A STUDY OF THE EFFECTS OF CERTAIN POTTING MEDIA AND FERTILIZERS ON THE GROWTH AND FLOWERING OF AZALEAS

by

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I. INTRODUCTION

The soils of Iowa present a difficult problem to the growers of azaleas and related acid-tolerant plants which require iron in a readily available form. This group of plants does not grow and flower normally in calcareous and high lime soils. The water available to most greenhouse operators is known as "hard water" and contains calcium and magnesium in such quantities as to be detrimental to the best soil conditions for the optimum growth of azaleas. These problems have long been a limiting factor to potential azalea growers in this state, and, for that reason, an attempt is being made to find the most practical treatment to correct this faulty growth condition.

Most of the suggestions for culture of azaleas have been based on recommendations of growers and research workers in other parts of the country where the conditions mentioned above are not as serious as in this area, and as a result have generally resulted in disappointment to those interested in the local culture of acid soil plants.

The sensitivity of the azaleas to disturbances in iron nutrition and its importance to commercial growers were largely instrumental in its selection for this study.

In view of the fact that two limiting factors, water and soil, might be acting in the culture of acid-tolerant plants in Iowa, rainwater was used as a soil moisture supply in this experiment to permit a more exacting study of the effects of fertilizers and potting media.

II. REVIEW OF LITERATURE

A. Classification and History

The azalea belongs to a family of so called "acid-loving" plants known botanically as Ericaceae (2, 17). Watson (38) describes azaleas as, "shrubs, varying considerably in stature with hard close grained wood. Leaves are entire, thick and leathery, or herbaceous. Flowers are produced in terminal heads, rarely axillary, and when in bud they are enclosed in scales. Calyx has five lobes, but is sometimes almost obsolete. Corolla campunulate or funnel-shaped or tubular, usually five-lobed; stamens five; anthers oblong, dehiscing by terminal pores; style long or short; fruit a woody capsule containing small seeds."

The azaleas used in this experiment are classified as Rhododendron obtusum f. ponticum, commonly referred to as the "Kurume" type (2, 8, 17, 38). Kurume azaleas vary from white through pink to deep crimson, with variations towards cerise and salmon, but not orange (35). Rhododendron obtusum was first found on Nishi-Kirishima, an active volcano in South Kyushu, Japan (8, 42). In their native habitat, these plants grow in volcanic ash above tree level, along with coarse grasses and miscellaneous shrubs (42).

Azaleas have been cultivated and hybridized by the Japanese for hundreds of years, and some of our fine greenhouse varieties are the result of their skill in breeding (38). The major part of hybridizing today is being carried on by Belgian and other European nurserymen (28). The first Kurume azaleas were introduced into eastern North America by John S. Ames in 1917 (42).

B. Culture

A general discussion on the culture of Kurume azaleas as greenhouse pot plants is given by Laurie and Kiplinger (18), Bailey (2), Bowers (5), and Schumacher (32). Also see cultural practices, p. 17.

Propagation by cuttage is most widely practiced with azaleas, although they are also grown from seed, grafted, and layered. Half ripened or semi-hardwood cuttings taken late in May are usually used as propagating material (2, 32), although Osburn (30) recommends heel or mallet cuttings made in late summer or fall, which should root in five to ten weeks in a 50-50 mixture (by volume) of non alkaline sand and acid peat. The presence of phosphorus in the rooting media is necessary for the best root initiation and development (1). Schumacher (32) recommends four or five daily syringings of the cuttings to aid in maintaining the necessary high humidity.

The comparative ease and speed of vegetative propagation limits seed propagation of azaleas to Belgian hybridizers and azalea fanciers (28). Most European hybrids and especially the garden varieties are grafted plants, tongue and whip grafting being most widely practiced (2). Rhododendron ponticum is used as the understock for European hybrids while Rhododendron catawbiense is hardier and seems better suited as an understock for the American garden varieties (10). Layering is practiced with the larger garden species; especially when a few large plants are desired in a short length of time (30).

The successful culture of azaleas depends upon (1) a well drained, moisture retaining, acid medium, (2) protection from drying winds, (3) partial shade for tops and an organic mulch for the protection of the shallow roots from heat injury, and (4) protection from snow and extremely cold winds (2, 5, 8, 35, 38).

A well drained, moisture retaining acid medium may be had by the addition of naturally acid peat, humus, manure, or leaf mold to a well drained garden soil. Acid forming commercial and chemical fertilizers are used to supplement soils in which azaleas have been grown for several years. The use of some acid forming fertilizer to maintain acidity in soils is recommended by Anon. (1), Moore (27), Greider (14), Demonet (9), Gatke (13), and Rockwell (31). McElwee (23) recommends an acid forming fertilizer with an approximate analysis of 6-8-4, containing cottonseed meal, ammonium sulphate, ammonium phosphate, and other acid forming components.

Wilmot (41), and the Florists Exchange (1), infer that it is not the actual soil acidity which benefits these plants most, but rather the amount of iron and other elements which become more available as the soil acidity increases (lowering of pH). In situations where it is impossible to supply the proper soil reactions for favorable growth outdoors without danger of metal (iron, manganese, and aluminum) toxicity, removal of the original garden soil and the substitution of a mixture of acid-forming organic materials is suggested by Demonet (9), Dunbar (10), Gatke (13), and Millais (26). Beds intended for such plantings are dug out to a depth of 2½ to 3 feet (10), and filled in with humus and manure. The topsoil may be removed to the depth of a spade (about one foot), and a bushel of well rotted horse manure and one-half bushel of peat added for each square yard of bed space (14). The beds are then lined with boards or asbestos sheeting to minimize soil water movement and keep acidity in and alkalinity out (9). Azaleas will do well in light sandy soils with only a surface mulching of leaves or well rotted manure, provided such soils are not alkaline(10). Lemmon (19), suggests working in pine or hemlock needles, oak leaves, or peat, and keeping a permanent mulch of these materials to a depth of 3 or 4 inches.

