
Comparison of the Uptake of P\textsuperscript{32} and K\textsuperscript{42} by Intact Alfalfa and Oat Roots \textsuperscript{1-3}

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The growth of a legume grown as a companion with a grass has been shown by many workers (3, 4, 5, 8, 10, 11, 15) to be less than when the legume is grown in pure stand.

Explanations for this growth reduction of the legume include competition for light (5, 6), soil moisture (11, 15), nutrients (1, 4, 7, 9, 10, 13), excretion of toxic materials (2, 12, 14), and effects of the microflora (12).

Although all of these factors may influence the growth of both plants grown in close association, this paper reports investigation of the relative efficiency with which intact roots of alfalfa and oat plants absorb phosphorus-32 (P\textsuperscript{32}) and potassium-42 (K\textsuperscript{42}) when placed in a common nutrient solution or when treated separately.

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Materials and Methods

Alfalfa (Medicago sativa L., va. Ranger) and oats (Avena sativa L., var. Ajax) were grown in a controlled environment room maintained at 24° during a 12-hour photoperiod followed by a 12-hour nyctoperiod maintained at 18°. Seeds were germinated and the plants were supported on nylon screen held over a solution containing 2 mmoles of KH\textsubscript{2}PO\textsubscript{4}, KNO\textsubscript{3}, and MgSO\textsubscript{4}•7H\textsubscript{2}O; 3 mmoles of Ca (NO\textsubscript{3})\textsubscript{2}, 2\textsuperscript{-}4H\textsubscript{2}O; 2.5 ml of versenol iron chelate solution (24 g/liter); and 1 ml of a micronutrient solution (containing 2.5 g H\textsubscript{2}B\textsubscript{4}O\textsubscript{7}, 1.5 g MnCl\textsubscript{2}•4H\textsubscript{2}O; 0.1 g ZnCl\textsubscript{2}; 0.05 g CuCl•H\textsubscript{2}O; and 0.05 g MoO\textsubscript{3} per liter) in 1-liter polystyrene containers. The solution was aerated by forcing air through glass wool attached to a piece of glass tubing. After 7 or 15 days, the plants were removed and their roots either immersed in another container with the nutrient solution to which the radioisotope had been added or placed in a special apparatus designed to study the uptake of the minerals by part of one root. The solution used to study uptake by whole root systems was aerated during a 6-hour uptake period in the light at 750 ft-c. After the uptake period, the roots were rinsed 3 times in nutrient
solution to remove adhering radioactive solution. Each plant was then separated into root and shoot, dried at 105° for 24 hours, weighed, ashed with nitric acid, and counted in a proportional counter or counted without ashing in a gamma spectrometer.

A special apparatus was devised for study of the relative efficiency with which a 3-mm segment of intact alfalfa or oat root took up P^{32} or K^{42} (fig 1).

![Diagram of root system](attachment:image.png)

**Fig. 1.** Device used to study the uptake of P^{32} and K^{42} from 3-mm root segments of alfalfa and oat plants. The blotting paper and tubing well are placed in a petri plate as shown.

Pieces of tygon tubing (3-mm bore, 1.5-mm wall) 12 mm long were attached to plastic disks with glue to make a well for the mineral solution to be taken up by the root segment to be studied. Blotting paper circles with a 6-mm hole in the center were cut to fit into a 9-cm petri plate. A collar, made by placing a piece of 6-mm tygon tubing around the tubing well, prevented the paper from falling to the bottom of the plate. Modified Hoagland solution (50 ml) was placed in the petri plate and the blotting paper was bent to dip below the surface. Fifty μl of this solution was placed in the tubing well. The end of the tubing well was greased with lanolin to prevent creeping of the solution. The root segment 1 cm back from the tip was placed over the tubing well with the other portion of the root system lying on the blotting paper. A 7-cm filter paper circle with a 10-mm hole was placed over the remainder of the root system to maintain a moist atmosphere around the roots. Lanolin was placed over the root where it touched the tubing well. A 20-mm × 1-mm strip of Whatman No. 3 MM filter paper was dipped into a solution containing the radioisotope, dried, activity counted, folded into a V shape and placed over the root segment with the ends of the paper dipping into the solution in the tubing well. Although the wick was 1 mm wide, the portion of the root segment exposed over the well was 3 mm. After a 6-hour uptake period in the light at 750 ft.-c, the plants were cut into segments and treated as described earlier.

