of the profile appeared to be of such nature that rhizome development would be restricted seriously. On May 28, 1950, the seed bed was prepared by working the soil with a rotary tiller to a depth of approximately six inches. The area was divided into two plots, each consisting of five rows, 30 feet long and three feet apart.

Planting of the plots was done on June 1, 1950. Plot 1 was planted with seed which was covered with approximately one inch of soil. Portions of rhizomes, placed 18 inches apart in the row, were used to establish a stand on Plot 2. Two kinds of rhizomes were used, one a piece 3 to 5 inches in length containing 3 live buds and the other similar in length but supporting a growing shoot. The rhizomes were placed at a 45 degree angle, buds pointing upward, and covered with one and one-half inches of soil. The primary purpose for including Plot 2 in the experiment was to provide material to be studied in the event plants failed to develop from the seed which was planted in Plot 1. Observations were made on those plants started from rhizomes but the greater emphasis was placed on those started from seed.

The seedlings started to emerge on June 6 and at the end of one week they could easily be seen down the row. Three weeks after planting the seedlings were thinned to stand approximately

six inches apart in the row. The plots were cultivated as often as necessary to keep down weed growth.

Four weeks after planting, seedlings were selected at random and removed to observe height of plant, number of tillers, direction and length of rhizomes. The same information was again observed six and eight weeks after planting. The stage of maturity was also recorded on those plants removed eight weeks after planting. Observations recorded at two week intervals from then and until maturity were on the stage of maturity and on the vertical growth of rhizomes. Plants were removed again in the spring after frost had left the soil to ascertain the depth to which the rhizomes had penetrated and the amount of rhizome deterioration during the dormant season. As the spring progressed the rhizomes were also observed for regeneration of growth.

The removal of mature plants was accomplished by digging a trench about three feet deep along the end of the rows and with the aid of an ice pick and a screw driver the soil particles were worked away from around the rhizomes freeing the plant. A tripod made from three steel post was placed over the excavation. The plants were suspended from the tripod until all of the rhizomes had been worked free from the soil.

Photographs were taken at intervals to help record the observations which were being made.

OBSERVATIONS AND DISCUSSION

The development of the root system was observed by means of a number of plants excavated at two week intervals beginning one month after planting and continuing through the growing season. Data of the excavations are given in Tables 1 to 5 inclusive and Plates I and II. Additional excavations were made during the period of dormancy (Plates IV, V and VI).

Rhizome development of the plants that were removed four weeks after planting was somewhat indefinite (Table 1). Some of the growth which appeared to be rhizomes was directed toward the surface of the soil and later became a culm of the plant. On the larger plants rootstocks had definitely developed.

Six weeks after planting there was an increase in the number of tillers and a more definite development of underground growth in terms of rootstock material. At this stage of development only one of the plants excavated had a culm which was in the boot stage (Plate II). The general trend of the rootstock development was in a horizontal direction (Table 2). The formation of rhizomes before heading is not in accordance with the findings of the greenhouse study conducted by Sturkie (7). He found no rootstocks appearing until the heads were showing.

During the next two weeks, growth and development were more rapid. Two months after planting, approximately fifteen percent of the culms were in the boot stage. At this time the plants which had been started from rootstocks were more advanced in their development than the plants grown from seed.

Table 1. The growth and development of Johnson grass seedlings four weeks after planting, June 30, 1950.

Height of plant	Number of tillers	Direction of rhizome			Length of rhizome
		Vertical	45 degrees	Horizontal	
8"	2	x			1/8"
7"	2		x		1 1/4"
			x		2 "
7"	2		x		2 "
			x		2 1/2"
				x	2 3/8"
7"	4	x			1 1/2"
10"	2		x		2 3/4"
			x		3 "
5"	3		x		3 1/2"
				x	5 1/4"
4"	1			x	2 1/4"
				x	1 1/4"
5"	2	x			1 1/2"
				x	1 1/4"
4"	0			x	1 "
				x	1 1/4"
7"	2		x		2 3/8"
			x		2 1/4"
8"	3	x			3 "
				x	4 "
5"	1	x			1/8"
3"	1		x		1 "
6"	1		x		1 1/4"
12"	4		x		2 1/4"
				x	10 "
6"	3	x			2 "
				x	1 "
8"	4		x		2 1/2"
			x		3 "
5"	3			x	1 "
3"	0	0	0	0	0
7"	2	x			1 "
				x	1 1/4"
7"	3		x		3 "
8"	2	x			1/4"
8"	3			x	2 "
5"	1	x			1 "
			x		2 1/2"
			x		3 "
7"	5	0	0	0	0

