THE RESPONSE OF QUACKGRASS TO VARIATIONS IN HEIGHT OF CUTTING AND RATES OF APPLICATION OF NITROGEN

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THESIS

RESPECTFULLY SUBMITTED IN PARTIAL FULFILLMENT
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INTRODUCTION

Quack grass, Aprogpyron repens (L) Beauv. is considered a noxious weed and as it occupies large land acreages in Michigan and other northern states, it has become a plant of considerable importance. The plant is tenacious vegetatively and consequently difficulty is experienced in eradication. Several methods of quackgrass control are practiced, nearly all of which involve the exhaustion of root reserves and removal of photosynthetic tissue.

The following study is divided into two parts. The first part deals with the removal of photosynthetic tissue at different levels from high and low nitrogen cultures and the effect on not only the roots and rhizomes, but also on the amount of new growth following such removals. The second part deals with the sprouting ability of quack grass rhizomes grown under high and low nitrogen conditions and a study of the root, top and rhizome development of such plants.

REVIEW OF LITERATURE

The literature citations dealing with plant response to defoliation under various nitrogen fertilizer treatments are quite numerous. Several papers have extensive literature reviews on much the same subject as is considered here. Graber, Nelson, Luekel and Albert (3), Harrison (4), and Graber (2),

have extensive literature reviews on the relation of organic food reserves to growth of perennial herbaceous plants. Thomas (5) has covered the recent literature on vegetative response to nitrogen fertilizer applications.

In general, a study of the literature reveals that root and rhizome development and yield of grasses are associated with the cutting treatment. The more drastic the cutting treatment, as measured by amount and frequency of defoliation, the less is the yield of roots, rhizomes, and tops. The application of nitrogen to grasses having abundant reserves and which are subjected to severe defoliation, stimulates a vegetative response, the carbohydrate reserves are rapidly consumed and with slight opportunity for replenishment they often become the principal factors limiting growth.

As pointed out by Dexter (1) it is difficult to exhaust the organic reserves of quackgrass or to place it in a condition where it is extremely susceptible to injury by defoliation.

EXPERIMENT I. METHODS AND MATERIALS

On July 12, 1937, eighty 10-inch clay pots were planted with small vegetative segments of quack grass. Ten rhizome segments, 2-3 inches long, were placed in each pot. Sand cultures were used throughout the experiment. The plants

were grown in the greenhouse at East Lansing. The plants were supplied with a three-salt nutrient solution designated as type IR_2S_4.* The nutrients were supplied to the cultures by the slop culture technique.

Growth of the plants was steady and at the end of two months the pots were well filled with vigorous plants showing good rhizome development. On September 20 the nutrients were flushed out of 40 of the pots by repeated applications of tap water, the water being allowed to drip through the pot before each succeeding application. Subsequently, throughout the remainder of the time these plants were grown in a minus nitrogen solution. This was accomplished by substituting equal molar quantities of calcium chloride in place of calcium nitrate. The other 40 cultures were supplied continuously with available nitrogen. For convenience, these cultures will be known as minus and plus nitrogen cultures, respectively.

On Oct. 29, 1937 the plus and minus nitrogen cultures were divided into five sets of plants with six cultures as replications in each set. Three cultures were washed free of sand and were separated into roots, rhizomes and tops. The weights of these cultures served as initial checks. Each series was cut on Oct. 29 and once a week thereafter for 24 consecutive weeks, or through March 29, 1938. In both the plus and minus nitrogen treatments the following cutting prac-

*A plan for cooperative research on the salt requirements of Agricultural plants. 2nd. Ed. 1919 by B. E. Livingston.

tices were followed. In series 1 the cultures were defoliated as close to the sand level as possible. Series 2 was cut back to one inch, series 3 to three inches, series 4 to six inches and series 5 to eight inches. Green and dry weight determinations were made on each individual culture for each clipping except in cases where the "recovery" growth was very small, in which case the clippings from the 6 replications of a given series were weighed as one. After cutting from September to February 1, two of the cultures from the close cutting treatments, both plus and minus nitrogen, were covered to shut out all light and prevent photosynthetic activity. On November 26 an extra plus nitrogen and a minus nitrogen culture not included in the experiment, and which had not been subjected to cutting, were covered so as to prevent photosynthesis. Once each week these cultures were completely defoliated. The recovery growth from both cultures was yellow in color at every cutting date.

On April 5, when the experiment was discontinued, the sand was carefully washed from the roots and rhizomes of all the cultures which were alive. The rhizomes, roots and tops were separated and the green and oven dry weight for each determined. At the close of the experiment three plus and three minus nitrogen cultures which had not been cut throughout the experiment, were treated likewise and served as final checks.

On April 5 photographs were taken of a representative culture from each cutting treatment, both plus and minus nitrogen. Pictures were taken both before and after cultures were washed out.

DATA EXPERIMENT I.

When the cutting treatments were initiated on October 29, the plus nitrogen plants had a vigorous top, rhizome and root growth. The leaves were dark green in color, and tended to droop over the edges of the pot. The minus nitrogen plants were very similar to the plus nitrogen plants in rhizome and root development, but had less top growth. In contrast with the leaves on the plus nitrogen plants, these were of a lighter shade of green, stiff and upright. This contrast in leaf character between the plus and minus nitrogen plants became more and more exaggerated as the experiment progressed. This was particularly true of the check plants. This difference is shown in Fig. I and III.

The various cutting treatments had a very marked and variable effect on the subterranean parts of the plus nitrogen plants in particular. The effects of cutting were first noticed in the close cutting treatment. Within two weeks after cutting was started, some of the rhizomes had

Figure I.