Fifty 1-cm segments of oat or alfalfa roots were used to study the respiration rate of the root tip (1 cm) and the second centimeter back from the tip. The segments were placed in Warburg flasks containing 2 ml of modified Hoagland solution and 0.5 ml of 0.03 % sucrose with 0.3 ml of 20% KOH in the center well. The temperature of the bath was maintained at 22°. Oxygen uptake was measured by the direct method of Warburg.

**Results**

**Growth of Alfalfa and Oat Root Systems in Aerated Hoagland Solution.** Plants of alfalfa and oats were harvested after 1, 2, or 3 weeks in aerated Hoagland solution in the controlled environment room and measurements were made of the number of root tips over 1 mm long, total length of the root system, and fresh and dry weight of roots and shoots (table 1). The number of oat root tips was approximately 4 times the number of alfalfa root tips after 1 week, about 5 times after 2 weeks, and almost 7 times after 3 weeks. The total length of oat roots was about 5 times that of alfalfa roots 1 week after germination and 4 times the total length of alfalfa roots after 2 and 3 weeks. Fresh weight of oat roots was about 6 times that of alfalfa roots of corresponding age. Fresh weight of oat shoots was about 5 times that of alfalfa shoots after 1 or 2 weeks and 6 times the fresh weight after 3 weeks. The dry weight of oat roots was 8 times the dry weight of alfalfa roots after 1 week and 5 times the dry weight of alfalfa roots harvested 2 or 3 weeks after germination. The dry weight of oat shoots was almost 30 times that of alfalfa 1 week after germination; however, after 2 or 3 weeks, the dry weight of oat shoots was 7 times that of alfalfa shoots.

**Table 1. Comparison of Ranger Alfalfa and Ajax Oats**

The plants were grown together in aerated solution culture and harvested 1, 2 and 3 weeks after planting. The figures are for 10 plants and are the averages of 2 replicates.

<table>
<thead>
<tr>
<th>Observations</th>
<th>Alfalfa Age in weeks</th>
<th>Oats Age in weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>No. root tips</td>
<td>10</td>
<td>77</td>
</tr>
<tr>
<td>Total length roots (cm)</td>
<td>49</td>
<td>121</td>
</tr>
<tr>
<td>Roots fr wt (mg)</td>
<td>79</td>
<td>118</td>
</tr>
<tr>
<td>Roots dry wt (mg)</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Shoots fr wt (mg)</td>
<td>266</td>
<td>499</td>
</tr>
<tr>
<td>Shoots dry wt (mg)</td>
<td>4</td>
<td>26</td>
</tr>
</tbody>
</table>
Comparison of Respiration of Excised Root Segments of Alfalfa and Oats. Fifty 1-cm root tips of alfalfa grown for 4 days in aerated Hoagland solution consumed less \( O_2 \) than oat root tips of the same age (table II). Root tips of 7-day-old alfalfa plants took up less \( O_2 \) than oat root tips of that age. Root tips of 7-day-old plants took up less \( O_2 \) than 4-day-old plants. Fifty 1-cm root segments from 1 to 2 cm back from the tip of 4-day-old alfalfa plants absorbed less \( O_2 \) than similar segments of oat plants of the same age.

Uptake of \( P^{32} \) and \( K^{42} \) by Whole Root Systems. The amount of \( P^{32} \) present in 15-day-old alfalfa and oat plants harvested after a 6-hour uptake period by whole root systems placed together in the light in aerated Hoagland solution containing 200 \( \mu \)c of \( P^{32} \) is shown in table III. Of the total amount of \( P^{32} \) present in plant material, 85 % was present in the oat plants. Most of the activity was found in the roots of both plants with the oat roots having 6 times the activity found in the alfalfa roots. Only 1 % of the \( P^{32} \) was translocated to alfalfa shoots and only 2 % was found in the oat shoots.

