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Root behavior in fall and spring planted roses ...

Griffith J. Buck
Iowa State College

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ROOT BEHAVIOR IN FALL AND SPRING PLANTED ROSES

by

Griffith J. Buck

A Thesis Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of

MASTER OF SCIENCE

Major Subject: Horticulture - Floriculture

Signatures have been redacted for privacy

Iowa State College
1949
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INTRODUCTION

During the past two decades the fall planting of woody plant material, especially roses, has become an increasingly frequent recommendation of horticultural writers and nurserymen in various sections of the country. This advice is often made with reference to climatic conditions peculiar to the eastern and southern sections of the country, but gardeners have applied it to regions with highly different climatic conditions, often with unfavorable results.

Fall planting of roses and other nursery stock has many advantages both to the nurseryman and to the amateur gardener. It allows the grower to dispose of a large portion of his crop without incurring the additional expenses incident to winter storage, reduces the loss due to unsalable plants caused by storage conditions, and lessens the labor load during the extremely busy spring planting season by spreading it over a relatively slack period. To the customer fall planting means that he will obtain freshly dug plants which have not been subjected to the deteriorating influences of the storage cellar, his order has been filled while stocks of all varieties have been complete, and the soil is usually in better condition for planting in the fall than in the spring. Then, too, autumn weather is more conducive to out-of-doors activity than that of early spring. However, fall planting of roses
has not been an unqualified success under Iowa conditions.

Unfavorable results following fall planting of roses have been blamed upon many factors, among them, poor soil conditions, poor drainage, fall pruning, immature planting stock, root breakage through the heaving of the soil caused by alternate thawing and freezing, and too late or too early planting. Obviously, the selection of a single factor responsible for the failure of fall planting is impossible since such results are undoubtedly due to a combination of several of these and other factors. The systematic exploration of their influence upon fall or spring planting would be beyond the scope of this paper.

One argument often advanced by the proponents of fall planting of roses is that the roses are planted while the soil is still warm thus allowing the formation of roots to replace those lost through the operations incident to digging and shipping the plants to the ultimate purchaser. Assuming this to be the most constant factor in fall planting, it was decided to determine by actual trial the validity of this statement. Were rose root replacements formed more quickly in the fall or spring, and, if they were formed in the fall, what happened to them in the course of a normal winter?

An additional objective of this project was to determine the location on the original roots of the adventitious roots which were to serve as replacements for those lost between digging in the nursery and re-planting in the garden. Current
planting practices are notably variable with respect to root pruning of woody plant material immediately prior to planting. Root pruning practices vary so widely that it is hoped that by determining the location of the root replacements upon the roots that recommendations for root pruning woody plant material in general, roses in particular, may be developed.
REVIEW OF LITERATURE

A thorough investigation of the literature has produced little information directly associated with the root behavior in newly transplanted rose plants under out-of-door conditions. The literature on other woody horticultural crops revealed information on the response of other woody plant materials to low temperatures which were of value in a study of the problem.

Books, popular garden magazines, station bulletins and circulars contain various recommendations for and against fall and spring planting practices (2, 6, 8, 12, 13, 17). These recommendations are empirical since they are based primarily upon observation of garden practices rather than on experimental investigation.

A number of investigations have been made on the influence of temperatures upon plant growth. The response of roots to various temperatures as well as to other factors has been reported upon by Nightingale (14) and Rogers (15). Other representative works on temperature effects are Allen (1), greenhouse crops; Allen and Asai (3) garden roses; Batjer, Magness, and Reigembal (4) apples; Brierley and Landon (5) red raspberries; and Shanks and Laurie (16) on greenhouse roses. This last investigation is particularly helpful in that it provides a yardstick against which the results of this problem might be compared.
Heinsoke (10) found that, in apple trees, little root growth takes place during the dormant period. New roots, if formed, may be killed by low temperatures or a high water table.

A study of the readiness with which root growth begins in the spring was made by Goff (9) who found that while root growth in many plants, especially in apple and Prunus, may start in the spring before leaf growth, active root growth does not begin until leafage starts.

In his study of raspberry root systems, Christensen (7) determined that root growth actively begins when the first leaves are formed. His investigation also dealt with the location of the adventitious root replacements.

Kains and McQuesten (11) contain an obscure reference to location of adventitious root replacements on transplanted apple trees, gooseberries and currants. According to this reference apples originate less than half of the new roots within the last half inch of the old roots; whereas, with currants and gooseberries more than half were produced from this half inch.

