RESPONSE OF QUACK GRASS TO DEFOLIATION AND FERTILIZATION

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Introduction

Studies of the response of many species of forage plants to various cutting and fertilization treatments have brought out certain general principles. In general, short and frequently repeated defoliation has been found to result in decreased root reserves and decreased yields of foliage. Heavy fertilization with nitrogen usually stimulates top growth, and is associated with decreased root growth. Frequent cutting in immature stages has been found to result in slower recovery after cutting. Rather extensive reviews of the literature pertaining to root reserves have been made by Thomas (8), Graber (1), Harrison (2), and others.

Quack grass, (Agropyron repens) is generally considered a noxious weed (3), particularly notable and objectionable because of its extreme vegetative persistence and its pronounced tendency to spread by means of rhizomes.

The most superficial consideration of the attributes and the reputation of this species makes it evident that it is not easy to exhaust its reserves of organic food, nor to produce in it a condition in which it is extremely susceptible to injury by defoliation. The present paper describes experiments designed to study the response of this species to various degrees of defoliation and nitrogenous fertilization. The behavior induced in the above-ground parts of the plant as well as the condition of the rhizomes were studied.

Experimentation

GREENHOUSE EXPERIMENTS

On February 20, 1935, sods were obtained in the field and weighed samples of rhizomes were planted in sand in the greenhouse. Certain of the cultures were supplied with a nutrient solution high in mineral nitrogen (plus nitrogen cultures), while others were supplied with a solution that contained very small amounts of nitrogen (minus nitrogen cultures). Three series of experiments were carried out. The cultures in series I were completely defoliated whenever growth reached a height of 1 inch. Those in series II were cut about 4 weeks after the leaves were 5 or 6 inches long. Those in series III were permitted to grow for 6 weeks without defoliation. After 6 weeks in the greenhouse, all cultures were overturned.

1 Contribution from the Section of Farm Crops, Michigan Agricultural Experiment Station, East Lansing, Michigan. Journal article no. 258 (new series).
in such a way that the plants were covered by about 6 inches of sand, in order to simulate plowing.

In series I plants (frequently defoliated) supplied with plus nitrogen nutrient made more foliar growth than plants supplied with minus nitrogen nutrient for a period of about 3 weeks, after which time the minus nitrogen plants were more vigorous. At the time of the simulated plowing, growth had practically ceased, no new rhizomes had formed, the original rhizomes were flabby and brown and they were dead at the ends. Identical total numbers of culms developed and were harvested from the two sets of cultures. The total dry weight of the plants harvested from the plus nitrogen cultures was about 8 per cent. more than that from the cultures low in nitrogen. Under these conditions, which permitted very limited photosynthesis, the dry weight of the harvested foliage was about 35 per cent. of the dry weight of the rhizomes originally planted. After the cultures were overturned to simulate plowing, no new shoots appeared above the soil surface.

In series II, no new rhizomes had formed, either at the time of cutting after 4 weeks of growth or at the time of simulated plowing, in either plus or minus nitrogen cultures. In an interval of two weeks after simulated plowing, many new shoots were formed in all pots of this series, but none penetrated to the surface of the soil. No difference could be observed between plus and minus nitrogen cultures in this regard.

In series III (not defoliated for 6 weeks), more foliage was produced by the plants of the plus nitrogen than by those of the minus nitrogen cultures, whereas the latter produced more roots and more new rhizomes than the former. It may be well to emphasize that the cultures that had abundant nitrogen produced new rhizomes freely, although they did not occur in as great numbers nor did they have as great weight as those with a limited nitrogen supply. The total dry weight and nitrogen content of the plants in the plus nitrogen cultures were decidedly greater than those of the minus nitrogen cultures.

After simulated plowing, many new shoots reached the surface in all pots, neither plus nitrogen nor minus nitrogen cultures showing superiority. The formation of new rhizomes and the vigorous recovery from simulated plowing would suggest that the old rhizomes of plants grown in both plus and minus nitrogen cultures were high in stored carbohydrates. Foliage and new rhizomes produced in plants of plus nitrogen cultures were in all cases higher in percentage of nitrogen and lower in percentage of dry matter than corresponding material from minus nitrogen cultures.

