ETHREL AS AN AID IN ROOTING[1]

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Abstract. Various concentrations and combinations of Ethrel, IBA, and NAA were applied to softwood cuttings of *Prunus tomentosa, Amorpha fruticosa* var. *angustifolia*,(A.fragrans).*Rhamnus cathartica, Forestiera neomexicana, Juniperus scopulorum* and *Cotoneaster racemiflora* var. *soongorica*. The cuttings were placed in sand or a peat/perlite mixture for rooting. Ethrel alon at 480 ppm was the most effective rooting treatment for *P. tomentosa* and *A.f.* var. *angustifolia (A.fragrans)*. Higher levels of Ethrel alone at 480-960 ppm and 1440-1920 ppm were most effective for rooting *F. neomexicana* and *C.r. soongorica*., *R. cathartica* and *J. scopulorum* rooted best when treated with a combination of 960 ppm Ethrel plus 2500 ppm IBA/NAA. Increases in root number were observed only with combinations of Ethrel, IBA and NAA, except with *F. neomexicana* where 240 ppm Ethrel provided greater root numbers than the control. Root length was increased by treatment with Ethrel alone and in combination. The effect of the medium was species-dependent.

The concept that ethylene functions as a natural phytohormone is now generally accepted. The most obvious influence of ethylene pertains primarily to the physiology of senescence and abscission or to phytogerontology (1, 3, 7, 8). Other responses such as enchanced seed germination (4, 12), induction of flowering in pineapple (21), stimulation of lateral and basal branching (9, 11), and enhanced protein and RNA synthesis (2, 8, 14) have been observed. Conflicting results as to the effect of ethylene on roots or rooting have been observed (5, 6, 8, 10, 13, 15, 16, 18, 19, 22). Carpenter and Carlson (10) indicated that Ethrel had no effect on chrysanthemum propagation with the exception of an indirect effect of increasing branching which provided a potential source of terminal cuttings (9). Kirshnamoorthy (13) reported that Ethrel increased the number of roots on mung bean hypocotyl cuttings. Although Ethrel is an ethylene-producing compound, and does increase rooting of sedum leaf cuttings, ethylene does not (6). Nell and Sanderson (15) observed a slight increase in rooting of azalea cuttings with the application of Ethrel and Schmid and Schurter (18) found that Ethrel stimulated rooting of hardwood cuttings.

Preliminary studies on juniper cuttings indicated that Ethrel may enhance rooting. It was the purpose of this study to evaluate the effect of Ethrel alone and in combination with IBA and NAA on the rooting of cuttings.

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MATERIALS AND METHODS

Softwood cuttings of *Prunus tomentosa, Amorpha fruticosa* var. *angustifolia (A. fragrans), Rhamnus cathartica, Forestiera neomexicana, Juniperus scopulorum,* and *Cotoneaster racemiflora* var. *soongorica* were taken on July 25. Cuttings varied from 5 to 8" long depending on the species. Six cuttings of each species were treated with each of the 14 treatments listed in Table 1 and stuck in sand or in a 1:1 peat-perlite mix under intermittent mist controlled by an electronic leaf. Bottom heat maintained the sand at 22-24°C and the peat-perlite at 20-22°C. All treatments[1] were made up fresh and were applied as a 3-min dip. The data were recorded after 60 days and analyzed separately for each species in a 2 x 14 x 6 factorial arrangement. Percent rooting, number of roots per cutting, and root length was recorded in each observa-

Table 1. Concentrations and combinations of chemicals used to treat softwood cuttings.

Treatment Number	Ethrel Conc. (ppm)	+	IBA Conc. (ppm)	+	NAA Conc. (ppm)
1	CONTROL (Distilled water)				
2	240				
3	480				
4	960				
5	1440				
6	1920				
7	480	+	2500		
8	480	+	5000		
9	960	+	2500		
10	960	+	5000		
11	480	+	2500	+	2500
12	480	+	4000	+	5000
13	960	+	2500	+	2500
14	960	+	5000	+	5000

Table 2. Ranking system for number of roots per cutting.

Rank	Number of Roots
1	0-5
2	6-10
3	11-15
4	16-20
5	21-25
6	26-30
7	31-35
8	〉35

[1] The author wishes to thank Amchem Company, Inc., Ambler, Pennsylvania for providing the chemicals used.

tion. The ranking system used to record number of roots is described in Table 2. Root length refers to the average length of the five longest roots.

RESULTS

Prunus tomentosa. The best rooting occurred with 480 ppm Ethrel; 100% rooted in both media with this treatment (Fig. 1). The largest improvement with this treatment occurred in peat/perlite where an 83% increase in rooting over the control occurred. Ethrel and IBA was not as beneficial as Ethrel alone and Ethrel + IBA + NAA was generally detrimental in both media. Very little callusing occurred; if the cutting was not rooted, it was dead.