Plus nitrogen cultures.
Upper, left to right; completely defoliated, cut to one and cut to three inches once a week.
Lower, left to right; cut to six and cut to eight inches once a week and uncut or final check. Cultures except upper left, which is dead, with one weeks recovery growth.
(April 5)

Figure II.

Plus nitrogen cultures.
Upper, left to right; cut to one, three and six inches.

Lower, left to right; cut to eight inches and final check.

(April 5)

Figure III.

Minus nitrogen cultures.
Upper, left to right; completely defoliated, cut to one and cut to three inches once a week.
Lower, left to right; cut to six and cut to eight inches once a week and final check.

Cultures with one weeks recovery growth.

(April 5)

Figure IV.

Minus nitrogen cultures.
Upper, left to right; completely defoliated, cut to one and three inches once each week.
Lower, left to right; cut to six and eight inches once a week and uncut or final check.

(April 5)

started to die back from the tips. By the end of the sixth week many of the rhizomes had died back to the second or third node, the tips taking on a watersoaked appearance. Dying back of the rhizome tips appeared in the plus nitrogen one-inch cutting cultures by the fifth week of cutting, but in the three-inch cutting it was much later and only to a limited extent. About the fifth week of cutting the rhizome tips started to die back in the minus nitrogen close cutting treatment, while in the one-inch cutting it was somewhat later and only to a limited extent. No dying back was apparent in the minus nitrogen three-inch cutting at any time during the course of the experiment.

A number of rhizome tips turned upward in the close and one-inch cutting of the plus nitrogen plants. These tips produced green leaves upon emergence. Likewise, some of the lateral buds initiated shoots which upon emergence produced green leaves. There was only a limited increase in the number of new culms during the first few weeks, the number decreased steadily, thereafter, especially in the close cutting treatments. After only a few weeks of cutting the shoots produced in the plus nitrogen close-cutting treatment were found entirely around the outer rim of sand in the pot. To a lesser extent this was also true in the cultures receiving nitrogen and cut to one or three inches. In the minus ni-

trogen cultures this tendency was apparent but not as pronounced.

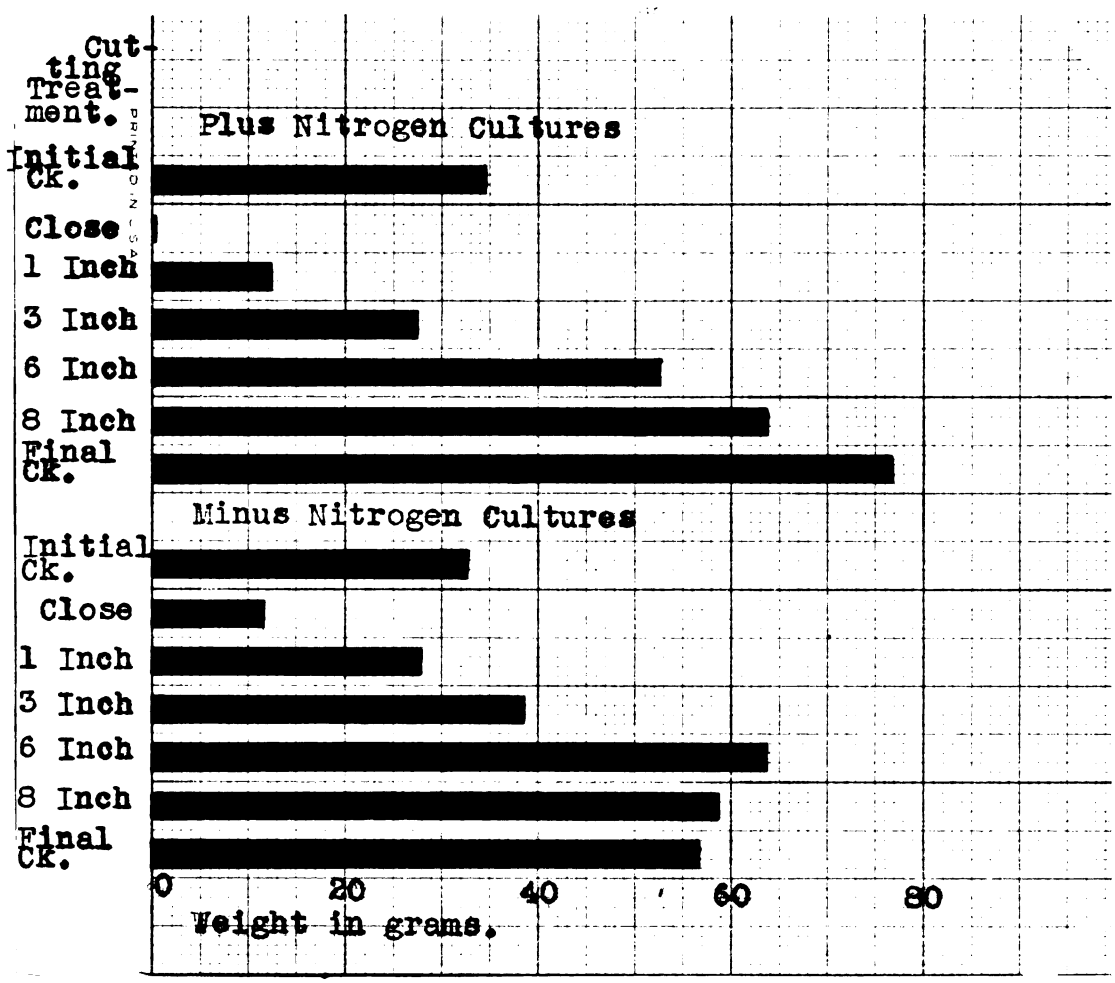
The severity of the cutting treatment and the amount of nitrogen supplied to the cultures had a direct bearing on the rhizome weight of each individual culture at the close of the experiment. Such results are represented graphically in Fig. V, by photographs in Fig. II and IV and by weight in grams in Table 1. Where nitrogen was supplied and the plants were cut close once a week for 24 weeks, the rhizome weight was negligible. Only one piece of rhizome about three or four inches long was left in each of two of these cultures. Cutting cultures receiving nitrogen back to one inch reduced the total rhizome weight when compared to the initial checks. In the culture cut to three inches there was a small loss in rhizome weight, when compared to initial checks. The rhizome weight of the minus nitrogen close and one-inch cutting treatments was about equal to that in plus nitrogen one and three-inch cutting treatments, respectively.