Table 2. The growth and development of Johnson grass seedlings six weeks after planting, July 14, 1950.

Height of plant	Number of tillers	Direction of rhizome			Length of rhizome
		Vertical	45 degrees	Horizontal	
19"	5		x		2"
13"	3			x	2"
				x	1"
16"	5			x	6"
14"	10			x	9"
				x	4"
10"	8			x	2"
13"	6	x			3"
			x		1"
				x	4"
13"	7		x		2"
				x	6"
				x	7"
15"	9			x	2"
				x	5"
35"	19			x	13"
				x	5"
				x	7"
				x	2"
20"	9			x	1"
				x	2"
				x	5"

EXPLANATION OF PLATE I

Johnson grass seedling six weeks after planting.

PLATE I

EXPLANATION OF PLATE II

Johnson grass seedling six weeks after planting.

PLATE II

About one-half of the plants were headed and the rhizome development was much more massive. The seedling plants had produced enough rhizomes that they could be classified as a perennial in habit of growth. The rhizomes present were concentrated in the top eight inches of soil and there appeared to be little if any vertical direction of growth. The data in Table 3 show the number and length of the rhizomes which had their orgin from the base of the crown of the original seedling. A considerable amount of branching and re-branching of these rhizomes had taken place, they varied in length from eight inches to a swelling bud. Some of the rhizomes which had extended laterally came to the surface and were producing another culm and crown which was separate from the main crown of the seedling. Several of the branches from the original rhizomes had also come to the surface and were producing a new crown and a culm.

According to the classification established by Cates and Spillman (3), the rootstocks which the seedlings had produced would have been classified as tertiary, however, some of them performed as secondaries in that they came to the surface of the soil and produced new crowns. This was also observed in Plot 2.

Ten weeks after planting about one-half of the seedlings were in bloom and the other one-half were in the boot stage. The plants established from portions of rootstocks were more advanced with a number of heads being mature and shattering occurring. The difference in vigor and maturity of the vegetative portion of the plants can be seen in Plate III.

During this two week period of growth, the lateral

Table 3. The growth and development of Johnson grass seedlings eight weeks after planting, July 28, 1950.

Height of plant	Number of tillers	Number of heads in the boot	Direction of rhizome			Length of rhizome
			Vertical	45 degrees	Horizontal	
40"	11	1	x			8"
			x			4"
			x			3"
					x	1"
					x	5"
43"	19	3	x			7"
			x			1"
36"	12	1	x			10"
			x x			7"
			x			5"
					x	7"
					x	6"
					x	5"
36"	9	0	x			3"
			x			2"
			x			4"
			x			6"
					x x	2"
46"	24	5			x x	8"
					x	5"
					x	11"
					x	16"
					x	17"
36"	23	1			x	6"
					x	7"
					x	8"
					x	11"
20"	8	0	x			4"
					x x	1"
					x	2"
					x	4"
30"	19	1	x			2"
					x	2"
					x	5"
					x	8"
					x	10"
32"	16	1			x	3"
					x	4"
					x	6"
					x x	16"
35"	22	4			x	6"
					x	18"

EXPLANATION OF PLATE III

Johnson grass seedlings to the left; plants started from portions of rhizomes to the right.

PLATE III

development of rootstocks in the top eight inches of soil increased and there was a movement of rhizome material in a downward direction. The depth of penetration was greater on those plants which were in full bloom or past blooming. The number and length of rhizomes varied as shown in Table 4.