An exhaustive investigation of winter protection practices was made by Wingert (15). His observations on the home storage of fall purchased rose plants were used as a basis for one of the treatments given to the rose plants used in this experiment. Also, he determined that success in fall planting was partially dependent upon the innate hardiness of each rose variety.
EXPERIMENTAL

Current Planting Practices

The method of planting roses varies little whether it be done in the spring or fall, regardless of the locality. Allen (2) and McFarland and Pyle (13) have described the procedure in detail. The bush is planted with the root system well distributed but deep enough that the bud union is slightly below the surface of the soil. Loose soil is firmed around the roots and settled by flooding with water. The final step consists of covering the plant with a cone of soil after the canes have been cut back to a length of six inches. If the plants are set in the fall, a covering of some material such as soy bean hay, salt marsh hay, or oak leaves is applied, preferably after the surface of the soil is frozen.

Materials and Methods

Description and arrangement of plants

The rose plants used in this experiment were two-year old, field-grown plants of the Hybrid Tea rose, Editor McFarland, budded upon Welch's Strain of *Rosa multiflora* understock. Five hundred ungraded, unpruned plants were received on November 4, 1948. The tops were somewhat shriveled to within two inches of
the bud union, but the roots were in excellent condition. The 
plants were sorted, and only those consisting of two or more 
strong canes and a well balanced root system were used. Of 
the 500 plants received, 300 were suitable for use in the prob-
lem.

The plants were potted in 8-inch pots, in a soil mixture 
composed of 2 parts loam, 1 part sand, and 1 part peat in order 
to confine the roots for convenience in taking data and to 
eliminate the factor of soil variability. In planting outside, 
the pots were plunged deeply enough to bring the bud union 
slightly below the soil surface. With the exception of potting 
the plants prior to setting, all planting methods were the 
same as described above. The potted roses were plunged in a 
well-drained area north of the Horticulture Building.

The 300 plants were divided into four groups or treat-
ments of 75 plants each. Each group of plants was further 
divided into five lots or replications of 15 plants, each re-
 replication being further divided into three groups of five 
plants each for convenience in taking the desired data. The 
location of the plants comprising each treatment in the exper-
imental plot was determined by random allotment.

Each branch root was divided into two zones (1) compris-
ing that area consisting of the last one-half inch of old root 
and (2) the remainder of the root (see Figure 1) for the pur-
pose of determining the location of the new adventitious roots 
on the old root system.
NO. 1 GRADE DORMANT PLANT
FIG. 1 - ROSE ANATOMY
Description of treatments

The 300 plants of the Hybrid Tea, Editor McFarland, were divided into four equal groups, each of which contained 75 plants. The following treatments were used during the fall, winter, and spring of 1948-1949.

A. Fall planting; plants not to remain in the ground over winter.

One lot of plants was planted using accepted planting methods on November 8, 1948. The root system was pruned only to the extent of removing dead and injured roots and making clean, fresh cuts on the ends of the roots which were retained. After planting in pots, the pots were plunged deeply enough to allow the bud union to be slightly below the surface of the soil, simulating normal planting practice. Since the set of fibrous roots varied considerably from plant to plant, it was decided to retain it, but to disregard the fibrous roots when collecting data. One-third of the plants were dug at the end of the first week after planting; a second third after three weeks; and the last third at the end of a five-week period.

B. Fall planting; plants to remain in ground over winter.

The second lot of plants was treated in the same manner as that just described with the exception that the plants were to remain in the soil over winter. As soon as the surface of the ground had frozen, a three-inch litter mulch consisting of stable litter was spread over the surface of the planting plot.
As soon as the ground was free of frost in the spring, a third of the plants were dug; a second third was dug two weeks later, and the last of the plants composing this treatment were dug four weeks after the digging of the first third. The litter mulch was removed as soon in the spring as the weather had warmed. The date of removal of the litter mulch from the beds in the Iowa State College rose garden provided the criterion for removal of the mulch from the experimental plot.

C. Plants held in common storage, planted outside in spring.

The third group of 75 plants were heeled-in in damp sand in the storage cellars at the Horticultural farm. They were removed from storage, planted in pots, and placed in the ground out-of-doors early in the spring of 1949. The same method was used in planting and taking data from this and the following treatment as was used in Treatment A.