Figure VI is a photograph taken on April 5 of the dead rhizomes taken from a plus nitrogen close-cutting culture and healthy rhizomes from a plus nitrogen check culture. The frayed discolored rhizomes will be noted in contrast to the sharp pointed round rhizomes with live roots at the nodes of the check cultures. The close and one-inch cutting treatments had a very striking effect on the root systems of the plus nitrogen plants. By January 11 or after

Table 1. Green and Dry Weight in Grams of Rhizomes, Roots and Tops of Plants Grown With and Without Nitrogen

	Plus Nitrogen Plants							
	Rhizomes		Roots		Tops		Total	
Treatment	G.Wt.	D.Wt.	G.Wt.	D.Wt.	G.Wt.	D.Wt.	G.Wt.	D.Wt.
Top growth completely removed	.1	.02	0	0	.1	.02	.2	.04
Cut back to 1"	57.5	12.8	2.41	.8	24.7	6.8	84.6	20.4
Cut back to 3"	97.7	27.3	27.9	6.9	49.4	15.8	175.0	50.0
Cut back to 6"	184.4	52.3	79.5	18.1	147.7	33.1	411.6	103.4
Cut back to 8"	238.0	64.7	95.4	23.2	230.0	63.0	563.4	150.9
Initial Check	142.7	34.4	93.7	27.8	165.7	36.7	402.1	98.9
Final Check	252.0	76.6	95.4	27.8	304.7	60.7	652.1	165.1
	Minus Nitrogen Plants							
Top growth completely removed	61.7	11.8	19.4	3.6	2.3	.52	83.4	15.9
Cut back to 1"	95.4	27.0	31.1	6.2	13.1	3.7	139.6	36.9
Cut back to 3"	125.0	38.8	59.4	9.7	39.3	8.8	223.7	57.3
Cut back to 6"	178.6	63.4	111.7	22.9	80.8	22.3	371.1	108.6
Cut back to 8"	176.0	58.6	126.6	29.0	87.6	28	390.2	115.6
Initial Check	127.7	33	58.7	149	137.6	27.8	324.0	75.7
Final Check	164.3	56.7	134.6	30	95.3	27.6	394.2	114.3

Figure V.



Dry Weights of Plus and Minus Nitrogen Quackgrass Rhizomes

Figure VI.

Healthy rhizome from plus nitrogen check plot at left and dead rhizome from plus nitrogen close-cutting treatment at right.

12 weeks of cutting, the root systems of the close cutting series had started to disintegrate. Disintegration of the root system was virtually complete by the end of the fifteenth week of cutting. When the experiment was discontinued after 24 weekly clippings, the root systems of the plus nitrogen one-inch cultures also were disintegrated completely, while the roots of the cultures receiving nitrogen and cut at three inches were also showing some decay.

In all the cutting treatments of the minus nitrogen plants the roots were in good condition at the close of the experiment. The root weights of the close, one-inch and three-inch cutting treatments, were lower than that of the average of the initial checks, but an examination of the photographs in Fig. IV will show that all of the roots are of good color and have every appearance of still being functional.

The average weekly green and dry weights produced for all cutting treatments are shown in Table II. An examination of this table will show that through the tenth consecutive week of cutting the plus nitrogen close-cutting cultures produced each week (with one exception) more dry matter than any other cutting treatment. After the tenth week the plus nitrogen six-inch cutting produced on the average the most dry matter. The one and three-inch cutting treatment produced more dry matter than close cutting after the fifteenth week.

Table 2. Green and Dry Weights in Grs. of Clippings Removed at Weekly Intervals From Plus and Minus Nitrogen Cultures.

Treatment	Oct. 19 G.W.	Oct. 19 D.W.	Oct. 26 G.W.	Oct. 26 D.W.	Nov. 2 G.W.	Nov. 2 D.W.	Nov. 9 G.W.	Nov. 9 D.W.	Nov. 16 G.W.	Nov. 16 D.W.	Nov. 23 G.W.	Nov. 23 D.W.	Nov. 30 G.W.	Nov. 30 D.W.	Dec. 7 G.W.	Dec. 7 D.W.
Plus Nitrogen Cultures																
Complete removal of top growth	99.5	23.3	13.9	3.03	6.50	1.73	5.19	1.0	5.64	.79	5.46	.72	3.42	.79	2.83	.61
Cut back to one inch	94.1	20.2	6.20	1.20	5.76	.89	5.15	.58	2.19	.44	1.98	.41	1.92	.40	1.79	.28
Cut back to three inches	54.1	15.0	7.93	1.83	4.97	1.32	2.91	.60	1.98	.43	3.0	.63	1.86	.41	2.06	.49
Cut back to six inches	28.8	6.6	6.36	1.68	2.51	.74	.40	.11	.38	.11	.53	.13	1.98	.43	1.83	.39
Cut back to eight inches	10.3	1.7	3.01	.92	1.25	.41	.39	.11	.49	.14	.14	.04	.31	.08	.40	.09
Minus Nitrogen Cultures																
Complete removal of top growth	57.0	17.1	9.21	2.52	3.49	1.33	2.63	.73	2.23	.63	2.25	.65	2.19	.65	2.18	.63
Cut back to one inch	51.8	12.4	2.87	.73	2.06	.61	.87	.23	1.04	.25	.74	.22	.69	.16	.72	.18
Cut back to three inches	41.1	11.0	4.21	1.35	2.01	.65	.91	.27	.39	.11	.49	.09	.45	.11	.47	.12
Cut back to six inches	13.8	4.0	3.36	1.03	.41	.22	.19	.06	.15	.07	.06	.02	.04	.009		
Cut back to eight inches	5.50	1.6	2.13	.70	.40	.23	.33	.10	.27	.11	.14	.04				