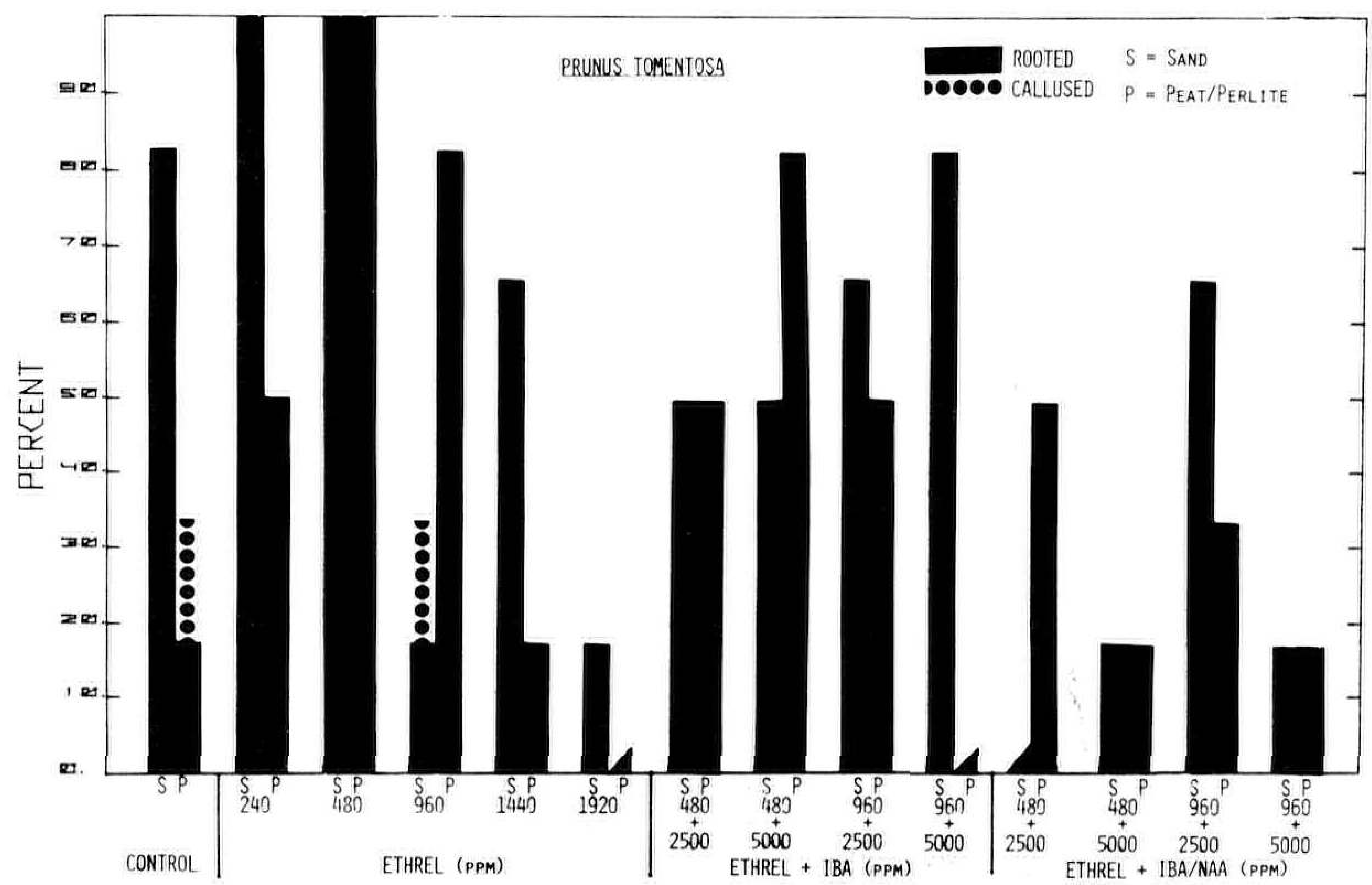

Figure 1. Percent root and callused *Prunus tomentosa* cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA in sand and in peat/perlite. Base line triangles indicate no rooting.

A significant difference in the number of roots occurred between treatments. Although Ethrel alone produced plants with the greatest number of roots, the number of roots per cutting from the Ethrel treatment did not differ from the control (6 to 10 roots). However, with the addition of IBA and NAA, the number of roots increased (30 to 35).

The combination of 480 ppm Ethrel + 2500 ppm IBA, produced significantly longer roots (13-14 cm) than the control (8-9 cm) or any other treatment (Table 3). Thus, an inverse relationship generally existed between number of roots and root length. A significant treatment-media interaction did occur for root length;

however, it was mainly due to the greater root length produced in peat/perlite than sand at 480 ppm Ethrel plus 2500 ppm IBA.

In summary, Ethrel alone at 480 ppm appeared to be the most effective treatment to enhance rooting. The effect of the medium was dependent on the treatment.

Amorpha fruticosa var. *angustifolia (A. fragrans)*. Ethrel significantly increased the percent rooting over that of the control. Eighty to 100% rooting occurred with 240-1440 ppm Ethrel in either medium except in peat/perlite at the 1440 ppm concentration (Fig. 2). This compares to 33% in sand and 0% in peat/perlite for the control. One hundred percent rooted in sand and 80% rooted in peat/perlite with 480 ppm Ethrel + 2500 ppm IBA. Rooting decreased to 50% in sand for all remaining treatments except for 480 ppm Ethrel + 2500 or 5000 ppm IBA/NAA, wherein no rooting occurred. Rooting in peat/perlite remained at 80-100% with the exception of 960 ppm Ethrel + 2500 ppm IBA/NAA wherein 65% rooting occurred.