On February 20, other samples of rhizomes were placed between blotters in a seed germinator at 25° C, in the dark. New growth was cut from these at weekly intervals for a period of about 8 weeks. At first, considerable apical dominance was in evidence, but within 2 weeks, sprouts appeared at
all nodes. At the end of 4 weeks, none of the rhizomes were dead, but some were making very slow growth. Some sheets were watered with tap water, and others with nutrient solution containing mineral nitrogen, but there was no observable difference in growth between them. At the end of 8 weeks, 35 per cent. were entirely dead. An additional 40 per cent. of the rhizomes were described as "not growing," while 25 per cent. appeared able to grow slightly. At this time, rhizomes from the germinator were placed in sand at a depth of about 1 inch. From 20 rhizomes, 5 of which had apparently living buds at the nodes, only 2 leaves finally appeared above-ground, and these were about the width of a coarse bristle. The percentage of dry matter in the rhizomes was determined. Samples of rhizomes were placed in the germinator to sprout. The sprouts were collected, counted, weighed, measured, and dried. Collections were taken weekly until sprouting virtually stopped. The amount of nitrogen in both sprouts and residual rhizome material was determined in some cases. The date and amount of formation of new rhizomes was determined in the various plats. Part of the data from the plats at East Lansing is shown in table I. All figures in the tables are reduced to the basis of a 10-gm. sample of fresh rhizomes.

Table II shows data obtained sprouting rhizomes which were dug from

FIELD EXPERIMENTS

Experiments similar to those conducted in the greenhouse were carried out in the field. Plats were laid out in two locations. Those at East Lansing were on a fertile black loam; those at Lake City, about 150 miles north of East Lansing, were on a sandy loam. Ammonium sulphate was added to the plats at East Lansing at the rates of 0, 400, and 800 pounds per acre. At Lake City, ammonium sulphate was applied at the rates of 0, 200, 400, and 600 pounds per acre, and some of the plats received phosphate and potash in addition. The fertilizers were applied early in the spring.

In all cases, ammonium sulphate induced foliar growth greater than that on the unfertilized plats. The growth on sod, receiving 600 or 800 pounds per acre, was extremely heavy, and in all cases the foliage of plants receiving nitrogen was higher in percentage of nitrogen than that of the unfertilized checks.

At intervals throughout the spring, samples of sod were removed from each of the various plats for examination. The percentage of dry matter in the rhizomes was determined. Samples of rhizomes were placed in the germinator to sprout. The sprouts were collected, counted, weighed, measured, and dried. Collections were taken weekly until sprouting virtually stopped. The amount of nitrogen in both sprouts and residual rhizome material was determined in some cases. The date and amount of formation of new rhizomes was determined in the various plats.
TABLE I

DATA ON SPROUTING QUACK GRASS RHIZOMES GROWN IN BLACK LOAM AND FERTILIZED WITH AMMONIUM SULPHATE AT THE RATES OF 0, 400 AND 800 POUNDS PER ACRE, RESPECTIVELY

<table>
<thead>
<tr>
<th>Date put in germinator</th>
<th>Percentage dry matter in fresh rhizomes</th>
<th>Dry weight of rhizomes after sprouting</th>
<th>Total dry weight of new growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ammonium sulphate</td>
<td>Ammonium sulphate</td>
<td>Ammonium sulphate</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>400</td>
<td>800</td>
</tr>
<tr>
<td>April 9</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>&quot; 23</td>
<td>42.4</td>
<td>42.4</td>
<td>42.4</td>
</tr>
<tr>
<td>&quot; 30</td>
<td>37.64</td>
<td>34.53</td>
<td>36.14</td>
</tr>
<tr>
<td>May 14</td>
<td>35.99</td>
<td>33.26</td>
<td>31.68</td>
</tr>
<tr>
<td>&quot; 21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; 28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>37.43</td>
<td>34.76</td>
<td>33.16</td>
</tr>
</tbody>
</table>

sandy soil at Lake City. Each figure is the average, reduced to a 10-gm. sample basis, of four 40-gm. samples of fresh rhizomes.

TABLE II

DATA ON SPROUTING QUACK GRASS RHIZOMES GROWN IN SANDY LOAM AND FERTILIZED WITH AMMONIUM SULPHATE AT THE RATES OF 0, 200, 400, AND 600 POUNDS PER ACRE, RESPECTIVELY. GERMINATED AT 25° C. IN DARK

<table>
<thead>
<tr>
<th>Date put in germinator</th>
<th>Number of new shoots in five weeks</th>
<th>Dry weight of new shoots</th>
<th>Dry matter left in rhizomes after sprouting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ammonium sulphate</td>
<td>Ammonium sulphate</td>
<td>Ammonium sulphate</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>May 27</td>
<td>18</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>June 6</td>
<td>4.9</td>
<td>23.5</td>
<td>33</td>
</tr>
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</table>