The amount of \( K^{42} \) present in 7-day-old alfalfa and oat plants grown together in aerated Hoagland solution containing 300 \( \mu \)c of \( K^{42} \) for 6 hours in the light is shown in table IV. Only 9 % of the activity was found in the alfalfa plants. Of the total amount of \( K^{42} \) present in alfalfa plants 65 % was present in the shoots. In the oat plants, 40 % of the \( K^{42} \) was translocated to the shoots.

Uptake of \( P^{32} \) and \( K^{42} \) by 3-mm Segments of Attached Roots. The amount of \( P^{32} \) taken up in 6 hours from a filter paper wick by a 3-mm roots segment 1 cm back from the tip of 4- and 15-day-old alfalfa and oat plants is shown in table V. Root segments and shoots of oat plants contained more \( P^{32} \) than comparable segments of alfalfa plants of the same age. Also, roots and shoots of 4-day-old plants contained more \( P^{32} \) than 15-day-old plants. Of the total amount of \( P^{32} \) taken up, 19 % moved out of the treated 3-mm root segment to other portions of the root and shoot of 15-day-old alfalfa plants, 32 % out of 4-day-old oat shoots, and 10 % out of 15-day-old oat plants.

Alfalfa root segments and shoots contained more \( K^{42} \) than comparable portions of oat plants of the same age (table VI). Four-day-old alfalfa plants took up more \( K^{42} \) than 15-day-old alfalfa plants but 15-day-old oat plants took up more \( K^{42} \) than 4-day-old oat plants. In all the plants, more than 95 % of the \( K^{42} \) taken up is shown in the shoots of the plants.
was translocated out of the 3-mm treated root segment.

Table VI. Comparison of the Amount of K\textsuperscript{42} Present in 4- and 15-Day-Old Ranger Alfalfa and Ajax Oat Plants

<table>
<thead>
<tr>
<th>Plant part</th>
<th>Radioactivity (cpm \times 10^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Age in days</td>
<td>Oats Age in days</td>
</tr>
<tr>
<td>Root tip (1 cm)</td>
<td>4 15 4 3</td>
</tr>
<tr>
<td>Treated root segment</td>
<td>9 7 7 10</td>
</tr>
<tr>
<td>Remainder of treated</td>
<td>36 21 5 51</td>
</tr>
<tr>
<td>External roots</td>
<td>305 140 187</td>
</tr>
</tbody>
</table>

Discussion and Conclusions

Although the greater length of oat roots compared to alfalfa roots might explain the difference in competition for nutrients, the observation that intact 3-mm root segments of oat plants took up more P\textsuperscript{32} than comparable segments of 4- or 15-day-old alfalfa plants indicated that an additional factor might be involved in the competition for phosphate between alfalfa and oat plants. The observation that root segments of 4-day-old plants absorbed more P\textsuperscript{32} than those of 15-day-old plants suggested that the root segments of the younger plants might be more active metabolically. Higher rates of O\textsubscript{2} absorption were found with excised oat root segments than with alfalfa root segments. Higher rates of O\textsubscript{2} absorption were also found using root segments from 4-day-old plants compared to root segments from 7-day-old plants. These observations suggest that phosphate uptake may be related to respiration and that the effective competition for phosphate by oats may be due partly to greater metabolic activity of the root segments in addition to the larger root volume and greater number of root tips.

In similar tests, however, alfalfa root segments took up and translocated more K\textsuperscript{42} than oat plants of the same age and 15-day-old oat plants absorbed and translocated more than 4-day-old oat plants suggesting that potassium uptake may not be as directly related to respiration. If the assumption that alfalfa takes up more K\textsuperscript{42} per root segment than oats is true for each root segment of plants of the same age, the effective competition for potassium by oats must be due primarily to the greater volume of roots or to the greater number of root tips.