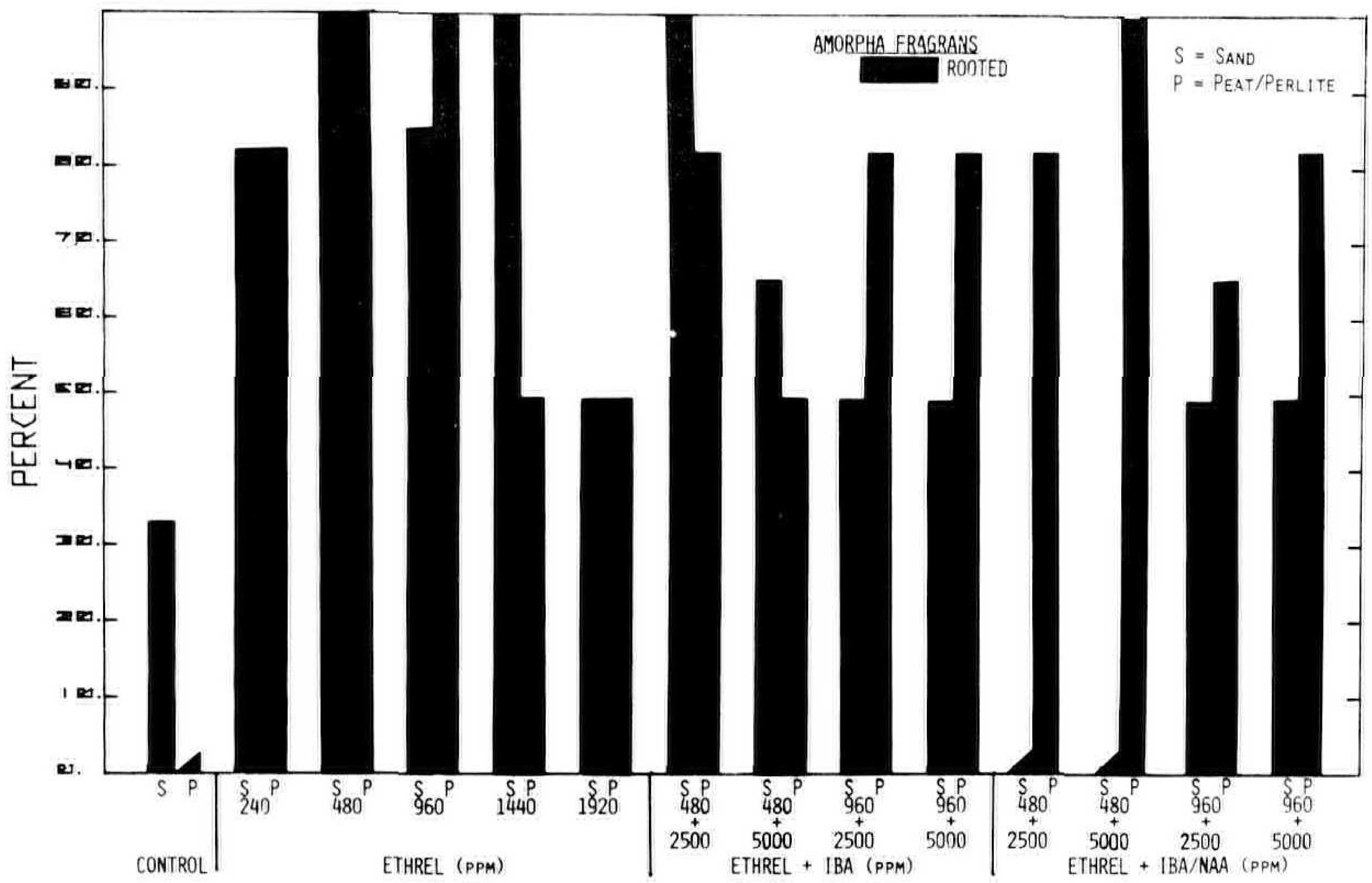

Figure 2. Percent rooted *Amorpha fruticosa* var. *angustifolia (A. fragrans)*. **cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA in sand and in the peat/perlite. No callusing occurred, if the cutting did not root, it was dead. Base line triangles indicate no rooting.**

No differences in number of roots occurred between treatments; however, a highly significant difference in root length was observed. All treatments of Ethrel alone produced significantly longer roots than the control (Table 3). Two Ethrel tretaments, 960 and 1440 ppm produced longer roots than all but one of the combination treatments.

In summary, peat/perlite appeared to be the best medium and Ethrel alone at 480 ppm was the most effective treatment.

Table 3. Mean root length of 3 species of softwood cuttings treated with Ethrel and combinations of Ethrel and IBA or IBA/NAA in sand or a peat/perlite mix.