Treatment	Dec. 14 G.W.	Dec. 14 D.W.	Dec. 21 G.W.	Dec. 21 D.W.	Dec. 28 G.W.	Dec. 28 D.W.	Jan. 4 G.W.	Jan. 4 D.W.	Jan. 11 G.W.	Jan. 11 D.W.	Jan. 18 G.W.	Jan. 18 D.W.	Jan. 25 G.W.	Jan. 25 DW.
Plus Nitrogen Cultures														
Complete removal of top growth	2.64	.61	3.16	.61	3.1	.60	2.14	.40	1.88	.39	1.65	.36	1.53	.36
Cut back to one inch	2.10	.46	2.58	.52	2.05	.47	1.98	.43	1.47	.34	1.23	.28	1.48	.31
Cut back to three inches	2.35	.52	1.60	.38	1.40	.33	1.96	.43	.82	.20	1.36	.32	.92	.21
Cut back to six inches	1.71	.38	2.88	.59	4.83	1.13	3.34	.69	2.31	.50	2.40	.50	.85	.26
Cut back to eight inches	.55	.13	.78	.19	1.77	.40	.81	.17	.92	.19	1.00	.23		
Minus Nitrogen Cultures														
Complete removal of top growth	1.49	.43	2.00	.43	1.76	.39	1.18	.26	.85	.21	1.05	.26	1.13	.26
Cut back to one inch	1.16	.29	1.11	.24	.73	.19	1.11	.44	.58	.15	.76	.21	.60	.14
Cut back to three inches	1.49	.37	1.00	.22	.67	.19	1.24	.29	.73	.18	1.11	.26	.79	.18
Cut back to six inches							.91	.32						
Cut back to eight inches														

Treatment	Feb. 1 G.W.	Feb. 1 D.W.	Feb. 8 G.W.	Feb. 8 D.W.	Feb. 15 G.W.	Feb. 15 D.W.	Feb. 22 G.W.	Feb. 22 D.W.	Mar. 1 G.W.	Mar. 1 D.W.	Mar. 8 G.W.	Mar. 8 D.W.	Mar. 15 G.W.	Mar. 15 D.W.	Mar. 22 G.W.	Mar. 22 D.W.	Mar. 29 G.W.	Mar. 29 D.W.	Total Average Recovery Growth G.Wt.	Total Average Recovery Growth D.Wt.
Plus Nitrogen Cultures																				
Complete removal of top growth	1.31	.28	1.47	.29	1.16	.20	1.23	.25	.68	.15	.45	.09	.32	.06	.27	.05	.21	.04	64.14	13.41
Cut back to one inch	1.48	.33	1.86	.36	1.90	.37	2.77	.57	1.65	.39	1.94	.44	.88	.20	1.12	.24	2.54	.55	50.00	10.46
Cut back to three inches	.76	.18	1.44	.32	.96	.21	1.53	.35	.70	.18	1.68	.41	1.46	.33	3.18	.73	3.07	.69	49.90	11.50
Cut back to six inches	1.51	.34	2.63	.57	2.75	.60	3.97	.87	2.28	.59	2.61	.62	1.70	.40	4.23	1.00	6.62	1.61	60.61	14.24
Cut back to eight inches					2.38	.51					2.12	.50					4.76	1.13	21.06	5.24
Minus Nitrogen Cultures																				
Complete removal of top growth	1.01	.21	1.60	.28	1.61	.28	2.03	.35	1.69	.34	1.92	.33	1.47	.27	1.56	.32	1.29	.27	47.82	12.03
Cut back to one inch	.65	.15	.80	.19	.86	.22	1.16	.28	.84	.26	1.28	.28	.85	.20	1.02	.25	.79	.22	23.29	6.09
Cut back to three inches	.36	.08	.76	.20	.58	.14	1.17	.28	.46	.13	.67	.18	.68	.17	.78	.20	.28	.09	21.70	5.84
Cut back to six inches					.67	.16											.37	.13	5.79	1.89
Cut back to eight inches																			3.27	1.18

Through the twelfth week the recovery growth of the plus nitrogen close cutting treatment measured from three to six inches in height each week. Up to the last few weeks the recovery growth of all other culture receiving nitrogen was shorter than that of the cultures cut close. The recovery growth of the minus nitrogen close cutting was slightly shorter than that of the plus nitrogen close cutting treatment.

The leaves produced by the plus nitrogen close cutting treatment became narrow and paler in color as the experiment progressed. This tendency was also apparent in the minus nitrogen close cutting treatment, but was at no time as pronounced. The leaf color of the other plus nitrogen plants tended to vary somewhat with the amount of sunlight. During a prolonged period of very low sunlight the plants became a paler green and as the sunlight increased, the deep green color returned. The minus nitrogen plants stayed a pale green color throughout the experiment.

Only two cultures, numbers four and six, of the plus nitrogen close-cutting treatment had any green shoots on April 5. In these only two or three weak shoots per pot were visible. In this series, cultures one, two and three failed to produce new shoots on March 15 and culture number five failed to produce new shoots on March 29.