The data in table II show the same trends as those in table I. The rhizomes that were dug from heavily fertilized soil made vigorous growth in the germinator. The contrast between fertilized and unfertilized plats is less distinct on the rich soil at East Lansing than it is on the sandy soil at Lake City. In each case, the foliar growth in the field was greater and the content of dry matter in the rhizomes was less in the plants grown in the plus nitrogen nutrients than those grown in the minus nitrogen nutrient.
In spite of this apparent drain upon the storage in the rhizomes, the rhizomes of plants dug from fertilized soil have a much greater ability to sprout in the germinator. As in the experiments conducted in the winter, many rhizomes that appeared to be in perfectly healthy condition failed to sprout. This was particularly notable in the case of plants grown in the minus nitrogen nutrient. Table II shows that, of the samples collected on June 6, those plants that received 600 pounds of ammonium sulphate per acre produced approximately 10 times the number and 10 times the dry weight of new shoots that the rhizomes produced which had been dug from unfertilized soil. So far as their appearance was concerned, there appeared to be no reason why the rhizomes grown in the minus nitrogen nutrient should not sprout as well as the rhizomes grown in the plus nitrogen nutrient. The analyses for dry matter content show that the rhizomes grown in the minus nitrogen nutrient were higher in dry matter than those grown in the plus nitrogen nutrient.

The rhizomes which provided the data for table III were dug at Lake City on June 6. The amount of nitrogen in the original rhizomes, the amount harvested in new shoots, and the amount remaining in the rhizomes after sprouting was virtually complete, are shown in the table. The percentage of nitrogen in the leaves harvested for hay is included to show how the composition of the entire plant was affected. Data are included from plats receiving complete fertilizer (400 pounds per acre of 0-14-6 in addition to the ammonium sulphate) as well as from plats receiving ammonium sulphate only.

Table III shows that a large amount of nitrogen was stored in the rhizomes dug from soil that was high in nitrogen and that, at the same time, foliage that was high in nitrogen was produced on these plants. The plus nitrogen rhizomes placed in the germinator produced sprouts containing from 10 to 20 times the quantity of total nitrogen found in the sprouts from rhizomes dug from unfertilized soil. Although the rhizomes dug from fertilized soil, both before and after being placed in the germinator, were lower in dry matter than those from unfertilized soil, they sprouted much more freely than the minus nitrogen rhizomes. This superior vigor of sprouting continued for 5 weeks, since the production of sprouts continued proportionately greater during the last weeks of the test. It would appear in this case that the ability to sprout was limited more by nitrogen supply than by other factors, and that even the plus nitrogen plants were high in stored carbohydrates. That is, quack grass stored excess nitrogen, as shown by the analysis of the rhizomes, but also developed a superior ability to sprout. From examination of the analyses of the leaves cut for hay, it would appear that still heavier fertilization with nitrogen would probably have given foliage with an even higher nitrogen content. It is of
TABLE III

<table>
<thead>
<tr>
<th>Fertilizer Treatment</th>
<th>Nitrogen in Original Rhizomes</th>
<th>Nitrogen Harvested in New Shoots</th>
<th>Nitrogen Left in Rhizomes After Sprouting</th>
<th>Percentage Protein (N x 6.25) in Dry Leaves Harvested as Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ammonium Sulphate</td>
<td>Ammonium Sulphate</td>
<td>Ammonium Sulphate</td>
<td>Ammonium Sulphate</td>
</tr>
<tr>
<td>0</td>
<td>200</td>
<td>400</td>
<td>600</td>
<td>0</td>
</tr>
<tr>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
</tr>
<tr>
<td>N (only)</td>
<td>15.46</td>
<td>18.60</td>
<td>30.16</td>
<td>43.76</td>
</tr>
<tr>
<td>P, K, and N</td>
<td>13.68</td>
<td>18.60</td>
<td>17.90</td>
<td>23.30</td>
</tr>
</tbody>
</table>

*Analyses for nitrogen were made by the section of Agricultural Chemistry, Michigan Agricultural Experiment Station.
some interest to observe that the rhizomes of the grass receiving a complete fertilizer stored less nitrogen than those of the grass fertilized with nitrogen alone. This may be due to the fact that the grass grown on the soil receiving a complete fertilizer produced a greater weight of foliage which was, in addition, somewhat higher in nitrogen than foliage from plants grown on soil receiving only ammonium sulphate. It was observed that rhizomes from soil receiving a complete fertilizer tended to rot more quickly in the germinator than those from soil receiving only nitrogen fertilizer.