	Mean Root Length (cm)		
Treatment Number	Prunus tomentosa	Amorpha f. var. angustifolia	Rhamnus cathartica
1	8.8 bc	1.9 a	1.0 a
2	9.0 bc	7.8 bc	4.4 bc
3	8.9 bc	8.3 bc	—
4	8.3 ab	10.1 bc	8.9 d
5	6.9 ab	10.1 bc	3.5 abc
6	9.4 bc	6.2 b	—
7	13.0 c	6.2 b	6.6 cd
8	7.5 ab	5.8 ab	2.7 ab
9	3.9 a	7.3 bc	4.4 bc
10	4.1 a	5.3 ab	5.6 bc
11	4.9 ab	5.6 ab	4.8 bc
12	8.5 bc	4.3 ab	5.3 bc
13	6.9 ab	5.1 ab	—
14	7.0 ab	5.5 ab	7.6 cd

* Numbers within species followed by the same letters are not significantly different as *determined by using the harmonic mean in a LSD mean separation.*

Rhamnus cathartica. This more-difficult-to-root species did not root particularly well with any of the treatments. No control cuttings rooted in sand and only 15% in peat/perlite. The highest percent rooting with Ethrel alone was only 50% which was obtained with 240 ppm Ethrel in sand. The most effective treatment was 960 ppm Ethrel + 2500 or 5000 ppm IBA in which 80% and 65% rooting respectively was obtained in peat/perlite (Fig. 3). All other treatment combinations were considerably less effective including the three-way combination. Very little callusing occurred; however, the cuttings that were not rooted or callused were not dead.

None of the treatments produced a significantly greater number of roots than the control. Within the treatments which rooted, all but two treatments (1440 ppm Ethrel and 480 ppm Ethrel + 5000 IBA) had longer roots than the control (Table 3). Cuttings treated with 960 ppm Ethrel - 2500 ppm IBA had 80% rooted and had roots approximately 4 cm long. Root length was not indirectly proportional to root number in this species as it was with *P. tomentosa*.

In summary, the treatment of 960 ppm Ethrel + 2500 ppm IBA in peat/perlite was most effective; however, it was only within this treatment combination that the medium appeared to have any effect.

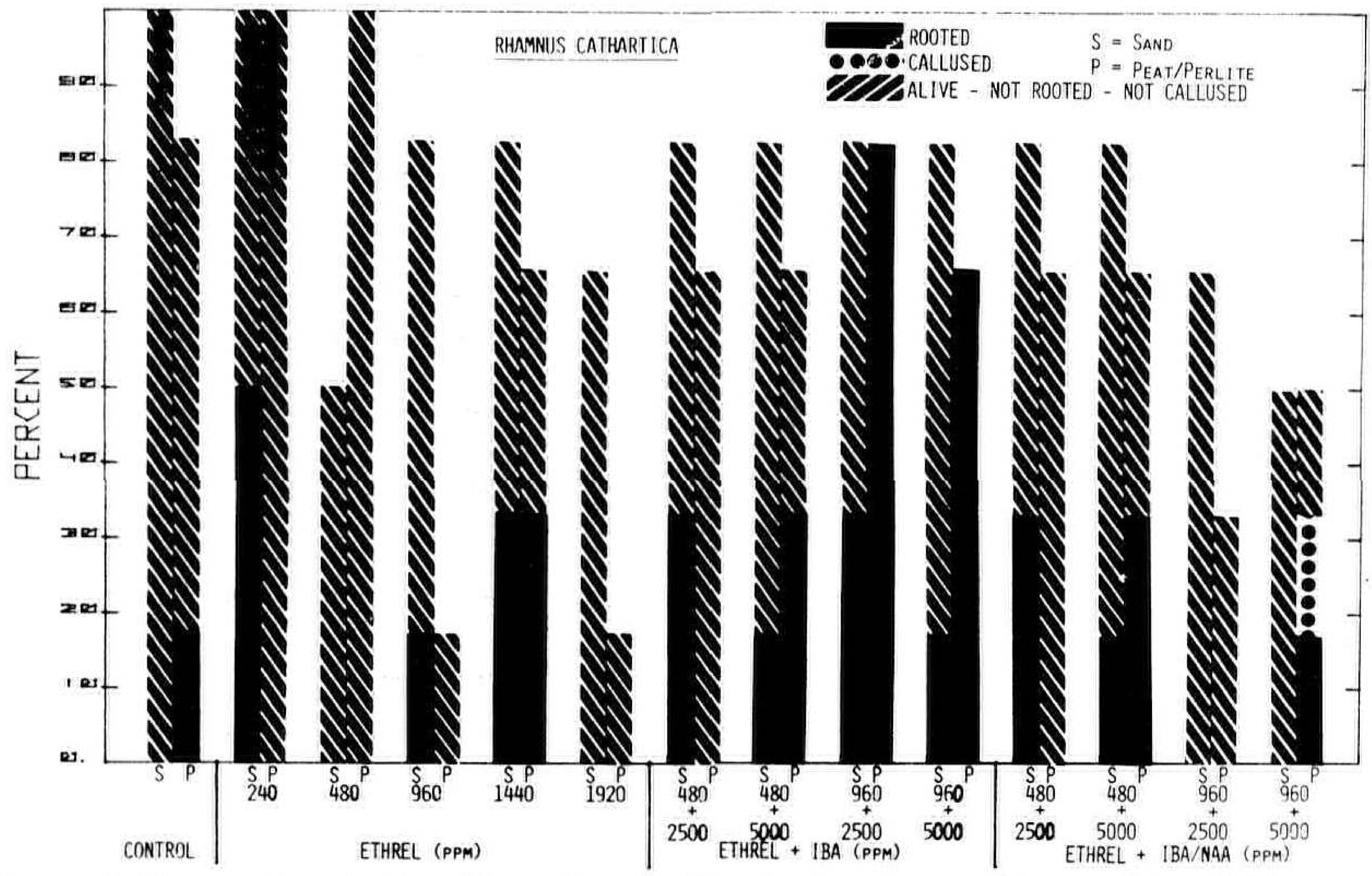

Figure 3. Percent rooted, callused and alive but not rooted or callused *Rhamnus cathartica* cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA in sand and in peat/perlite.