D. Healing plants in pits; planted outside in spring.

The last group of 75 plants was divided into bundles of 12 plants each for convenience in handling and buried horizontally in a pit which was deep enough to insure the uppermost bundles' being 18 inches under the surface of the soil. A litter mulch was applied to these plants at the same time it was applied to Treatment B. In the spring, these plants were treated the same as those in Treatment C.

In order to determine the soil temperatures prevalent at the root-zone during the winter, the bulb of a Fries recording
The thermograph was buried horizontally at a depth of 12 inches. This depth was determined experimentally as being the center of the zone of fibrous roots. The average depth of the root system from the bud union to the tip of the longest vertical root determined this measurement. In choosing plants from which to secure this information, 25 plants were selected at random.

Dates of the practices required in Treatments A, B, C and D were as follows:

- Plants received
- Treatments A and B planted
- Treatment C placed in common storage
- Treatment D heeled-in
- Litter mulch applied to Treatments A, B, and D
- Litter mulch removed from Treatments A, B, and D
- Removal of soil mounds from Treatment B
- Treatments C and D planted
- Removal of soil mounds from Treatments C and D

Dates of taking data:
- Treatment Aa
- Treatment Ab
- Treatment Ac
- Treatment Ba
- Treatment Bb
- Treatment Be
- Treatments Ca and Da
- Treatments Cb and Db
- Treatments Ce and De

- November 4, 1948
- November 8, 1948
- November 9, 1948
- November 9, 1948
- December 16, 1948
- March 28, 1949
- April 20, 1949
- April 23, 1949
- May 3, 1949
- November 15, 1948
- November 29, 1948
- December 13, 1948
- April 6, 1949
- April 20, 1949
- May 4, 1949
- April 30, 1949
- May 14, 1949
- May 28, 1949
Experimental Results

Comparison of Treatment A with Treatment B

Table 1 contains these data. The plants in Treatment B produced a significantly greater number of roots than those in Treatment A. Since both groups of plants were given similar planting treatments, it is assumed that those plants in Treatment A reflected a similar degree of root formation and development in Treatment B during the fall and early winter months. During the period between the last taking of data in Treatment A and the first taking of data in Treatment B (December 13 - April 6) soil temperatures were considerably below 45° F. (Figure 2) which has been determined as the critical point below which new root formation and development becomes negligible. There was no significant difference between the number of roots formed at the time of the December 13 digging and the April 6 digging.

Comparison of Treatment C with Treatment D

The data for this comparison are found in Table 2. The plants used in these two treatments had matured during the winter and were in excellent condition when removed from storage. Root formation began promptly upon planting. Characteristics of the new roots which formed on the roots of the plants in these two treatments were similar to those formed on
Figure 2. Soil Temperatures 1948-1949
Table 1

Total Number of Roots on Fall Planted Roses Dug at Various Intervals in the Fall and Spring

<table>
<thead>
<tr>
<th>Repli-</th>
<th>Treatment A</th>
<th></th>
<th>Treatment B</th>
<th></th>
<th>Total No. of roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>cations</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>23</td>
<td>92</td>
<td>125</td>
<td>41.67</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>29</td>
<td>36</td>
<td>67</td>
<td>22.33</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>29</td>
<td>67</td>
<td>113</td>
<td>37.67</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>53</td>
<td>98</td>
<td>153</td>
<td>51.00</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>51</td>
<td>38</td>
<td>89</td>
<td>29.67</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>185</td>
<td>331</td>
<td>547</td>
<td>182.33</td>
</tr>
<tr>
<td>Mean</td>
<td>6.2</td>
<td>37.0</td>
<td>66.2</td>
<td>109.4</td>
<td>92.0</td>
</tr>
</tbody>
</table>

\[ t = \frac{306.8}{55.439} = 5.53 \quad P > 5\% \]

a, b, c = Harvest dates

Treatment A = Fall planted; root count taken in fall.
Treatment B = Fall planted; root count taken in spring.
Table 2

Total Number of Roots on Spring Planted Roses Subjected to Different Storage Conditions

<table>
<thead>
<tr>
<th>Replications</th>
<th>Treatment C</th>
<th>Treatment D</th>
<th>Total No. of roots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>352</td>
<td>330</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
<td>254</td>
<td>148</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>251</td>
<td>301</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>165</td>
<td>546</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>138</td>
<td>365</td>
</tr>
<tr>
<td>Total</td>
<td>102</td>
<td>1160</td>
<td>1690</td>
</tr>
<tr>
<td>Mean</td>
<td>20.4</td>
<td>232.0</td>
<td>338.0</td>
</tr>
</tbody>
</table>

\[ t = \frac{241.6}{114.73} = 2.105 \quad P < 5\% \]

\(a, b, c = \text{Harvest dates}\)

Treatment C = Plants held in common storage; planted in spring.