It will be noted that culture number six which was covered at the same time as number four on February 1, still had a short piece of live rhizome in it and was producing one or two weak shoots. Thus it is seen that covering these cultures had no effect in hastening the death of the plants. No difference in rhizome or root development could be noted in the minus nitrogen cultures which were covered on February 1, as compared to those left uncovered. The plus nitrogen culture which was covered on November 26 and defoliated once each week, was still producing two or three very weak shoots on May 11. The minus nitrogen culture which was treated likewise was still producing many shoots on May 11.

In the plus nitrogen cultures the greatest total recovery growth was made by the six-inch cutting. It was, however, only slightly greater than that made by the plus nitrogen close cutting treatment. The production of top growth above eight inches was only slightly more than one-third that of the six-inch cutting. These data are shown in Table 2. After removal of the original top growth the minus nitrogen close-cut cultures produced in the twenty-three weekly cuttings almost as much as the plus nitrogen close-cutting treatment and about two times as much dry matter as any other cutting treatment in the minus nitrogen series.

Data in Table 1 show that the average total plant weight in both the plus and minus nitrogen treatments in the close, one and three inch cutting series, was less than that of the initial check. There was very little difference in the average total plant weight of the six and eight-inch cutting series and final check of the minus nitrogen treatment. In the plus nitrogen cultures the total plant weight was greatest in final check cultures, less in eight and six-inch cutting.

Rhizomes from cultures receiving nitrogen were much higher in protein than rhizomes from cultures receiving no nitrogen as shown in Table 3. In the plus nitrogen cultures, rhizomes from the one inch cutting treatment were highest in protein. In minus nitrogen cultures, rhizomes from the close cutting treatment were higher in protein than those from any other cutting height and the final check. Rhizomes from the final checks in the plus nitrogen cultures were higher in protein than the initial checks, while in the minus nitrogen cultures the opposite was true, here the initial checks were highest in protein.

Table 3. Per Cent Protein on Dry Basis in Rhizome from Plus and Minus Nitrogen Cultures Subjected to Various Cutting Treatments

Treatment	% Protein (dry basis	
	Plus N. Cultures	Minus N. Cultures
Completely defoliated		6.56
Cut back to one inch	13.25	4.08
Cut back to three inches	10.56	4.04
Cut back to six inches	10.88	4.43
Cut back to eight inches	11.00	4.69
Initial check	11.31	7.38
Final check	12.50	5.44

*Analysis for nitrogen were made by the Section of Agricultural Chemistry, Michigan State College, East Lansing.