By the first of September, 12 weeks after planting, the plants in Plot 1 were well along towards maturity. Many of the leaves had fallen to the ground and some of the heads had shattered their seed. There was no general increase in the number of rhizomes growing vertically but their depth of penetration had become more uniform. The length of some of the rhizomes was greater than the depth of penetration because the growing tip had turned and was directed toward the surface of the soil. The heaviest concentration of rhizome material was still located in the top eight inches of soil. The lateral spread of the rhizomes varied considerably, the widest being 58 inches.

The rhizome development in Plot 2 was also concentrated in the top eight inches of soil and the vertical penetration was essentially the same. There was one difference observed between the rhizome development of the plants in Plots 1 and 2. The rhizomes of the seedling plants were about one-half as large in diameter as those of the plants started from portions of rhizomes (Plates IV and V). In Plot 2 there were more rhizomes that came to the surface of the soil and formed crowns other than the original crown.

After the frost had left the soil in the spring, the extent of rhizome deterioration was observed by making more excavations.

Table 4. The growth and development of Johnson grass seedlings six weeks after planting, August 15, 1950.

Stage of maturity	Number of vertical rhizomes	Depth of vertical rhizomes
Most of the heads were in bloom and a few in the boot	x x	8" 16"
Prebloom and early boot	x x	5" 6"
Some of the heads are past bloom, some blooming and a few still in the boot	x x x	15" 17" 18"
Most of the heads are in bloom with some still in the boot.	x x	10" 15"
No heads in bloom but most of them are in the boot	0	0
A large number of heads are in bloom and a few in the late boot stage	x x	14" 17"
Just beginning to bloom with most of heads in the boot	x x x	9" 11" 15"
Most of the heads are in bloom with a few still in the boot, several are past bloom	x x	14" 20"
Several of the heads have just emerged from the boot.	x	10"
Most of the heads are in full bloom with just a few in the late boot stage	x x	15" 16"

Table 5. The growth and development of Johnson grass seedlings three months after planting, September 1, 1950.

Stage of maturity	Number of vertical rhizomes	Depth of vertical rhizomes
A few of the heads in the boot with most of them in bloom and a few mature	x	10"
	x	11"
	x	18"
Most of the heads are mature, a few in late bloom	x	19"
Some of the heads are well matured, most of them in dough stage, several in bloom	x	14"
	x	23"
Late bloom and milk stage	x	9"
	x	16"
Most of heads have seed which is in dough stage with some in late bloom	x	22"
Blooming	0	0
Some heads with seed in milk stage but most in dough stage	x	12"
	x	15"
A few of the heads have matured seed while the bulk are in the dough stage	x	20"
Blooming and in milk stage	x	8"
	x	11"
	x	13"
Some seed mature, greater portion in dough stage	x	18"

EXPLANATION OF PLATE IV

Johnson grass seedlings showing natural position of rhizomes prior to resumption of growth in spring.

PLATE IV

EXPLANATION OF PLATE V

Johnson grass plant started from a portion of rhizome showing natural position of rhizomes prior to resumption of growth in spring.

PLATE V

Table No. 6. Weather data recorded at Manhattan, Kansas.

Date	Precipitation in inches	Departure from normal	Average temperature degrees F.	Departure from normal
June 1950	3.61	- 1.00	74.0	- 0.7
July 1950	13.68	9.95	70.9	- 9.3
Aug 1950	3.98	- 0.26	71.9	- 6.6
Sept 1950	0.22	- 3.71	66.4	- 4.1
Oct 1950	1.32	- 0.93	62.1	4.0
Nov 1950	0.53	- 1.24	39.4	- 4.6
Dec 1950	0.03	- 0.83	30.2	- 2.0
Jan 1951	0.53	- 0.18	28.7	0.5
Feb 1951	1.44	0.22	34.0	1.6
Mar 1951	2.77	1.15	37.6	- 6.4
April 1951	2.75	0.09	49.9	- 5.3
May 1951	10.29	5.86	64.7	- 0.1

A very small percentage of rhizome material was destroyed during the winter. This decaying occurred in some of the rhizomes that were located near the surface two inches of soil. The soil moisture was below normal throughout most of the dormant season (Table 6). Also, the January and February average temperatures were above normal. The amount of deterioration which took place was considered to be below average because of the abnormal climatic conditions which prevailed during the dormant period. This observation is in agreement with that of Cates and Spillman (3).