Treatment D = Plants buried in trench; planted in spring.
the roots of the plants in Treatment B which were planted in the fall and harvested in the spring. There was no significant difference between the root behavior of the plants comprising Treatment C and Treatment D.

Comparison of Treatments B, C, and D

These data are contained in Table 3. There was no difference between the plants in these three treatments in the quality of the roots which each produced. No significant difference was found between the number of roots produced by the plants in each of the three treatments.

The location of new adventitious roots developed in transplanted roses

The data for this portion of the problem are contained in Table 4. A total number of roots formed on all plants used in the experiment was 7,404. Of this number, 2,731 roots, or 36.86 per cent, were formed in the last half inch of each old root (Zone 1). The remainder of the roots, 4,673 or 63.11 per cent, were formed on the balance of the root system.
Table 3

Total Root Development in Roses Subjected to Different Conditions of Winter Storage

<table>
<thead>
<tr>
<th>Replications</th>
<th>Treatment B</th>
<th></th>
<th>Treatment C</th>
<th></th>
<th>Treatment D</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Mean</td>
<td>Total</td>
<td>Mean</td>
<td>Total</td>
<td>Mean</td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>584</td>
<td>194.67</td>
<td>682</td>
<td>227.33</td>
<td>416</td>
<td>138.67</td>
<td>1682</td>
</tr>
<tr>
<td>2</td>
<td>309</td>
<td>103.00</td>
<td>431</td>
<td>143.67</td>
<td>601</td>
<td>200.33</td>
<td>1341</td>
</tr>
<tr>
<td>3</td>
<td>412</td>
<td>137.33</td>
<td>592</td>
<td>197.33</td>
<td>134</td>
<td>44.67</td>
<td>1138</td>
</tr>
<tr>
<td>4</td>
<td>299</td>
<td>99.67</td>
<td>729</td>
<td>243.00</td>
<td>114</td>
<td>38.00</td>
<td>1142</td>
</tr>
<tr>
<td>5</td>
<td>477</td>
<td>159.00</td>
<td>518</td>
<td>172.67</td>
<td>459</td>
<td>153.00</td>
<td>1454</td>
</tr>
<tr>
<td></td>
<td><strong>2081</strong></td>
<td><strong>693.67</strong></td>
<td><strong>2952</strong></td>
<td><strong>984.00</strong></td>
<td><strong>1724</strong></td>
<td><strong>574.67</strong></td>
<td><strong>6757</strong></td>
</tr>
<tr>
<td>Mean</td>
<td><strong>416.2</strong></td>
<td></td>
<td><strong>590.4</strong></td>
<td></td>
<td><strong>344.8</strong></td>
<td></td>
<td><strong>2252.33</strong></td>
</tr>
</tbody>
</table>

Treatment B = Fall planted; root count taken in spring.
Treatment C = Held in common storage, plant in spring; root count taken in spring.
Treatment D = Buried in trench, planted in spring; root count taken in spring.
Table 4
A Comparison of the Location of New Roots Developed in Transplanted Roses