Watering artificially with water containing calcium salts is detrimental to azaleas. "Softening" such water with an acid or using rainwater is recommended by Cox (8), Greider (14), and Schumacher (32). Ballhorn (3) in studies of the influence of soil acidifying techniques on the growth of azaleas, found that plants grown in an alkaline peat and watered with sulphuric acid acidified water produced significantly more flowers than did the plants watered with phosphoric acid acidified water.

In their native habitat, azaleas are found growing where the conditions are temperate or sub-tropical (38). Humidity is an absolute necessity, hence, the precaution of protection against drying winds by Dunbar (10), Cox (8), Schumacher (32), and Gatke (13). The use of an evergreen windbreak or planting on the northeast slope of an earth bank are two methods generally employed to protect azaleas and rhododendrons from drying winds.

Azaleas and rhododendrons cannot be expected to do their best in full sunlight. Using lath houses or planting near a deep rooted shade tree so that the plants will receive, at most, only half sunlight is conducive to rapid vegetative growth and flower development (8, 9, 10, 13, 19, 24, 30). Syringing the plants each afternoon, especially during hot, dry weather, will aid vegetative and flower growth (8, 30).

The fibrous, shallow root system of the azalea necessitates keeping the soil temperatures as low as possible during the hot summer months. To this end, and to serve as a constant supply of organic matter, a two to four inch mulch of pine or hemlock needles, oak leaves, sawdust, or peat may be used

(8, 9, 10, 13, 19, 22). This mulch must never be allowed to dry out completely, nor must it be kept saturated with water (2, 26). The compact, fibrous root system near the surface permits transplanting azaleas without injury. For the newer, tender hybrids, it is recommended that they be dug in the fall and carried through the winter in cold frames or cool greenhouses in subdued light, keeping the soil ball moist at all times; then set out in spring between the time the ground thaws and color shows in the flower buds (13, 14, 31, 23).

Most azaleas are evergreen, so must be protected from drifting snow during the winter to prevent their "suffocating." Planting other evergreens on the north and west sides of the azaleas will serve this purpose, and provide protection against winter and summer winds (10, 14).

C. On Soil Acidity and Plant Nutrition

The natural distribution of rhododendrons is governed by specific soil and site requirements more than by climate; they are found in ravines and on rocky hillsides when the soil reaction ranges from pH 5.2 to 2.9 (34). Natural stands of rhododendrons are nearly always found on the north slope of a hill or ravine, away from direct sunlight and where drainage is good, or under larger trees which provide shade and a constant supply of leaf mold (7).

* Soil acidity refers to the ratio of H and OH ions in the

soil. This relationship is commonly expressed as pH, which is the reciprocal of the log of the hydrogen ion concentration. The potential acidity or buffer action of a soil is a very important factor. Humic, colloidal substances, acid phosphates and salts of lime, or any base tend to act as buffers or "reaction regulators" which have a strong tendency to resist any change of the hydrogen ion concentration of the soil solution (11). The addition of organic matter to soils increases the amount of humic substances which in turn increases the buffer capacity of the soil (39). Acids, principally carbonic acid, released upon decomposition of organic matter form soluble salts with lime, magnesium and other bases (15). Ionic hydrogen released upon the ionization of carbonic acid readily replaces the exchangeable calcium and other bases on the colloidal complex, and these compounds are removed by leaching in areas of high rainfall leaving behind an excess of hydrogen ions in the soil solution and lowering the pH (increasing the acidity) (21).

The principal mineral elements contained in organic matter are sulphur, phosphorus, potassium, magnesium, and calcium (37). Sulphur and phosphorous are present as organic compounds in fresh organic materials. As decomposition progresses the sulphur and hydrogen sulfide left behind are biochemically oxidized to the sulfite form and immediately further oxidized to sulfate, which form is most readily available to plants (37). Phosphorus is probably liberated as the PO4 ion which is readily fixed and becomes available to plants at pH range of 5 to 7. Above pH 7, complex calcium phosphates are formed, while below pH 5, phosphorus is markedly fixed by iron and aluminum (21, 36).

As the pH of a soil is lowered, iron, aluminum, manganese, copper and zinc become more available. Disturbances in iron nutrition are probably the most recognized disorders causing chlorosis. Wilmot (41), and Meyer and Andersen (25), infer that it is not the acid condition which azaleas and other "acid-loving" plants like, but rather amount of iron which becomes more available as the acidity of the soil increases.

Four commonly recognized ways in which the iron nutrition of a plant may be affected so as to bring about a chlorotic condition are: "(1) true iron deficiency, (2) an upset in the phosphorus-iron balance, (3) an upset in the manganese-iron balance, and (4) lime induced chlorosis" (21). The latter is perhaps the most wide-spread.

Weiss (40) found that the growing of soybeans in water cultures with high calcium concentrations resulted in a high sap pH and a copious precipitation of iron in the roots and lower stem regions. He found also that a decrease in the sap pH (becoming more acid) and a lack of iron deficiency symptoms were associated with the addition of potassium to the medium.

In experiments with Lemma major in water cultures, Fly (12) found that inorganic iron becomes quickly unavailable when the solution was neutral, but when organic iron (ferric) citrate) was used, the growth rate for any definite pH, up to a certain limit, was increased by added amounts of iron. For each concentration of iron, an optimum pH was observed.

Iron is utilized by the plant in the production of the enzyme catalase (12), as a part of the enzyme peroxidase, which functions as an oxidizing enzyme in oxygen transfers in respiration (25), and plays an important role, either direct or indirect in the synthesis of chlorophyll in green plants. The state of iron in the plant tissues may also influence its utilization by the plant. Weiss (40) found that considerable quantities of iron may be present in the tissues of plants which exhibit symptoms of iron deficiency or chlorosis. On the other hand, if the soil acidity is high (low pH), toxicities of alumimum, etc., may develop. For equal concentrations, ferrous salts are more toxic than ferric salts (25). For a detailed discussion of these elements in toxic quantities, the conditions under which they exist, and their effects upon the plant, see Ballhorn (3) pp. 15-28.

III. MATERIALS AND METHODS

A. Plants

The azalea is one of the more important flowering pot plants for Valentine's Day, Easter and early spring sales throughout the Midwest. The problems involved in growing and producing satisfactory plants to meet the demand have formed the basis for this study. The Kurume type azalea, variety Snow, was obtained as rooted cuttings December 10, 1946, from Verkades Nurseries, Wayne, New Jersey. For details as to treatment of plants, see cultural practices, p. 17.