Rhizomes dug and placed in the germinator on May 27, were in better condition on August 6, so far as ability to sprout and freedom from decay were concerned, than similar rhizomes dug and placed in the germinator June 6. Table I indicates an explanation for this condition. Rhizomes dug early in the spring were found to be far more able to sprout and less subject to decay than those dug at later dates.

New rhizomes, cut from old rhizomes, to about the end of May, made no further growth and rotted when placed in the germinator. Those cut after this date made considerable growth in the germinator. The formation of new rhizomes seemed about equally abundant on heavily fertilized and on unfertilized plats. It was noted, however, that rhizome formation was very scanty in dense sods and abundant in thin sods, regardless of fertilization.

**Eradication**

Plats of grass at East Lansing, some unfertilized and some receiving 800 pounds of ammonium sulphate per acre, were cut at various dates throughout the spring. Shortly after cutting, the sod was spaded to a depth of about 8 inches, in such a way that the sod was overturned rather than standing on edge. New growth, therefore, had to penetrate approximately 8 inches of soil. When new leaves extended about 4 inches above the surface of the soil, they were cut off with a hoe.

The difficulty of eradication was very great in plants cut and spaded May 13. Grass that was cut on May 13 and again on May 27, and then spaded, was much easier to eradicate by hoeing than that cut only on May 13; but was not observably different from that cut only on May 27. Grass cut on June 11, just before heading, was easier to eradicate by spading and hoeing than any other. Grass cut on June 29 was next easiest, whereas that cut on July 13, when the seed was almost ripe, was very difficult to eradicate. This change in difficulty of eradication corresponds with other records (3). Table I shows that the old rhizomes were relatively unable to sprout on June 11. At that time the new rhizomes were not sufficiently mature for vigorous vegetative extension.

The fertilized grass made the most rapid initial growth, after spading, on
all plats, regardless of the date of cutting. After repeated defoliations, however, the fertilized grass appeared to become weakened to such an extent that the unfertilized grass made somewhat more top growth. This corresponds with observations in the greenhouse, but seems somewhat in contradiction to the results obtained from rhizomes grown on the germinator pads. The plus nitrogen rhizomes grown on the germinator pads were always superior to the minus nitrogen rhizomes in ability to sprout, even after weeks of continued removal of new sprouts. Possibly these unfertilized plants were able to obtain nitrogen from the soil for later growth, by which time the high nitrogen plants may have exhausted their carbohydrate supply by vigorous initial growth. The differences between rhizomes grown in fertilized and unfertilized soils obtained from East Lansing were never particularly great, however, even on the germinator pads.

Summary

1. Frequently repeated complete defoliation of quack grass prevented rhizome formation and killed the plants, regardless of fertilization treatment. Under these conditions of defoliation, plus nitrogen plants tended to produce more growth in the first stages and less in the later stages of exhaustion than minus nitrogen plants.

2. Rhizomes taken from plants supplied with plus nitrogen nutrient and with minus nitrogen nutrient at various times in the spring and early summer, and then placed in a seed germinator, progressively decreased in ability to sprout as compared with samples collected in the very early spring. Plus nitrogen rhizomes sprouted more freely than did minus nitrogen rhizomes. These shoots were longer, heavier, and contained a higher percentage of nitrogen than shoots from minus nitrogen rhizomes, but were lower in the percentage of dry matter.

3. Plus nitrogen rhizomes, remaining after sprouting had ceased, were higher in nitrogen and lower in dry matter than those from minus nitrogen plants. Plants receiving nitrogen only stored more nitrogen in the rhizomes than those receiving phosphorus and potassium in addition to nitrogen.

4. When quack grass sod, fertilized heavily with ammonium sulphate, was cut and spaded at various times in the spring and early summer, renewed growth was always more rapid and more vigorous than on adjacent unfertilized plats. After such growth was hoed off several times, the grass in the unfertilized plats seemed somewhat more persistent than that on the highly fertilized, but not markedly so.

5. New rhizomes formed in approximately equal abundance in fertilized and unfertilized sods, but new rhizome formation was very scanty in dense sods as compared with thin sods.

6. Quack grass responds to nitrogenous fertilization by producing
greater top growth which is higher in nitrogen than grass from unfertilized
plats.

7. Under the conditions of heavy fertilization with nitrogen in field plats
and in the greenhouse cultures, no plants were produced that could be con-
sidered low in carbohydrates. Storage, as evinced by formation of new
rhizomes and by ability of the old rhizomes to sprout vigorously, occurred
in even the most highly fertilized series.

Further experiments are in progress relating to the adaptability of fer-
tilization and cutting practices to the control and eradication of this plant,
and to its use in the production of forage.

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