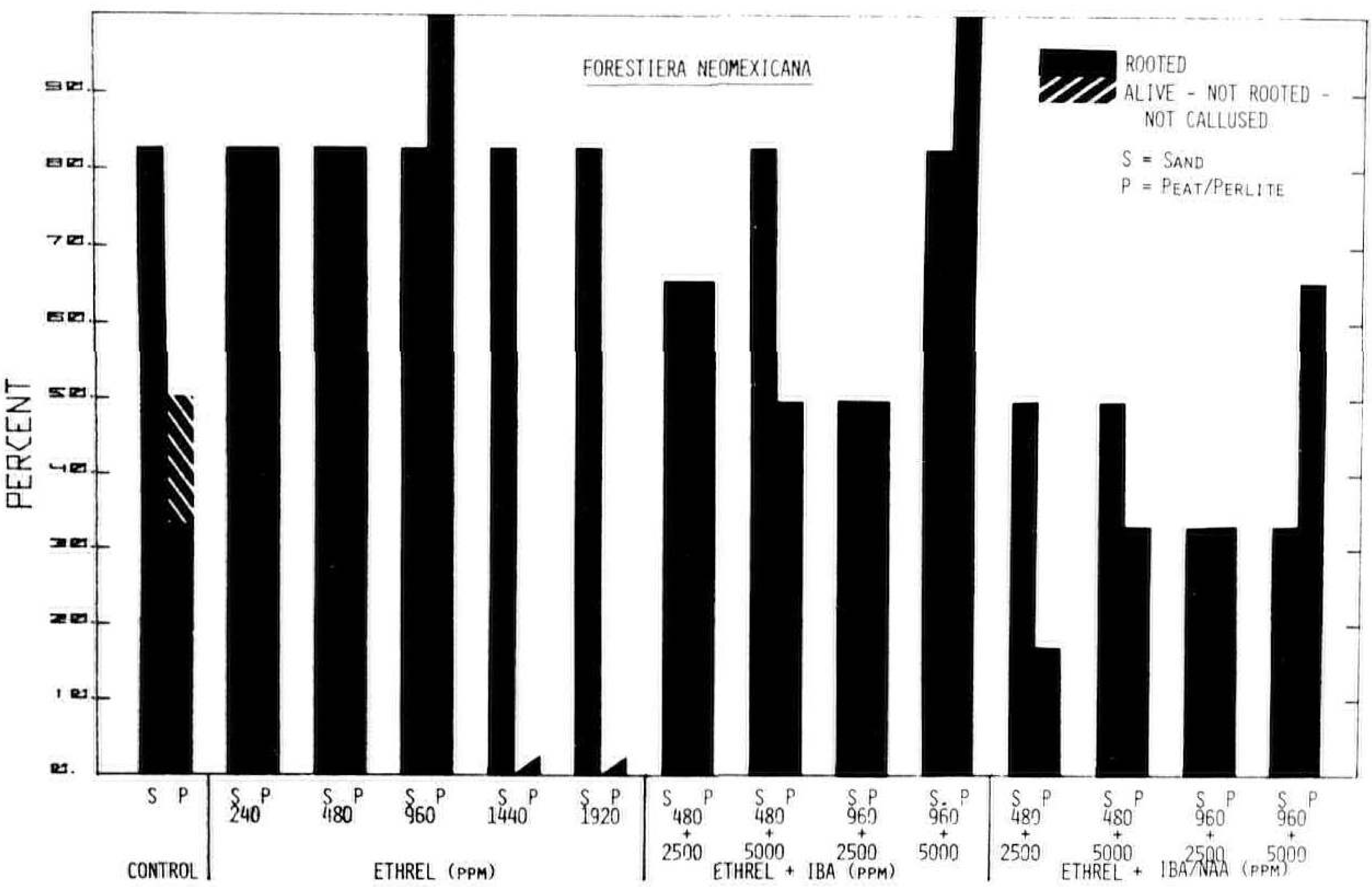

Figure 4. Percent rooted, and alive but not rooted or callused *Forestiera neomexicana* cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA in sand and in peat/perlite. Base line triangles indicate no rooting.

Forestiera neomexicana. The control rooted 80% in sand and 35% in peat/perlite. Rooting in peat/perlite increased with the addition of Ethrel up to 960 ppm (100% rooted) (Fig. 4). At higher concentrations, rooting dropped to zero in peat/perlite, but remained at 80% in sand. Ethrel + IBA was beneficial in increasing rooting only at 960 ppm Ethrel + 5000 ppm IBA. Ethrel + IBA/NAA was detrimental at all concentrations except 960 ppm Ethrel + 5000 ppm IBA/NAA. The 960 ppm Ethrel treatment appeared to be beneficial in all three of the treatment combinations.