B. Soil

Rhododendrons and other so-called acid loving plants occur naturally in soils which are generally high in organic matter and acid in reaction (4, 5, 7, 10, 13, 14, 34). Keeping these facts in mind, and remembering the cost involved in transporting soils, the most readily available and possibly suitable local mineral and organic soils were used. Two types of peat were used as potting media for some treatments; acid sphagnum peat from a Minnesota source with pH 5.50 and an Iowa hypnum peat of pH 6.95.

Nelson (29), recommends the use of a potting mixture of one-half compost, one-fourth acid peat, and one-fourth oak-leaf mold (by volume) for potted azaleas. The oak-leaf mold used was from the College golf course, and had a pH of 6.5. Compost, composed of strawy manure and Webster soil with a pH of 6.5, was obtained from the Horticulture Farm.

C. Fertilizers

Some plants were left untreated while others were grown in the same potting media with various acid reacting fertilizers added. Liquid fertilizers were used in an effort to alter the soil reaction of certain potting media to make them more favorable for the growth of azaleas. Dry fertilizers were mixed with the potting medium of other plants prior to potting and shifting.

The following table gives the treatments applied to the various potting media employed.

Table I. Cultural Practices

Treatment Number	Potting Media	Fertilizer Applied
1	Iowa peat	None
2	Iowa peat	Vigoro (4-12-4) applied as top dressing at the rate of ¼ lb per sq yd every 6 weeks from May to August
3	Iowa peat	Watered every 6 weeks with liquid fertilizer (1½ oz each of aluminum sulphate and ferrous sulphate in 5 gallons water)

Table I (Continued)

Treatment Number	Potting Media	Fertilizer Applied
4	Iowa peat	Watered every 6 weeks with liquid fertilizer (1 oz each of ammonium sulphate, aluminum sulphate, and ferrous sulphate in 5 gallons of water)
5	Iowa peat	Monopotassium phosphate (5 gms) and sulphur (2 gms) mixed with each pound of peat at potting time
6	Acid peat	None
7	Acid peat	Same as No. 2
8	Acid peat	Same as No. 3
9	Acid peat	Same as No. 4
10	Acid peat	Same as No. 5
11	Oak leaf mold	None
12	½ compost, ¼ acid peat, ¼ oak-leaf mold (by volume)	None
13	Same as No. 12	Same as No. 4
14	Same as No. 12	Sulphur, ferrous sulphate, and aluminum sulphate mixed in equal parts (by wt) 4 gms of mixture added to each pound of potting soil mixture
15	Acid peat	Same as No. 14
16	Acid peat	Same as No. 14 plus Vigoro (4-12-4) applied as in No. 2

Table I (Continued)

Treatment Number	Potting Media	Fertilizer Applied
17	Acid peat	7 gms of 6-8-4 mixed with each pound of peat at potting time
18	Acid peat	Same as No. 17, plus Vigoro (4-12-4) applied as in No. 2
19	Acid peat	Monopotassium phosphate (5 gms) and magnesium sulphate (½ oz) mixed with each pound of peat at potting time well
20	Compost	Same as No. 19 ← poor died.
21	Acid peat	7 gms of 6-8-8 mixed with each pound of peat at potting time
22	Acid peat	7 gms of 6-8-16 mixed with each pound of peat at potting time
23	Acid peat	Monopotassium phosphate (10 gms), and dried blood (6.4 gms) mixed with each pound of peat at potting time
24	Acid peat	Liqua Vita (1/250 dilution) applied every 10 days during spring, and dried blood (6.4 gms) mixed with each pound of peat at potting time
25	Acid peat	Standard 4-12-4 applied as fertilizer No. 2

The fertilizers applied to treatments No. 3, 4, 8, 9, and 13 were selected as the most practical from treatments used by Ballhorn (3). McElwee (23) recommends the application of a 6-8-4 (treatments No. 17 and 18) fertilizer of acid-forming components. The potassium content of this fertilizer was doubled and quadrupled (treatments No. 21 and 22) to see if an increase would duplicate the results obtained by Weiss (40) with soybeans in water culture.

Treatments 19 and 20 were suggested by Hogensen (16) as a fertilizer to make alkaline soils suitable for azaleas.

Treatment No. 23 was recommended by Kemble Smith in Boone, Iowa, one of the state's largest commercial growers of azaleas.

Liqua Vita is a commercial liquid fertilizer, used in treatment No. 24 as a comparison with other liquid fertilizer treatments.

The standard 4-12-4 fertilizer in treatment No. 25 was used in a comparison with Vigoro (also basically a 4-12-4) in treatment No. 7

The 6-8-4, 6-8-8 and 6-8-16 fertilizers were prepared by mixing ammonium nitrate, monopotassium phosphate, and potassium chloride in the following quantities:

6-8-4:
1.8 lbs ammonium nitrate
5.0 lbs monopotassium phosphate
0.8 lbs potassium chloride
Add sand to 10 lbs

6-8-8:
Same as 6-8-4 except 1.6 lbs potassium chloride

6-8-16:
Same as 6-8-4 except 3.2 lbs potassium chloride

D. Water

Rainwater was used exclusively for watering and syringing the entire experiment. The consistant use of the local tap water, which contains copious quantities of calcium salts, would have resulted in the deposition of these salts in the potting media.

E. Cultural Practices

Rooted cuttings were received and potted in 2½ inch pots on December 10, 1946. A sufficient quantity of cuttings was ordered to permit a selection of uniform cuttings for the treatments. Block arrangements were made on December 12 and the plants placed in a 60° house.

On June 14, 1947, the plants were shifted to four-inch pots and moved to a well shaded greenhouse.

All vegetative growth was regularly soft-pinched to three inches to promote branching. Laurie and Kiplinger (18) recommend pinching until June 15 to allow time for the new shoots to develop sufficiently before flower buds are initiated. The plants were watered regularly so that the peat did not dry out. Syringing was done with lawn sprinklers installed in the greenhouse. During the hot, dry days of the summer, the sprinklers were turned on twice daily to maintain a high humidity and promote vegetative growth.