The first indication that growth was resuming was observed on April 27, the buds at the nodes of the rhizomes had begun to swell. One week later many of the nodes of the rhizomes had begun to swell and as much as one inch of new growth had developed. The new growth was all directed toward the surface of the soil. Fibrous roots had begun to develop and their direction of growth was downward. This resumption of growth was taking place throughout the entire profile of rootstocks.

At this time many seedlings were emerging from the seed which had shattered the previous fall. On May 10, two weeks after the first indication of resumption of growth, there was evidence of vegetative growth above the surface of the soil which had originated from last season's rhizomes.

SUMMARY AND CONCLUSIONS

Under known environmental conditions, a seedling of Johnson grass can develop enough rhizomes in a two month growing period to justify classifying it as a perennial in habit of growth.

Lateral development of rhizomes takes place throughout the growing season. This lateral development may come to the surface of the soil and produce new crowns and shoots.

The vertical development of rhizomes begins about the time the plant begins to head and continues until maturity. The maximum depth of penetration of the vertical rhizomes in the plants excavated was 26 inches.

Under known environmental conditions, the average Johnson grass seedling and plants established from cuttings of root-stocks produced rhizomes which penetrated to a depth greater than the average depth of frost penetration.

New plants originating from rhizome cuttings became established more quickly and made more vegetative and root growth than similar plants started from seed.

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BIBLIOGRAPHY

(1) Bailey, L. H.
Cyclopedia of American Agriculture. II: 110 & 448. 1907.

(2) Barnett, R. J.
Ground cover affects frost penetration. Kansas State Horticultural Society Biennial Report. LXIV: 92-97. 1938.

(3) Cates, J. S., and W. J. Spillman.
A method of eradicating Johnson grass. U.S.D.A. Farmer's Bul. 279. 1907.

(4) Elder, W. C.
Controlling Johnson grass in Oklahoma. Okla. Agr. Expt. Sta. Mimeo. Cir. M-215. 1951.

(5) Fuelleman, R. F.
Research Report. North Centeral Weed Control Conference. 18. 1950.

(6) Cates, F. C.
Weeds in Kansas. Report of the Kansas State Board of Agri. 40 : 63. 1941.

(7) Sturkie, D. G.
The influence of various top-cutting treatments on root-stocks of Johnson grass (Sorghum halepense). Amer. Soc. Agr. Jour. 22 : 82-93. 1930.

(8) Vinall, H. N. and M. A. Crosby.
The production of Johnson grass for hay and pasturage. U.S.D.A. Farmer's Bul. 1597. 1929.

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Plants to be studied were obtained by planting seed and portions of rootstocks on June 1, 1950. Plants were randomly sampled at two week intervals to observe the number, length, and direction of rhizome development.

Seedlings removed after two months of growth had produced enough rhizome material so they could be classified as a perennial in habit of growth. About heading time, there was a downward movement of the rhizomes which continued until plant growth had ceased in the fall. Plants varied somewhat in the amount and depth of this downward movement. The average depth of penetration was approximately 18 inches, with some being as much as 30 inches. The area of heaviest concentration was in the top eight inches of soil. A very small percentage of deterioration took place during the winter dormant period. The rhizomes produced by a plant started from a portion of a rhizome were larger in diameter than those produced by a seedling plant. The depth of penetration and area of concentration were essentially the same.

On April 27, 1951, the nodes of the rhizomes had begun to swell which was an indication of resumption of growth. One week later many of the buds had developed into new growth which was directed toward the surface of the soil. Fibrous roots also had begun to develop at the nodes and were directed downward.