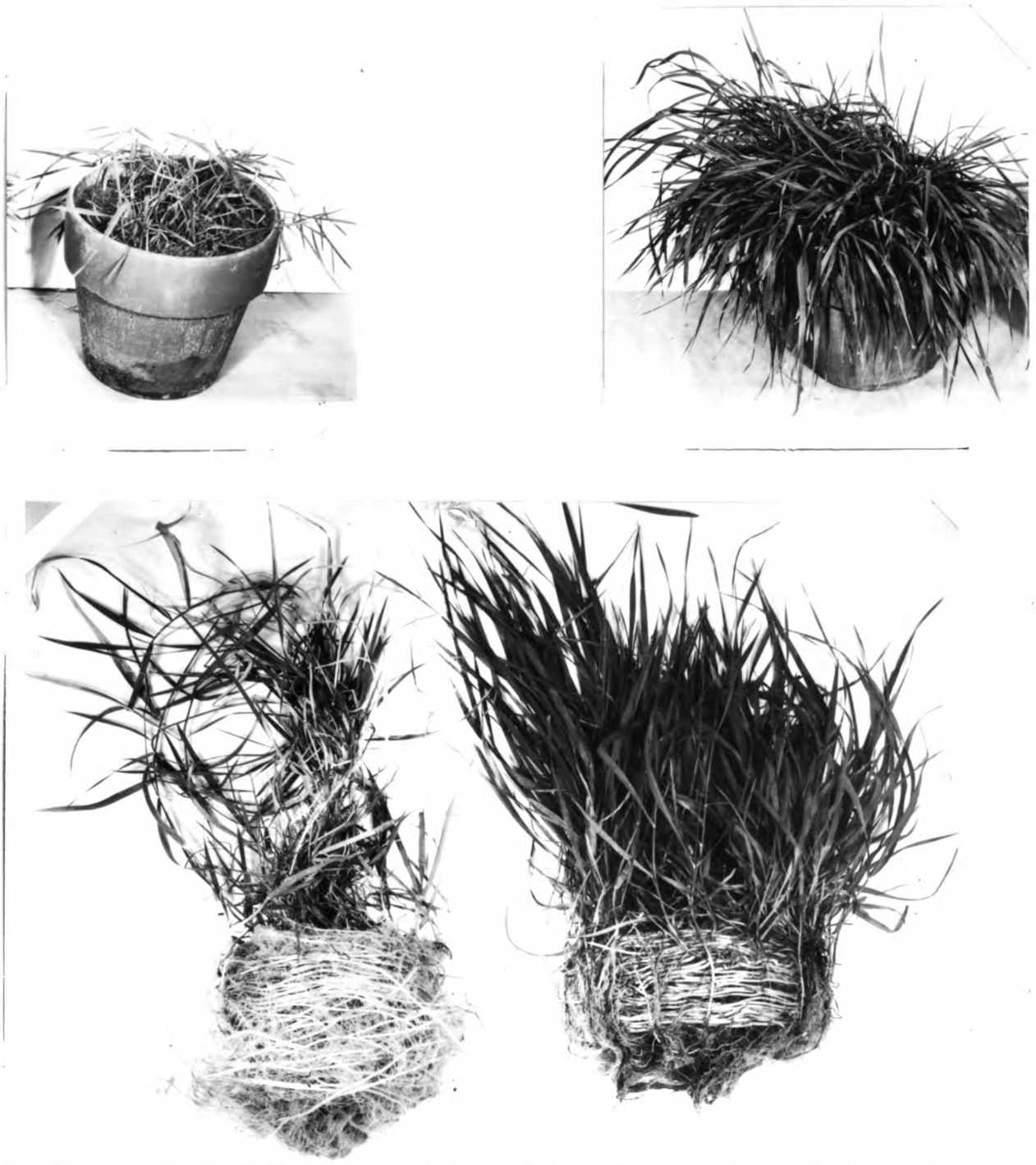
EXPERIMENT II. METHODS AND MATERIALS

Quackgrass cultures were planted Nov. 10, 1936, by the method previously described in Experiment I. The cultures were supplied a complete nutrient solution until May 12, 1937, when 20 cultures were flushed out and calcium chloride substituted for the calcium nitrate.

On June 29 respresentative duplicate cultures with and without a continuous supply of nitrogen were selected. The sand was washed from the roots and green and dry weights determined on the roots, rhizomes and tops. Photographs were taken of one each of these cultures before and after the plants were washed out. (Fig. VII) The leaf color and abundance and appearance of subterranean parts indicate plants which had had a high and low nitrogen supply. A 10-gram sample of rhizomes was taken from each pot for sprouting in sand.

On June 29 the cultures which had received a continuous nitrogen supply and those which had received a minus nitrogen solution after May 12, were thoroughly flushed with tap water, and the nutritional treatment of the two sets of cultures was reversed. The cultures previously receiving nutrients high in nitrogen were given no nitrogen and the

Figure VII.



Left - upper and lower, cultures grown without nitrogen since May 12.
Right - upper and lower, cultures grown with a continuous supply of nitrogen.
(June 29, 1937)

Figure VIII.

Above:
Left, culture grown without nitrogen since June 29, with nitrogen before June 29.
Right, culture grown with nitrogen since June 29, without nitrogen before June 29.

Below:
Left, culture cut to three inches and grown without nitrogen since June 29.
Middle, same as upper right.
Right, same as upper left.

(Photographed Aug. 31, 1937)

cultures previously receiving nutrients with no nitrogen were given nutrients high in nitrogen. One series which prior to June 29 were high nitrogen plants, were kept cut back to three inches for the duration of the experiment and given a minus nitrogen solution.

On dates as indicated in Table 4, duplicate cultures receiving nitrogen and those not receiving nitrogen and one culture from the series cut back to three inches were washed free from sand, green and dry weights were determined of the rhizomes, roots and tops. Ten-gram samples were taken from the rhizomes in each culture, and put in sand for sprouting. The sand flats were kept covered to shut out the light. The sprouts produced from each sample were harvested every two weeks, counted, and green weights determined. Table 5.

DATA EXPERIMENT II.

The average green and dry weights of the tops, roots and rhizomes of all the cultures are recorded in Table 4. It will be noted that in the cultures receiving no nitrogen after June 29, the rhizome weight increased from a dry weight of 22 grams on June 29 to a dry weight of 68.5 grams on Aug. 31. In the same series the top and root weights were quite variable with no definite trend. In the series receiving

Table 4. Weight of Plant Parts in Grs. on Various Dates at Which Cultures Were Washed Out.

Date Cultures Washed Out	Tops		Roots		Rhizomes	
	G.Wt.	D.Wt.	G.Wt.	D.Wt.	G.Wt.	D.Wt.
Cultures Receiving No Nitrogen After June 29						
6/29	121	23.5	59	10.7	87	22
7/2	116.5	20.7	53.5	8.5	115	29.7
7/6	173.5	50.4	96.0	28.7	105	30.9
7/13	172	47.5	93.0	28.5	126	47.2
7/20	108.5	31.5	48.5	9.3	112.5	38.4
7/27	115.5	28.5	80	18.3	175	44.9
8/10	106.5	36	74.7	18.5	171.5	47.6
8/31	136	43.7	91.5	24	216	68.8
Nitrogen Added After June 29						
6/29	24.5	8.7	69	14.3	108.5	28.4
7/2	25.5	8	34.8	6.5	102	29.7
7/6	47	14.3	76.5	19.2	85.5	21.7
7/13	58	13.5	62.5	16	89.5	24.2
7/20	45.5	23.8	59.5	10.3	76.5	20.7
7/27	94	17.3	45	12.5	157.0	36.8
8/10	167	38.5	45	9.9	175	39.7
8/31	192.5	49	61	14.5	277	60.2
Culture Receiving No Nitrogen After June 29 - Tops cut to 3 inches.						
7/6	105	23	77	24.5	199.0	55.7
7/13	72	17	42	10	111.0	35.2
7/20	74	20	35	5.5	131	37.4
7/27	67	18	93	27	104	29
8/10	96	22	36	8	164	42.6
8/31	62	13	35	9	114	30.7

Table 5. Average Number and Weight in grs. of Shoots from 10 gr. Samples of Rhizomes Sprouted in Sand and Collected at Bi-Weekly Intervals.