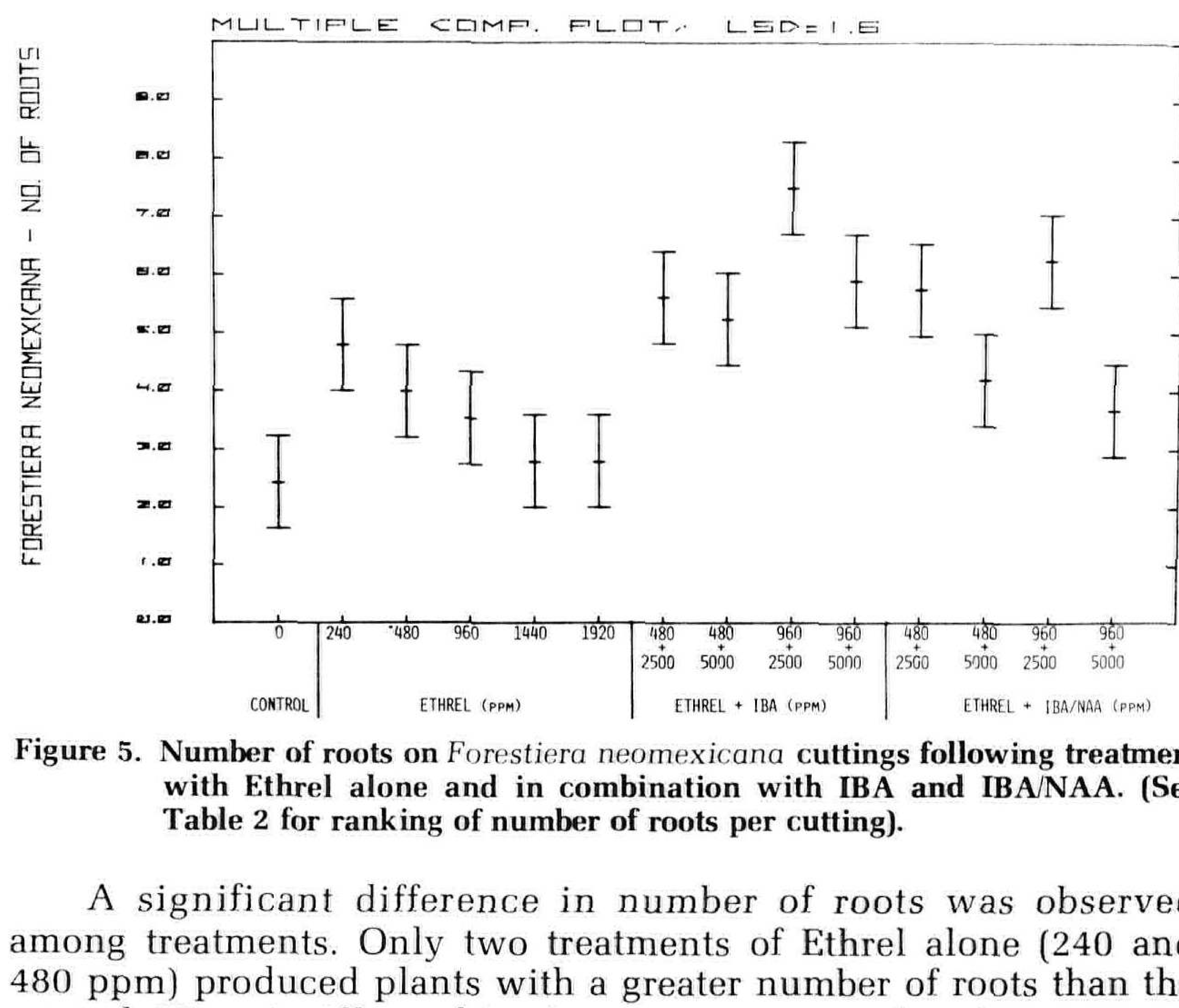

Figure 5. Number of roots on *Forestiera neomexicana* cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA. (See Table 2 for ranking of number of roots per cutting).

A significant difference in number of roots was observed among treatments. Only two treatments of Ethrel alone (240 and 480 ppm) produced plants with a greater number of roots than the control (Fig. 5). All combination treatments produced more roots than the control with the exception of 960 ppm Ethrel + 5000 ppm IBA/NAA. Ethrel at 960 ppm + 2500 IBA produced significantly more roots (〉 40 roots) than any other treatment. It, however, promoted only 50% rooting in either medium, whereas 960 ppm Ethrel + 5000 ppm IBA had 25-80 roots with 80-100% rooting. No differences in root length were observed among treatments.

In summary, 240, 480 and 960 ppm Ethrel and 960 ppm Ethrel + 5000 ppm IBA increased rooting over the control with the most beneficial response occurring in the peat/perlite medium.

Juniperus scopulorum. Significant differences in percent rooting were observed among treatments, but none of the treatments resulted in a high percentage of rooting. None of the control cuttings or those treated with Ethrel alone rooted; however, over 50% of the Ethrel-treated cuttings were callused except for the 1440 and 1920 ppm treatment (Fig. 6). Thirty-five and 50% rooting occurred in sand and peat/perlite respectively at 960 ppm Ethrel plus 2500 ppm IBA. Very little callusing occurred in this treatment combination and in most instances, the cuttings were dead if not rooted or callused. All cuttings treated with the Ethrel + IBA/NAA combination were dead with the exception of those treated with 960 ppm Ethrel + 5000 ppm IBA/NAA in which 17% rooted.