On August 1, all shading was removed from the roof of the greenhouse to harden vegetative growth and hasten flower bud development.

F. Arrangement of Treatments

There was a total of 25 treatments, six replications per treatment and two plants per replication. The arrangement used (lattice square, 33), was developed with the kind assistance of Mr. Walter Federer. Randomization was accomplished by the use of a table of random numbers. The rows and then the columns of each block were randomized. Block arrangement consisted of lettering each block, placing six numbers in a hat, and assigning each block of plants (in alphabetical order) as the numbers were drawn.

G. Collection of Data

Data collected included:

1. pH of the media
2. Number of flower buds
3. Foliage color
4. Plant quality

1. <u>pH of the media</u>.

pH determinations were made just prior to shifting the plants from 2½ inch to 4 inch pots (June 14), and at the conclusion of the experiment (October 10). All pH determinations were made with a Coleman glass electrode pH meter. Ten ml samples of air dried media were mixed with an equal volume of distilled water, stirred and allowed to stand one-half hour, and the solution decanted off for the determinations.

2. Number of flower buds

The number of flower buds produced on the plants of each treatment was used as an index of the general response of the plant to fertilizers and potting medium.

3. Foliage color

The color of the foliage of an azalea is generally an indication of the presence of nutritional iron disorders. Leaves deficient in chlorophyll (chlorotic) are not as efficient as normal leaves.

The plants were graded on the basis of foliage color. A score of five signified a plant with normal, dark green foliage, and so down to a score of one which indicated a plant with extremely chlorotic leaves.

4. Plant quality

Quality was based on vigor, color, size of leaves, and size of plants. Each of the four points considered counted one point toward the score the plant was given. The plants having the highest quality were given a score of four.

Fig. I. Plants growing in the greenhouse, showing arrangement and sprinklers used for maintaining humidity.

IV. RESULTS AND DISCUSSION

The selection of uniform plants at the outset of this study was instrumental in reducing the amount of variation within treatments, as substantiated by the fact that although the experiment was originally designed as a lattice square experiment with (k+1) replicates, a preliminary analysis of variance showed that there was very little variation within treatments and the efficiency of this method of analysis was no better than that of a randomized complete blocks design. As a result all data were analyzed by the latter method.

Data collected and analyzed included pH of the potting media prior to shifting (June 14) and at the conclusion of the experiment (Tables II and IV); the number of flower buds produced by the plants in each treatment (Table VIII); the foliage color as measured by a numerical scale dependent upon the intensity of green color in the leaves (Table IV); and plant quality or horticultural desirability of the plants as measured by a numerical scale (Table X).

Observations and pH determinations made on treatments left from an earlier experiment led to the analysis of covariance of pH and foliage color in this experiment, shown in Table VII. The purpose of this analysis was to determine whether or not pH was related to foliage color.

Treatment 23 (acid peat; KH_2PO_4, dried blood) was used as the check in this study, since it is the treatment employed by a local commercial greenhouse operator with considerable success. All references to significance in the discussion of treatment means are based on the treatment mean of this check treatment.

Only the mean pH readings taken October 10 will be considered in the discussion of the final effect on the plants, since there were no significant differences between readings taken on the two dates. The readings taken June 14 served as a check against any unexpected changes which might have occurred during the course of the experiment. An analysis of variance comparing the pH values taken at the two dates is given in Table XII.

Nearly all the plants in treatments 11, 12, 14, and all the plants in treatment 20, grown in organic and mineral soils from local sources, died during the course of the experiment as a result of treatment effects.

Comparison of treatments 1-8

Comparison of treatments 9-16

Comparison of treatments 17-25.
All of treatment 20 were dead.

Fig. II. Comparison of plants from the different treatments.

Table II. pH of Potting Media June 14

Treatment Number	1	2	3	4	5	6	7	8	9	10	11	12
pH June 14	6.95	6.55	6.35	5.60	5.90	5.10	4.91	4.68	4.76	4.38	7.38	7.08

Treatment Number	13	14	15	16	17	18	19	20	21	22	23	24
pH June 14	6.26	6.98	4.91	4.71	4.91	4.68	5.03	7.30	5.71	5.18	5.33	5.41

Treatment Number	25
pH June 14	5.46

Each value is a mean of 12 readings.

Table III. Analysis of Variance of pH taken June 14

	Degrees of Freedom	Mean Square
Replicates	5	0.270
Treatments	24	5.250**
Error (Treatments x Replicates)	120	0.0087

Difference required for significance:

at the 5% level = 0.34
at the 1% level = 0.45

Table IV. pH of Potting Media October 10, and Scores on Foliage Color of Plants

Treatment Number	1	2	3	4	5	6	7	8	9	10	11	12
pH Oct. 10	6.94	7.16	6.92	6.72	5.96	5.36	5.26	4.88	5.01	3.96	7.21	7.33
Foliage Color Score	3.58	2.80	4.33	4.50	3.91	4.00	4.00	5.00	4.00	3.91	0.33	0.66

Treatment	13	14	15	16	17	18	19	20	21	22	23	24
pH Oct.10	6.93	6.59	4.33	4.44	5.40	5.28	5.47	6.91	5.19	5.00	5.57	5.38
Foliage Color Score	3.16	1.16	3.58	4.25	4.41	4.33	3.25	0.00	3.91	4.25	3.83	3.91

Treatment Number	25
pH Oct.10	5.35
Foliage Color Score	4.16

Each value is an average of the values of 12 plants.

Table V. Analysis of Variance of pH Taken October 10.