Weeks		2		4		6		8		10		12		14		16		18		Total	
	Date Planted	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
1.	6/29	25.7	1.085	22.2	.972	14.5	.352	8	.13	2.3	.022	.05	.005							72.5	2.75
Cultures	7/2	22.5	.705	26	.81	16	.40	6.5	.06	.05	.05									71.05	2.03
grown with	7/6	38.0	2.625	31.5	1.54	13.5	.435	3	.025											86	4.63
nitrogen	7/13	30.0	2.265	13	.39	4	.145	2	.06											49	3.22
prior to	7/20	22.5	1.51	17	.86	12.5	.15	6	.085	.5	.09	1.5	.02	.5	.01			.05	.005	65.05	2.73
June 29 and	7/27	10.5	.575	15	.73	10.5	.37	8.5	.19	4.5	.07	1	.01			.05	.005			50.05	1.95
without ni-	8/10	14.5	.805	14	.325	10	.18	6	.14	7.5	.125	6.5	.07			4.5	.05			63.0	1.70
trogen after	8/31	10	.485	8.5	.30	7	.245	7	.11			4	.05							36.5	1.19
June 29.																					
2.																					
Cultures	6/29	37.7	1.345	23.5	.74	22.25	.435	19.2	.34	14.7	.167	13.75	23.7	1.8	.045	.5	.015	.5	.005	133.9	3.54
grown with-	7/2	29	1.37	26.5	1.145	33	1.14	20	.155	6	.50	9.5	.14	6	.145	2	.08	1.5	.015	133.5	4.69
out nitrogen	7/6	29	1.945	20	1.035	9.5	.30	3	.03	2.5	.035									64	3.35
before June	7/13	28.5	2.14	13	.245	3.5	.085	.5	.005											45.5	2.48
29 with ni-	7/20	13.5	.89	3	.14	1	.02													17.5	1.05
trogen after	7/27	8.5	.535	11	.395	8	.18	3.5	.125	3	.07	2	.015							36	1.32
June 29.	8/10	11.5	.53	12.5	.215	7	.175	3	.08	1	.03	.5	.005			2	.01			37.5	1.05
	8/31	19.5	1.41	14.5	.535	7	.195	8	.115			.5	.005							49.5	2.26
3.																					
Cultures cut	7/6	25	1.16	17	.95	3	.11													45	2.22
to three in-	7/13	27	2.05	14	.43	4	.05	1	.01											46	2.54
ches. Grown	7/20	18	1.50	15	.42	3	.04													36	1.96
without ni-	7/27	10	.46	15	.54	11	.44	10	.42	2	.04	1	.01							49	1.91
trogen after	8/10	8	.47	19	.89	24	.68	12	.28			2	.02			3	.04			86.0	2.38
June 29.	8/31	12	.89	14	.43	14	.33	1	.01			8	.10							49.0	1.76

an abundance of nutrient nitrogen after June 29 the average dry weight of rhizomes had decreased from 28.4 grams on June 29 to 20.7 grams on July 20 and then increased to 60.2 grams by Aug. 31. In this series the dry weight of top growth increased from 8.7 grams on June 29 to 49 grams on Aug. 31. The top, root and rhizome weight of the series cut to three inches and receiving no nitrogen was extremely variable.

Table 5 shows the average number and weight of shoots harvested at bi-weekly intervals from all cultures. The largest numbers and greatest weights of shoots were harvested from rhizome samples taken from the cultures washed out on June 29 and July 2 which had received no nitrogen previous to June 29. The total number and weight of shoots harvested from duplicate samples of this series decreased to a low point on July 20, which was also the date on which the rhizome weight was the lowest. The average total number and weight of shoots harvested from this series increased from this date on, as did the average rhizome weight. No definite trend can be established in the number and weight of shoots harvested from rhizome samples taken from either series of cultures receiving a minus nitrogen solution after June 29. The rhizomes which lived the longest under repeated defoliation in the dark were those grown from cultures in a minus nitrogen solution. Further study of Table 5 shows that the

rhizomes which lived the shortest length of time and produced the lowest number of shoots, were those collected on July 20 from the high nitrogen series.

DISCUSSION

A consideration of the results shows that quackgrass has a marked and diverse response to differences in defoliation and application of nitrogen.

Plus nitrogen quackgrass cultures which were completely defoliated once a week had very few functional shoots remaining after 24 weeks. Conversely plants completely defoliated once each week and receiving no nitrogen were still in excellent condition after an equal period of cutting. Cutting cultures to one inch once a week was very injurious to plus nitrogen plants but caused only small injury to minus nitrogen plants. When plants receiving a continuous nitrogen supply were cut back to three inches, a loss in weight of rhizomes, roots and tops resulted, when compared to the initial checks. In a comparable treatment of minus nitrogen plants, there was a slight gain in rhizome weight, some loss of root weight and a large loss in top weight.

Applications of nitrogen stimulated a vegetative response, resulting in more top growth. If this top growth is repeatedly removed by complete defoliation, the plant must draw on its carbohydrate reserves to produce new leaves. This

treatment ordinarily results in carbohydrate starvation and death of plants. Quackgrass cultures in these experiments were, however, very conservative in their response to complete defoliation and heavy nitrogen applications. Plants receiving an abundance of nitrogen with little or no opportunity for carbohydrate synthesis, survived up to 24 weeks. Nitrogen applications did, however, have a marked effect on vegetativeness. There is a marked contrast between the effect of complete and repeated defoliation on minus nitrogen and plus nitrogen cultures. In the minus nitrogen cultures the rhizome and root weight was about one-third as great as that of the initial checks, while under the same conditions plus nitrogen plants were dead.

A further effect of nitrogen applications and repeated defoliations was noted in the total average dry weights of cultures from the various cutting treatments. In the plus nitrogen series the total average dry weight of cultures in the six-inch cutting treatment was nearly equal to that of the initial check. In this treatment, however, the average rhizome weight was about one-third greater than that of the initial checks. In the plus nitrogen three-inch cutting treatment, the average rhizome weight was less than that of the initial check. Considering these facts, it seems probable that the balance between vegetativeness and carbohydrate storage, as measured by rhizome response, was somewhere between the three

and six-inch cutting treatments. On the other hand, this balance in the minus nitrogen cultures was between the one and three-inch cutting treatment. As will be noted, the rhizome weight of the initial checks was about midway between the rhizome weights of the one and three-inch cutting treatments. The final average plant weight of the three-inch cutting was less than that of the initial checks, but the difference in top weight accounts for most of the difference.