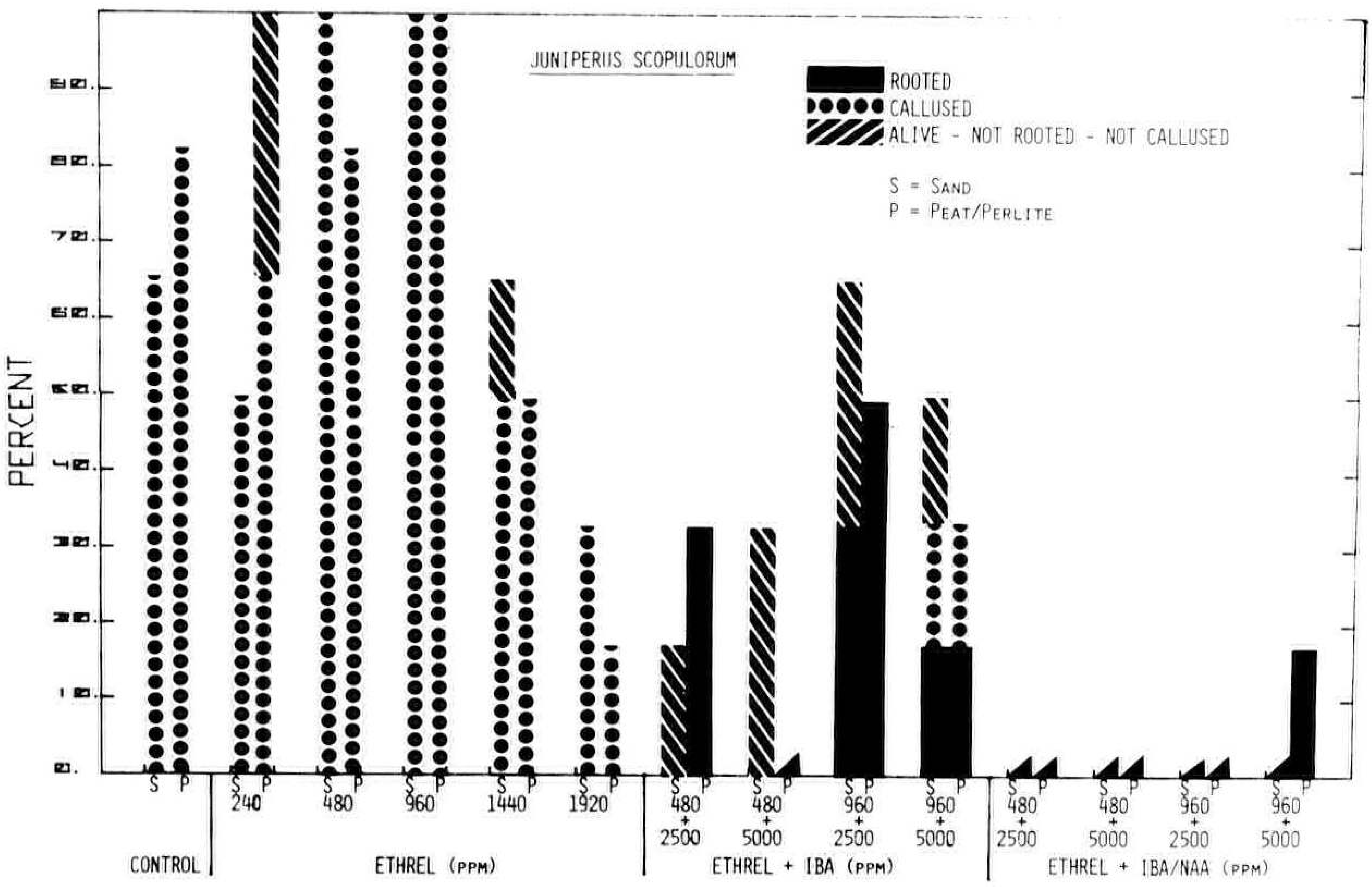

Figure. 6 Percent rooted, callused and alive but not rooted or callused *Juniperus scopulorum* cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA in sand and in peat/perlite. Base line triangles indicate no rooting.

Sufficient rooting did not occur to provide a meaningful analysis of root number or root length. In summary, Ethrel alone had no effect, 960 ppm Ethrel + 2500 ppm IBA induced 30-50% rooting, but Ethrel + IBA/NAA at all concentrations resulted in approximately 100% death of the cuttings. The medium had no specific effect.

Cotoneaster racemiflora var. soongorica. No control cuttings rooted in either sand or peat/perlite. In sand, 50% rooting occurred at 960 ppm Ethrel and 80% rooted at 1440 and 1920 ppm (Fig. 7). Little or no rooting occurred in peat/perlite in any of the treatments of Ethrel alone or in combination with IBA or IBA/NAA. Sixty-five percent rooting occurred at 480 ppm Ethrel + 5000 IBA, but rooting was much less or absent in all other treatment combinations. Ethrel + IBA/NAA treatments were detrimental to rooting. Considerable callusing did occur within all treatments, but in slightly decreased amounts with treatment combinations. No significant differences in number of roots or root length occurred between treatments.

In summary, 1440 and 1920 ppm Ethrel induced 80% of the cuttings to root in sand. Essentially, no cuttings of this species rooted in peat/perlite regardless of treatment.