	Degrees of Freedom	Mean Square
Replicates	5	0.22
Treatments	24	6.04**
Error (Replicates x Treatments)	120	0.34

Difference required for significance:

at the 5% level = 0.207
at the 1% level = 0.225

Table VI. Analysis of Variance of Scores on Foliage Color

	Degrees of Freedom	Mean Square
Replicates	5	0.47
Treatments	24	11.06**
Error (Replicates x Treatments)	120	0.25

Difference required for significance:

at the 5% level = 0.57
at the 1% level = 0.75

Table VII. Analysis of Covariance of pH and Foliage Color

	Degrees of Freedom	Sx^2	Sxy	Sy^2	Errors of Estimate: Sum of Squares	Errors of Estimate: Degrees of Freedom	Errors of Estimate: Mean Square
Total	149	185.26	-138.48	298.01			
Replicates	5	0.04	0.10	2.39			
Treatments	24	143.98	-120.66	265.38			
Error (R x T)	120	41.24	-17.92	30.24	22.45	119	0.189
Treatments + Error	144	185.22	-138.58	295.62	191.94	143	
Differences for testing adjusted treatment means					169.49	24	7.060**

Table VIII. The Number of Flower Buds Produced

Treatment Number	1	2	3	4	5	6	7	8	9	10	11
Number Flower Buds	5.5	10.5	6.1	20.4	18.8	25.6	27.3	23.4	25.7	18.8	0.0

Treatment Number	12	13	14	15	16	17	18	19	20	21	22	23
Number Flower Buds	0.5	18.1	3.6	22.8	31.6	24.0	23.7	19.1	0.0	20.9	20.3	25.6

Treatment Number	24	25
Number Flower Buds	23.5	21.4

Each number is the mean of 12 plants

Table IX. Analysis of Variance of the Number of Flower Buds Produced

	Degrees of Freedom	Mean Square
Replicates	5	41.01
Treatments	24	536.43**
Error (Replicates x Treatments)	120	20.08

Differences required for significance:

at the 5% level = 5.09
at the 1% level = 6.73

Table X. Scores on Plant Quality

Treatment Number	1	2	3	4	5	6	7	8	9	10	11
Plant Quality Score	1.00	1.25	1.00	2.08	2.66	2.91	3.24	3.83	3.61	2.66	0.00
Treatment Number	12	13	14	15	16	17	18	19	20	21	22
Plant Quality Score	0.00	2.00	0.25	3.25	3.25	3.41	2.91	2.83	0.00	2.91	3.08
Treatment Number	23	24	25								
Plant Quality Score	3.08	2.83	3.33								

Each score is an mean of 12 plants

Table XI. Analysis of Variance of Scores on Plant Quality

	Degrees of Freedom	Mean Square
Replicates	5	0.42
Treatments	24	9.24**
Error (Replicates x Treatments)	120	0.33

Difference required for significance:

at 5% level = 0.66
at 1% level = 0.87

Fig. III. Comparison of a stunted (treat. 3; Iowa peat; $Al_2(SO_4)_3$, $FeSO_4$) and a chlorotic plant (treat. 12; ½ compost, ¼ oak-leaf mold, ¼ acid peat) with the check (treat. 23; acid peat; KH_2PO_4, dried blood).

Fig. IV. Comparison of treatments 1-5 (Iowa peat; fertilizers) and 6-10 (Acid peat; fertilizers)

A. Comparison of Treatments 1-5 (Iowa Peat; Fertilizers) and 6-10 (Acid Peat; Fertilizers) as to pH of the Potting Media, Foliage Color, Number of Flower Buds Produced and Plant Quality

In treatments 1-5 and 6-10, in which Iowa and acid peats respectively were compared, the mean pH of treatments 1, 2, 3, 4, and 5 were significantly high, while that of treatments 8, 9, and 10 were significantly low (Table IV). On the other hand, Table IV shows also that the foliage color score of treatment 2 was significantly lower than the experimental check, and treatments 4 and 8 were significantly higher. The number of flower buds produced by plants grown in acid peat was not significantly different, with the exception of treatment 10, which was lower than the check (Table VIII). The range of flower bud production in treatments 1-5 was from 5.5 to 20.4, with the mean of treatment 5 identical to that of treatment 10. Scores on plant quality as presented in Table X reveal that treatments 1-4 were significantly lower than the experimental check treatment; that treatments 5, 6, 7, and 10 did not vary significantly; and that treatment 8 was significantly higher.

Treatments 1 and 6 represent azaleas grown on two types of naturally occurring peat soils without the addition of fertilizers; Iowa, hypnum peat in the former case and Minnesota, sphagnum peat in the latter. Foliage color scores on these two treatments reveal that the plants were able to absorb and utilize sufficient iron to maintain almost the same leaf color in the vegetative growth made. The larger number of flower buds produced by treatment 6 (Table VIII) is an indication that the acid, sphagnum peat had a better balance of the essential mineral elements than did the Iowa, hypnum peat. Information from the producer reveals that both types are very low in phosphorus and potassium. Table X presents the scores on plant quality which reveal that treatment 1 is far inferior to treatment 6, which did not vary significantly from the check treatment.

The data presented in Table IV show that the pH readings of the potting media of treatments 2 (Iowa peat; Vigoro) and 7 (Acid peat; Vigoro) were significantly different. It might be well to note that the addition of Vigoro increased the pH of treatment 2 over that of treatment 1 and decreased the pH of treatment 7 below that of treatment 6; although neither treatment varied significantly from the untreated peats. The addition of Vigoro resulted in a lower foliage color score than was obtained with the unfertilized Iowa peat. The fertilizer effect might be explained in that the amount of available iron in Iowa peat is low and that the addition of phosphorus (when Vigoro was applied) aggravated the condition by reacting with the iron compounds present to render them insoluble or unavailable to the plant, or both. The foliage color score of treatment 7 was significantly better than that of treatment 2, but was identical to the score of treatment 6 (Acid peat, untreated), indicating that larger quantities of iron were probably available to the plant so that iron rendered unavailable by the phosphorus comprised that portion in excess of that required by the plant to maintain an almost normal green color. As heretofore mentioned, the possibility of a low supply of essential mineral elements in the Iowa peat when compared to the acid peat is more sharply pronounced when observing the data presented in Table VIII. Treatment 2 produced twice as many flower buds as did treatment 1, conversely, very little increase was noted when comparing treatments 6 and 7. The plant quality scores of treatments 2 and 7 (Table X) show that treatment 2 is significantly lower than treatment 7 and the check.