Cutting the tops of minus nitrogen plants at six inches allowed for approximately maximum development of total plant weight. In plus nitrogen plants, however, maximum plant weight was produced in the uncut or final check plants.

Up until they were killed by carbohydrate starvation, or during 24 weeks of weekly complete defoliation, the plus nitrogen cultures produced almost as great an average total recovery growth as the six-inch cutting treatment. (Table 2). Through the tenth week of cutting, the plus nitrogen close cutting treatment produced more dry weight than the cultures cut back to six inches, after which time the production of new top growth became gradually less and less. A high nitrogen culture completely defoliated once a week produced approximately as much new top growth up until its death as did a high nitrogen plant under a six inch cutting treatment.

It appears that organic reserves previously synthesized and stored by a quackgrass plant high in nitrogen, are

about as efficient for the production of new top growth as a high nitrogen plant with an optimum opportunity for photosynthesis. A plus nitrogen quackgrass culture given ample opportunity for photosynthesis tends to store organic food reserves rather than use all of the newly synthesized products in the production of new top growth.

In the minus nitrogen cultures, the amount of recovery growth produced by the close-cutting treatment was almost two times that produced by the next highest or one-inch cutting during the duration of the experiment. From this it would appear that to obtain maximum production of top growth under extreme minus nitrogen conditions, extreme defoliations would be necessary. Cultures under this cutting treatment lost about two-thirds of their total rhizome and root weight when compared to the initial checks.

Minus nitrogen plants grown with moderate defoliation tended to store carbohydrate reserves more readily than do plus nitrogen plants correspondingly defoliated. Productivity of new top growth diminished rapidly in all but the close cutting treatment in the minus nitrogen series.

The rhizomes of minus nitrogen plants increased in weight at a lower cutting level than was true under plus nitrogen conditions. Further, the production of new top growth at a one-inch cutting or above, was much smaller in minus nitrogen cultures than under similar cutting treatment of cultures

receiving nitrogen. Nitrogen became the limiting factor in leaf production of the minus nitrogen cultures cut to one inch or above. Under the close cutting treatment of the minus nitrogen series it was probable that the plants were able to obtain enough nitrogen from the decomposing roots and rhizomes to produce the faily high yield of recovery growth.

Using number and weight of shoots produced from weighed rhizome samples sprouted in the dark as criteria, data in Table 5, indicate that the rhizomes lowest in nitrogen are highest in organic food reserves. Ten-gram samples of rhizomes taken on June 29 and July 2, from cultures which had received no nitrogen previous to June 29, produced nearly twice as many shoots and a far greater weight than similar cultures grown with a continuous nitrogen supply. Further evidence that low nitrogen plants are higher in organic food reserves, was found in the close-cutting treatments of Experiment I. The plus nitrogen series produced a slightly higher recovery growth in dry weight than the minus nitrogen series. However, at the conclusion of the experiment, the plus nitrogen plants were nearly all dead, while the minus nitrogen plants still had about one-third of the original dry weight of rhizomes left. The dry weight of rhizomes at the beginning of the experiment was almost the same in both cases.

Data from Table 5 in the series given nitrogen after June 29, indicates further that the sprouting ability of quackgrass rhizomes was at least partially dependent on the amount of organic food storage. It will be noted that the lowest average total production of shoots from a ten-gram sample of rhizomes was from the cultures washed out on July 20. These were also the cultures which were lowest in rhizome weight. An application of nitrogen to what were minus nitrogen cultures on June 29 stimulated production of new top growth at the expense of the previously stored food reserves. This loss of subterranean storage was reflected in a decreased production of sprouts from the rhizome samples collected through July 20. After July 20 sufficient leaf area had been produced by these cultures to enable them to store organic reserves in the rhizomes remaining and further to produce new rhizomes. It will be noted that the rhizomes put in sand flats on July 20 were almost dead at the end of only two weeks of sprouting, only three sprouts appearing in the second to fourth week and only one sprout after that. This is evidence that most of the loss in rhizome dry weight was due to a withdrawal of stored reserves. It appears that high nitrogen plants store less organic reserves per unit weight of rhizome than do minus nitrogen plants.

CONCLUSIONS

1. After being defoliated completely once a week for 24 weeks, quackgrass cultures receiving a continuous supply of nitrogen had very few functional shoots.
2. Cultures receiving no nitrogen and defoliated once a week for an equal period of time were still in excellent condition.
3. Cutting cultures to one inch once a week was very injurious to plus nitrogen plants, but caused only slight injury to minus nitrogen plants.
4. Plus nitrogen cultures cut to three inches lost in rhizome, root and top weight. In minus nitrogen cultures receiving comparable defoliation the rhizome weight increased, there was some loss of root weight and a large loss in top weight.
5. Minus nitrogen quackgrass plants stored organic reserves in subterranean parts at a lower cutting level than plus nitrogen plants.
6. Plus nitrogen cultures completely defoliated once a week produced approximately as much recovery growth over a period of 24 weeks as cultures cut back to six inches.

7. Minus nitrogen cultures completely defoliated once a week produced only slightly less recovery growth than plus nitrogen cultures receiving the same cutting treatment, and about twice as much as the next highest minus nitrogen series.
8. Rhizomes from quack grass cultures low in nitrogen are highest in carbohydrate reserves. Such rhizomes produce more sprouts and live for a longer period when sprouted in sand without light than rhizomes from cultures high in nitrogen.

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