<table>
<thead>
<tr>
<th>Date</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30+</th>
<th>Total</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>67</td>
<td>43</td>
<td>21</td>
<td>17</td>
<td>16</td>
<td>12</td>
<td>9</td>
<td>195</td>
<td>78</td>
<td>42</td>
<td>47</td>
<td>23</td>
<td>40</td>
<td>36</td>
</tr>
<tr>
<td>b</td>
<td>295</td>
<td>188</td>
<td>53</td>
<td>66</td>
<td>49</td>
<td>101</td>
<td>144</td>
<td>906</td>
<td>296</td>
<td>243</td>
<td>149</td>
<td>128</td>
<td>118</td>
<td>216</td>
</tr>
<tr>
<td>c</td>
<td>243</td>
<td>218</td>
<td>177</td>
<td></td>
<td>203</td>
<td>237</td>
<td>196</td>
<td>369</td>
<td>395</td>
<td>375</td>
<td>451</td>
<td>395</td>
<td>474</td>
<td>2671</td>
</tr>
<tr>
<td>Total</td>
<td>605</td>
<td>449</td>
<td>251</td>
<td>286</td>
<td>302</td>
<td>309</td>
<td>522</td>
<td>2731</td>
<td></td>
<td>920</td>
<td>545</td>
<td>528</td>
<td>626</td>
<td>516</td>
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</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>Per cent of roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>Last half: Remain-</td>
</tr>
<tr>
<td>of roots</td>
<td>inch of: der of:</td>
</tr>
<tr>
<td>old root: root sys.</td>
<td></td>
</tr>
<tr>
<td>6.93</td>
<td>2.63</td>
</tr>
<tr>
<td>24.10</td>
<td>12.24</td>
</tr>
<tr>
<td>43.01</td>
<td>22.02</td>
</tr>
<tr>
<td>74.04</td>
<td>36.86</td>
</tr>
</tbody>
</table>
DISCUSSION

Comparison of Treatment A with Treatment B

This comparison of Treatment A and Treatment B was desirable for the purpose of determining whether the bulk of new roots were formed in the fall between the time of planting and before soil temperatures in the root zone have fallen below 45°F or in the spring after soil temperatures around the roots have exceeded 45°F. This temperature was determined by Batjer, Magness, and Regeimbai (4), Nightingale (14) and Rogers (15) as that point below which root growth becomes negligible. At no time during the winter were the roots subjected to temperatures lower than 31°F which is much higher than the temperature which Allen and Assai (3) found would kill roots of *Rosa multiflora*.

The new roots which formed on the roots of the plants which were fall planted and fall harvested (Treatment A) were long, white, succulent, large in diameter, and exhibited little, if any, lateral branching. At the time of the second and third harvests of Treatment B, the plants which were fall planted and spring harvested, lateral branching on the new roots became increasingly evident. Root formation on the roots of the plants in Treatment B was more profuse than in Treatment A. In these two treatments, as well as in the
remaining treatments, the new roots were exceedingly perishable when exposed to the dessicating effects of light and air, and their succulence made handling them without injury difficult.

**Comparison of Treatment C and Treatment D**

The plants comprising these two treatments were in excellent condition when they were removed from storage. Mold had developed on the upper portions of the canes which extended above the sand with which the roots and lower portions of the canes were covered. The plants had been stored (heeled-in) in sand in common storage. Although the portions of the canes which had molded were blackened and dead at the time of removal from storage, the root system and the basal parts of the canes were plump and bright in color, indicating excellent condition. The dead portion of the canes would have been removed in normal nursery storage or planting practice. These were the plants which comprised Treatment C. The plants which had been buried in a pit over winter, Treatment D, were similar in appearance to those in Treatment C with the exception that the former had not been attacked by mold.

The new roots which formed on the plants in Treatments C and D were formed sparingly by the end of the first week after planting. However, more profuse root formation and development was evident at the end of the third week after planting.
However, more profuse root formation and development was evident at the end of the third week after planting. This harvesting date followed the removal of the soil mounds from the plants by one week, during which the foliage showed very extensive development. This suggests that roses exhibit the same correlation between root and foliage growth which is found in raspberry (7). By the end of the fifth week after planting, the new roots were quite similar in appearance to those in Treatments A and B except that they were more profusely branched. During the period in which the plants comprising Treatments C and D were observed (April 23 - May 28), soil temperatures at the branch root zone ranged from 47.5°F to 69°F (Figure 2) with an average for the period of 59.5°F. This average temperature approached that found optimum for the growth of rose roots in the greenhouse by Shanks and Laurie (16) and the growth of peach roots by Nightingale (14), and considerably above that found by Goff (9) in the case of apple.

Comparison of Treatment B, Treatment C, and Treatment D

This is a comparison of root formation and development in roses subjected to different methods of winter storage and harvested in the spring. In making this comparison fall planting was considered a method of winter storage. In a
broader sense, it allows a comparison of the root behavior in fall and spring planted roses. The plants in the two spring planted treatments (C and D) developed a greater number of new roots than did those planted in the fall (Treatment B). However, the numerical difference was not significant. There was no difference in the quality of the roots produced by the plants in either of the three treatments.