The pH determinations of treatments 3 (Iowa peat; $Al_2(SO_4)_3$, $FeSO_4$) and 8 (Acid peat; $Al_2(SO_4)_3$, $FeSO_4$) (Table IV) were significantly different. While the pH of treatment 3 was significantly higher than the experimental check, that of treatment 8 was significantly lower. Attention is called to the fact that the pH of treatment 3 did not vary significantly from that of treat 1 (Iowa peat; Untreated); yet the foliage color scores (Table IV) reveal that treatment 3 was significantly better than treatment 1. The fertilizer applied to treatments 3 and 8 supplied iron in an inorganic form, which form was either immediately available or rendered available to the plants in another form in large enough quantities to maintain excellent foliage color (particularly in treatment 8).

Data in Table VIII shows that treatment 8 produced nearly four times as many flower buds as did treatment 3, but did not vary significantly from the check. The plant quality scores in Table IX show that treatment 3 received a score that was identical to that of treatment 1. On the other hand, the quality score of treatment 8 was significantly larger than that of the experimental check. This was the only treatment in the experiment which had a plant quality score that was significantly larger than that of the check.

In comparing the pH of treatments 4 (Iowa peat; NH_4SO_4, $Al_2(SO_4)_3$, $FeSO_4$) and 9 (Acid peat; NH_4SO_4, $Al_2(SO_4)_3$, $FeSO_4$) (Table IV), the treatments varied significantly from one another, and from the check treatment; treatment 4 being larger and treatment 9 smaller. Data on foliage color in Table IV show that treatments 4 and 9 did not differ significantly, and since treatment 4 received the best score of all plants grown on Iowa peat, it might be said that the problems of iron absorption and utilization of plants grown in this media were most nearly met in this treatment. Fertilization of the plants in these two treatments with a mixture of compounds, each of which was a sulfate probably induced base exchange reactions in the media which released iron in a readily available form. The use of ammonium sulfate in treatment 4 in addition to the fertilizer applied in treatment 3 ($Al_2(SO_4)_3$, $FeSO_4$), produced highly significant differences in the number of flower buds produced and the plant quality score of the former treatment.

The plant quality score of treatment 9 was much larger than that of treatment 4, but did not differ significantly from the experimental check (Table X).

Table IV reveals that the mean pH reading of treatment 5 (Iowa peat; KH_2PO_4, Sulphur) was much higher than that of treatment 10 (Acid peat; KH_2PO_4, Sulphur) and that both differed significantly from the experimental check; the former being greater and the latter less. The foliage color scores of treatments 5 and 10 were identical (Table IV) and did not vary widely from the check treatment. Treatment 5 was grown in a media which is probably low in available iron and was supplied with a source of phosphorus with which the iron reacted. Sulphur was also supplied and tended to acidify the soil and intensify this reaction, leaving less iron available to the plant in proportion to the amount of vegetative growth made. In treatment 10, soil acidity was increased beyond the point of tolerance of the Kurume Azalea (about pH 4.0) by the addition of sulphur; and the phosphorus supplied reacted with the available iron to render both unavailable and cause the plants to make only spindly growth and the leaves to be yellowish green.

The numbers of flower buds produced by treatments 5 and 10 were also identical (Table VIII); both varying significantly from the experimental check. Scores on plant quality were identical with no significant variation from the check treatment (Table X).

Fig. V. Comparison of treatments 7 (Acid peat; Vigoro) and 25 (Acid peat; 4-12-4)

Fig. VI. Comparison of treatments 10 (Acid peat; KH_2PO_4, sulphur), 19 (Acid peat; KH_2PO_4, $MgSO_4$), and 23 (Acid peat; KH_2PO_4, dried blood)

Fig. VII. Comparison of treatments 17 (Acid peat; 6-8-4), 18 (Acid peat; 6-8-4, Vigoro), 21 (Acid peat; 6-8-8), and 22 (Acid peat; 6-8-16)

B. Comparison of Treatments 7 (Acid Peat; Vigoro) and 25 (Acid Peat; 4-12-4) as to pH of the Potting Media, Foliage Color, Number of Flower Buds Produced and Plant Quality

Data presented in Table IV disclose that the pH of treatments 7 and 25 were not significantly different from one another, nor from the experimental check treatment. The same is true of their foliage color scores as presented in Table IV, and plant quality scores as presented in Table X. The number of flower buds produced by treatment 7 was significantly higher than that of treatment 25, but neither varied widely from the check (Table VIII).

Since the fertilizers used in both treatments 7 and 25 were basically 4-12-4 mixtures, an explanation for the increase in flower bud production in treatment 7 is that different chemical compounds were used in mixing each fertilizer. The compounds used in mixing Vigoro (treatment 7) contain essential minor and trace plant food elements which might not be found in a complete analysis of the standard 4-12-4 fertilizer.

C. Comparison of Treatments 8 (Acid Peat; $Al_2(SO_4)_3$, $FeSO_4$) and 24 (Acid Peat; Liqua Vita, Dried Blood) as to pH of the Potting Media, Foliage Color, Number of Flower Buds produced, and Plant Quality

pH readings presented in Table IV show that treatment 8 is significantly lower than treatment 24 and the check treatment. The foliage color score of treatment 8 was significantly larger than that of either treatment 24 or the check (Table IV);

however, Table VIII signifies that the number of flower buds produced by these two treatments was almost identical. Data in Table X reveal that the plant quality score of treatment 8 was significantly greater than that of treatment 24 and the check treatment.

The two liquid fertilizers used in treatments 8 and 24 were very different. The fertilizer applied to treatment 8 contained sulphur and ferrous sulphate in chemically pure form. This treatment proved to be the most outstanding in this study. On the other hand, Liqua Vita (applied in treatment 25), a concentrated liquid fertilizer with an approximate analysis of 6-9-7 and supposedly containing the essential major trace and plant food elements, produced plants whose quality score was significantly lower than that of treatment 8. Literature published on this fertilizer pertaining to its use on azaleas and gardenias states: "use aluminum or iron sulphate when leaves show yellowing, ½ lb. to 100 sq. ft." This statement might lead one to conclude that the constant application of Liqua Vita, even when diluted as recommended, will have a detrimental effect upon the availability of iron in the soil. The phosphorus contained in this fertilizer, through constant application, will tend to react with iron present in the media, rendering both unavailable and interfering with the normal growth processes of the plant.