Summary

The greater uptake of phosphorus-32 and potassium-42 by oats (\textit{Avena sativa} L., var. Ajax) compared with alfalfa (\textit{Medicago sativa} L., var. Ranger) when grown together in aerated solution culture might be explained partially by the greater total length and the larger number of oat root tips. When whole root systems of 7-day-old alfalfa and oat plants were immersed together in an aerated Hoagland solution containing potassium-42 for a 6-hour period in the light, 90% of the activity in the plant material was found in the oat plants. More potassium-42 was taken up from a wick by intact, 3-mm alfalfa root segments (1 cm back from the root tip) than from root outer segments of the same age plants, indicating that the greater effectiveness with which oats compete with alfalfa for potassium must be due primarily to the larger root system of the oat plant. The uptake of phosphorus-32 from an aerated Hoagland solution in the light for 6 hours by intact, whole root system of 15-day-old plants was 6 times greater in the oat plants than in the alfalfa plants. The uptake of phosphorus-32 from a wick by intact, 3-mm oat root segments (1 cm back from the root tip) was greater than that of similar segments of alfalfa roots. Four-day-old plants took up more phosphorus-32 than 15-day-old plants. These observations, together with the observation that excised oat root segments absorb more oxygen in respiration than comparable root segments of alfalfa, indicate that the greater effectiveness with which oats compete with alfalfa for phosphorus may not be due entirely to the greater size of the oat root system.

Literature Cited

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Effects of Cotyledon Excision on the Flowering of Five Varieties of Pisum sativum

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Introduction

The numerous varieties of garden peas, Pisum sativum L., may be categorized by their habits of flowering into 2 groups defined by strikingly different responses to low temperature and photoperiod. The late varieties typically flower above the fifteenth node, respond to photoperiod as quantitative long-day plants, and are vernalizable. In contrast, the early varieties typically flower at the ninth or tenth node above the cotyledons, behave as day-neutral plants, and are not vernalizable.

The hormonal regulation of floral initiation in peas has been interpreted differently by several workers. Haupt (4, 5, 6, 7) has consistently advanced the view that floral initiation in peas is mediated by the positive action of a florigen, while suggesting also (7) that a flower-inhibiting substance may be present in vegetative plants. The work of Highkin (8) and Moore and Bonde (13) supported the concept of a florigen. Barber and his associates (1, 2, 14, 15) have developed the view that flowering in late peas is dependent upon the disappearance of a flower-inhibiting hormone, but they suggested that flowering of early varieties may be mediated by the positive action of a florigen.

Several workers have investigated the roles of the cotyledons in the control of growth and flowering in peas (1, 2, 3, 4, 5, 6, 7, 11, 14), and Varner et al. (16) recently reported an interesting reciprocal influence of the shoot axis on the cotyledons. In particular, Haupt (4, 5, 6, 7) and Barber et al. (1, 2, 14) reported that excision of the cotyledons from very young seedlings of certain varieties has significant effects on the number of nodes preceding the first flower.

The purpose of this investigation has been to determine the effects of cotyledon excision on the growth and flowering of early and late varieties of peas, as a preliminary approach to broader studies of the hormonal regulation of growth and flowering in these plants. The varietal differences in response to cotyledon excision are interpreted as being of a quantitative rather than qualitative nature.

Materials and Methods

Five varieties of peas were studied: Dwarf Telephone (dwarf, late), Tall Telephone (tall, late), Massey (dwarf, early), Alaska (tall, early), and Unica (dwarf, late). The plants were grown in vermiculite and nutrient solution in a greenhouse. The temperature and light regime consisted of a 20±1° photoperiod for 10 hours and a 17±1° photoperiod for an additional 6 hours per day, combined with a nyctotemperature of 17±1° during the 8-hour dark period. The peas were grown under a light bank consisting of warm white and cool white fluorescent lamps in the ratio of 3 ww: 1 cw. The natural light striking the plants obliquely was ordinarily of very low intensity. The light intensity at...