Comparison of the Location of the New Adventitious Root Developed in Transplanted Roses

Each old root was divided into two zones. Zone 1 consisted of the last one-half inch of each old root; Zone 2 comprised the remainder of the root. This division follows that made in Kains and McQuesten (11). All of the roots which developed during this investigation were adventitious roots since they formed on well differentiated roots.

A total of 7,404 roots were developed on the 300 plants used in the experiment. Of this number 2,731 roots, or 36.86 per cent, developed in the region of the last half inch of each old root (Zone 1); whereas, almost twice as many, 4,673 or 63.11 per cent, developed from the remainder of the root system (Zone 2). The roots appeared first near the shank, and as the intervals between harvest and planting increased, they appeared further down the root approaching the tip. The adventitious roots were slow in appearing in the last half inch of old root, but by the end of the third week
they were increasing rapidly in number. The large numbers appearing in Table 4 for the first harvest (a) were made possible by the large number of roots which had formed on the roots of the plants in Treatment B by the time of the first harvesting of that treatment. New roots had appeared in quantity on the mass of fibrous roots which were present on some of the plants used in the investigation. However, since this mass of fibrous root material varied considerably in quantity, it was disregarded in the taking of data.

The size of the roots upon which the adventitious roots formed first were not necessarily the largest roots present, but all live roots ultimately developed adventitious roots. This correlates with Christensen's (7) work with raspberry roots.
CONCLUSION

Under the conditions of this investigation it can be concluded that although there is no difference in the number of new roots formed on plants transplanted in the spring or the fall, spring planting is to be preferred because of the more rapid root formation. Approximately twice as many new roots are formed on the other parts of the root system as were formed in the last half inch of each old root. Severe root pruning prior to transplanting is not advisable for this reason.
SUMMARY

Experiments were conducted during the fall, winter, and spring, 1948-1949, on the root behavior of fall and spring planted rose plants. Two year old, field grown plants of the Hybrid Tea rose, Editor McFarland, budded upon Rosa multiflora, Welch Strain were used. The plants were divided into four groups which were treated as follows: Treatment A was fall planted and fall harvested; Treatment B was fall planted and harvested in the spring; Treatment C was placed in common storage, planted and harvested in the spring; Treatment D was heeled-in over winter, planted and harvested in the spring. For the purpose of determination of the location of the new roots, the roots were divided into two areas: the last one-half inch of the each old root and the remainder of the root system.

The plants which were transplanted in the fall and harvested in the spring (Treatment B) produced more new roots than did those which were fall planted and harvested (Treatment A). There was no significant difference in the number of roots between the number of roots produced by the fall planted and spring harvested plants, those which were held in common storage and planted in the spring, and those which were heeled-in and planted in the spring (Treatments B, C and D). The last half inch of each old root produced 36.36 per cent of the new roots compared with 63.11 per cent for the rest of the root system.
LITERATURE CITED


ACKNOWLEDGMENT

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APPENDIX

The statistical analyses for Table 1, page 14, Table 2, page 15, Table 3, page 17, and the reason for not analyzing Table 4, page 18, statistically are as follows:

Table 1. The t-Test.

\[ t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{s^2}{n_A} + \frac{s^2}{n_B}}} = \frac{109.4 - 416.2}{\sqrt{(7683.75)(\frac{1}{3} + \frac{1}{5})}} = \frac{306.8}{55.439} = 5.53 \]

\[ P = > 5% \]

Table 2. The t-Test.

\[ t = \frac{\bar{X}_C - \bar{X}_D}{\sqrt{\frac{s^2}{n_C} + \frac{s^2}{n_D}}} = \frac{586.4 - 344.8}{\sqrt{(32995.5)(\frac{1}{9} + \frac{1}{2})}} = \frac{241.6}{114.73} = 2.105 \]

\[ P = < 5% \]

Table 3. Analysis of Variants.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>Treatment (M.S.)</th>
<th>Error (M.S.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>4</td>
<td>87431.73</td>
<td>21857.93</td>
<td>77030.47</td>
<td>29111.88</td>
</tr>
<tr>
<td>Treatments</td>
<td>2</td>
<td>154060.93</td>
<td>77030.47</td>
<td>( \frac{154060.93}{2} ) = 77030.47</td>
<td>( \frac{29111.88}{2} ) = 14555.94</td>
</tr>
<tr>
<td>Error</td>
<td>8</td>
<td>232911.07</td>
<td>29111.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>474403.73</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. The material contained in this table was not considered suitable for statistical analysis because of the large number of possible variables inherent in this particular data.