D. Comparison of Treatments 10 (Acid Peat; KH_2PO_4, Sulphur), 19 (Acid Peat; KH_2PO_4, $MgSO_4$), and 23 (Acid Peat; KH_2PO_4, Dried Blood) as to pH of the Potting Media, Foliage Color, Number of Flower Buds Produced, and Plant Quality

Data in Table IV indicate that treatment 10 had a pH value which was significantly lower than that of the experimental check. The foliage color score of treatment 19 (Table IV) is significantly lower than that of treatment 23. Treatments 10 and 19 both produced significantly less flower buds than did treatment 23. Scores on plant quality of the three treatments did not vary widely. The use of sulphur in treatment 10 was undoubtedly responsible for the lowering of the pH below that of both treatments 19 and 23. Magnesium sulphate as applied to treatment 19 seems to have had very little effect on the pH of the media, probably because of the small quantity used and the buffering action of the peat.

The better foliage color score of treatment 23 was probably due to the nitrogen and organic iron contained in dried blood. Production of a larger number of flower buds, and the higher score on plant quality (although not significant) of treatment 23 may also be attributed to the previously mentioned reasons.

E. Comparison of Treatments 11 (Oak Leaf Mold), 12 (½ Compost, 1/4 Acid Peat, 1/4 Oak Leaf Mold), 13 (Same as 12; $(NH_4)_2SO_4$, $Al_2(SO_4)_3$, $FeSO_4$), and 14 (Same as 12; Sulphur, $FeSO_4$, $Al_2(SO_4)_3$) as to pH of the potting Media, Foliage Color, Number of Flower Buds Produced and Plant Quality

Data presented in Table IV reveal that the media of Treatments 11, 12, 13, and 14 all have pH values which are significantly higher than that of treatment 23. Foliage color scores in Table IV show that treatment 13 was significantly better than treatments 11, 12 and 14, but that all were significantly less than the check treatment. Table VIII shows that, as a whole, this was about the lowest flower bud producing series of treatments in the study. Scores on plant quality in Table X reveal this same fact.

The potting media for this series came from a local source, hence the high pH values indicating a high lime condition. Nearly all the plants in treatments 11 and 12 were unable to make very much growth from the beginning because of their extreme chlorotic condition brought about by the unavailability of iron in the alkaline media.

Application of an acid forming liquid fertilizer in treatment 13 did not lower the pH of the medium below that of treatment 14, but plants in the former treatment had a much better foliage color score. Watering the plants in treatment 13 every 6 weeks with a liquid fertilizer provided a constant source of iron, which probably accounts for the better foliage color score of this treatment over that of treatment 14, to which ferrous sulphate was added only at potting time. The ammonium sulphate applied to treatment 13 is more than likely responsible for the larger number of flower buds produced; the higher plant quality score, to the combined effect of the $FeSO_4$ and $(NH_4)_2SO_4$.

F. Comparison of Treatments 15 (Acid Peat; Sulphur, $FeSO_4$, $Al_2(SO_4)_3$), and 16 (Acid Peat; Sulphur, $FeSO_4$, $Al_2(SO_4)_3$, Vigoro) as to pH of the Potting Media, Foliage Color, Number of Flower Buds Produced, and Plant Quality

Data presented in Table IV show that there are no significant differences in the pH readings of the potting media of treatments 15 and 16 and the experimental check treatment. The foliage color scores (Table IV) indicate that there is a significant difference between these two treatments; that of treatment 16 being higher. In Table VIII, highly significant differences in the number of flower buds produced by treatment 15 and 16 are in evidence; also between treatments 16 and 23. The plant quality scores of treatments 15 and 16 are identical (Table X).

pH readings of the media were also the same because Vigoro (basically a 4-12-4 fertilizer) is neutral in reaction. Differences in foliage color and flower bud production might be accounted for by the fact that a better nutritional balance existed in the medium of treatment 16 because of the minor elements supplied by Vigoro. Treatment 16 was the only treatment in the experiment which produced significantly more flower buds than did the experimental check treatment.

G. Comparison of Treatments 17 (Acid Peat; 6-8-4), 18 (Acid Peat; 6-8-4, Vigoro), 21 (Acid Peat; 6-8-8) and 22 (Acid Peat; 6-8-16) as to pH of the Potting Media, Foliage Color, the Number of Flower Buds Produced and Plant Quality

Table IV shows that the pH readings of treatments 17 and 22 differ significantly; and that treatments 21 and 22 both vary significantly from the check treatment. Data presented in Table III also reveal that there were no significant differences in foliage color. Treatment 22 produced significantly fewer flower buds than did the experimental check (Table VIII). Plant quality scores given in Table X verify that the score of these treatments do not vary widely from the check.

The fertilizer mixtures applied to these treatments failed to give the desired results. Since there was no significant increase in the acidity of the media after the fertilizer applications, it might be said that they were neutral in reaction. Increasing the potassium content of the fertilizer seemed to cause the plants in treatments 21 and 22 to produce fewer flower buds. However, these differences are not significant.

H. Comparison of Treatments 19 (Acid Peat; $KH_2PO_4MgSO_4$) and 20 (Compost; KH_2PO_4, $MgSO_4$) as to pH of the Potting Media, Foliage Color, the Number of Flower Buds produced and Plant Quality

From the data presented in Table IV, it will be seen that the pH values of treatments 19 and 20 vary significantly, and that of treatment 20 is significantly higher than the pH value of treatment 23. Differences in foliage color scores (Table IV), number of flower buds produced (Table VIII), and plant quality scores (Table X) between these two treatments are obvious; however, the foliage color score and number of flower buds produced by treatment 19 are both significantly lower than those of the experimental check.

This treatment, advocated many years ago as a corrective measure to render alkaline soils favorable for the growth of azaleas, proved to be anything but corrective. Application of this fertilizer to acid peat seemed to affect the azaleas most by lessening the intensity of green color in the foliage. Most of the plants in treatment 20 died because of the alkaline nature of the compost, and the fact that magnesium and phosphorus both tend to counteract the availability of iron to plants growing in any soil. Plants receiving this treatment failed to produce more than an inch of growth and died soon after the experiment had started.

I. The Analysis of Covariance of pH and Foliage Color

The highly significant value obtained as a result of the analysis of covariance in Table VII signified that the pH of the potting medium and the foliage color of azaleas in this experiment were independent of one another. This implies that the mean pH of the medium in which plants in a specific treatment are growing might be near the neutral point, yet the mean foliage color score for this same treatment might be high; while plants receiving another treatment and growing in the same media as the first group might have an almost identical pH, the foliage color score of plants in the second treatment will be comparatively lower (Table IV; treatments 3 and 1, 16 and 15). On the other hand, the pH of the medium might be low and the foliage color score low, and another treatment in the same medium might have a comparatively higher pH reading and a higher foliage color score (Table IV; treatments 8 and 10, 17 and 21).

The fact that the soil acidity is high (low pH) does not always imply that iron, the deficiency of which generally causes chlorosis in azaleas, is in a readily available form, or that if available, will be utilized by the plant for the formation of chlorophyll. Conversely, a high pH does not always mean that an azalea will be chlorotic; or that azaleas growing in what was known to be an alkaline soil before fertilizer was added, would be chlorotic if the pH of the media remained near the neutral point (treatment 13).

This variation from the accepted theory that "making the soil acid will control chlorosis" was first noted after observing and making pH determinations on treatments left from an earlier experiment. Observations in this investigation served to substantiate the earlier findings.

These findings are unexplainable at present and have led to planned investigations into the absorption and utilization of iron by azaleas.

Table XII. Analysis of Variance of pH Data Taken June 14 and October 10

	Degrees of Freedom	Mean Square
Replicates	5	0.13
Treatments	24	10.68
Error (Replicates x Treatments)	120	0.09
Dates	1	1.06
Dates x Treatments	24	0.57
Dates x Replicates	5	0.12
Dates x Replicates x Treatments	120	0.34

The F test revealed no significance between pH readings taken on the two dates.

V. SUMMARY

This paper is a report on Project #926 of the Iowa Agricultural Experiment Station and deals with an investigation of the responses of the azalea to certain media and fertilizers.

Rooted azalea cuttings of uniform size were grown in two types of peat (alkaline hypnum and acid sphagnum peats), soil and artifical manures from local sources (a mineral soil, compost, and oak-leaf mold), and some recommended combinations of these. Some plants were left untreated, while others in the same medium received applications of liquid and dry acid reacting fertilizers. Rainwater was used for watering and for syringing the plants.

Recommended cultural practices regarding temperature, watering, syringing, shading, and pinching were used.

After potting, the plants were arranged in a lattice square design with (k + 1) replicates. The plants were shifted from 2½ to 4 inch pots in June. Data were collected after flower buds had developed and included pH of the media, foliage color, number of flower buds produced and plant quality. Treatment 23 was chosen as the experimental check.

An analysis of variance of pH values taken on June 14 and October 10 showed that no significant changes had occurred during the course of this investigation. Plants grown in acid peat were significantly better than those grown in Iowa peat, with the exception of treatments 5 and 10 (KH_2PO_4, sulphur),

in which case all data except pH were identical. The plant quality score of the untreated acid peat (treatment 6) did not vary significantly from the experimental check treatment. Treatment 8 ($Al_2(SO_4)_3$, $FeSO_4$) had the best foliage color and plant quality scores of the experiment. The addition of sulphur to treatment 10 probably caused the pH of the medium to fall below the tolerance point for azaleas, producing unsatisfactory plants.

Applying Vigoro as a 4-12-4 fertilizer in treatment 7 caused the plants of that treatment to produce significantly more flower buds than treatment 25 which was fertilized with a standard grade of 4-12-4 fertilizer.

Treatment 8, fertilized with a liquid fertilizer ($Al_2(SO_4)_3$, $FeSO_4$), had significantly higher foliage color and plant quality scores than did treatment 24, which was fertilized with Liqua Vita and dried blood.

Of the plants grown in the media from local sources, only treatment 13 ($(NH_4)_2SO_4$, $Al_2(SO_4)_3$, $FeSO_4$) showed any favorable response.

When used in addition to sulphur, $Al_2(SO_4)_3$, and $FeSO_4$, Vigoro greatly increased the flower bud production and foliage color score of treatment 16 over that of treatment 15, which did not receive an application of Vigoro.

The use of an acid reacting 6-8-4 fertilizer (treatment 17) and subsequently doubling (treatment 21) and quadrupling (treatment 22) the potassium content, produced plants whose foliage color and plant quality scores were not significantly improved.

Magnesium sulphate and potassium acid phosphate proved to antagonize rather than correct lime induced chlorosis (treatment 20).

An analysis of covariance of pH and foliage color showed that the pH of the potting medium and the foliage color of azaleas were independent of one another.

VI. CONCLUSIONS

1. Most plants grown in acid peat were significantly better than those receiving the same treatment and grown in an alkaline Iowa peat.
2. From the standpoint of flower bud production, a mixture of sulphur, $FeSO_4$, $Al_2(SO_4)_3$, and Vigoro, was a better fertilizer for azaleas than KH_2PO_4 and dried blood.
3. $Al_2(SO_4)_3$ and $FeSO_4$, in combination, comprised a better fertilizer for azaleas than the fertilizer (KH_2PO_4, dried blood) now used in commercial greenhouses in this area.
4. Phosphorus, in sufficient quantities in the soil, will react with iron to render the iron unavailable and cause chlorosis of azaleas.
5. Maintaining a high soil acidity (pH 4.0) proved deleterious to the azalea by causing stunting and chlorosis.
6. It was possible to maintain a fairly good foliage color on azaleas grown in a mixture of Webster soil, acid peat, and locally obtained oak-leaf mold.
7. Doubling and quadrupling the potassium content of a 6-8-4 fertilizer had no effect on the foliage color and quality of azaleas so treated.
8. The foliage color of azaleas and pH of the medium in which they are grown were independent of one another.

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