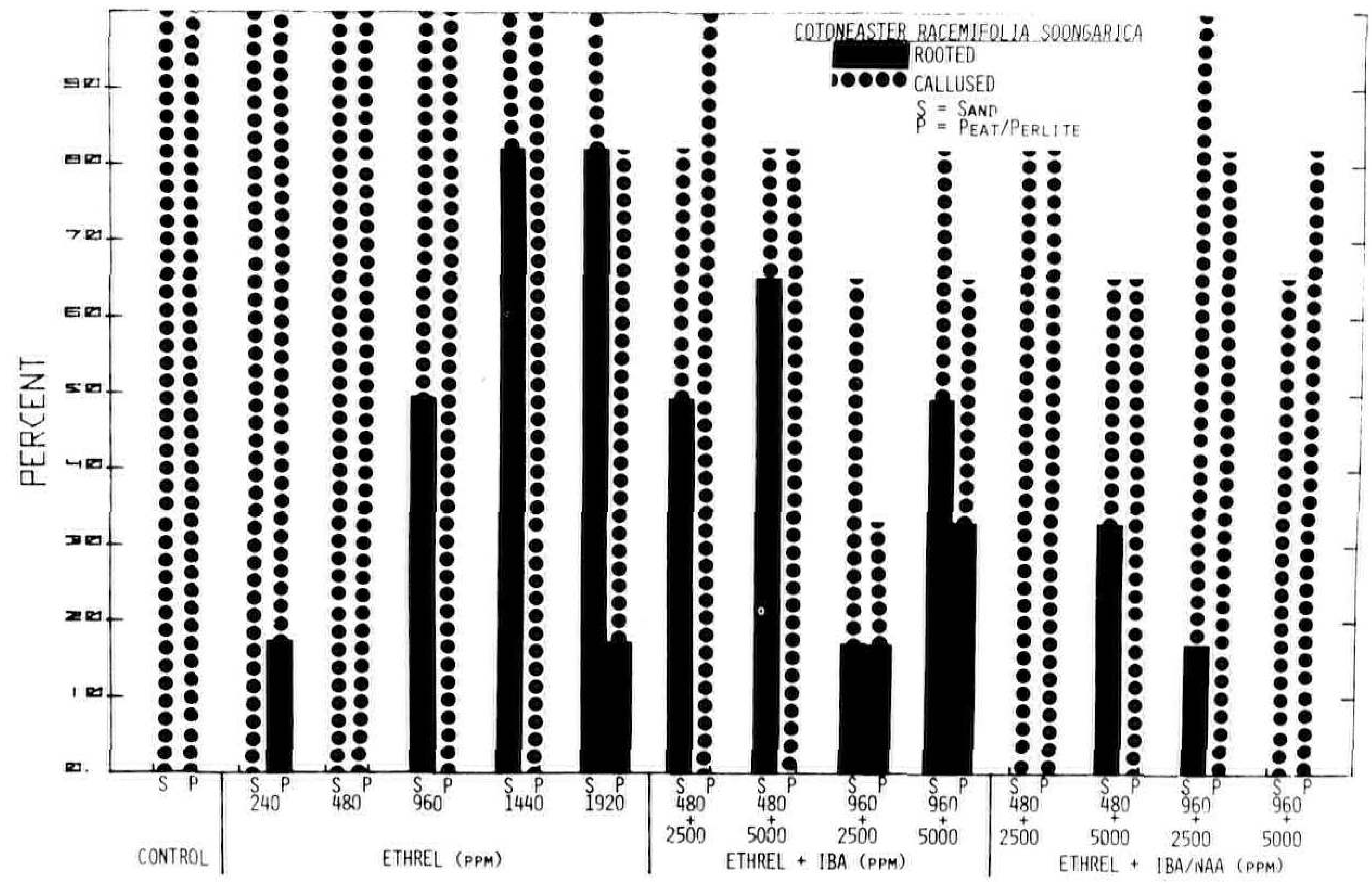

Figure 7. Percent rooted and callused *Cotoneaster racemifolora* **var.** *soongtrica* **cuttings following treatment with Ethrel alone and in combination with IBA and IBA/NAA in sand and in peat/perlite.**

DISCUSSION

The overall response to treatment was species dependent. Both *Prunus tomentosa* and *Amorpha fruticosa* var. *angustifolia* (*A. fragrans*) rooted best with 480 ppm Ethrel alone. *Forestiera neomexicana* rooted best at 240 and 960 ppm Ethrel and *Cotoneaster racemiflora* var. *soongorica* rooted best at 1440 and 1920 ppm Ethrel. *Rhamnus cathartica* required 960 ppm Ethrel + 2500 ppm IBA to obtain 80% rooting. *Juniperus scopulorum* also rooted best at this same treatment (50%). This variability among species is in agreement with Shanks (20) and Nell and Sanderson (15) who observed variations in response not only among species, but also among cultivars.

Four of the six species tested rooted best and satisfactorily with Ethrel alone. These results support the hypothesis that Ethrel may have potential as an aid in the propagation of certain species (6, 13, 17, 18). *F. neomexicana* was the only species in this investigation that showed an increase in root number with Ethrel (240 ppm) alone; however, additional increases were obtained with Ethrel combined with IBA + NAA. Root length was increased by Ethrel alone and in combination with IBA + NAA. Root length was increased by Ethrel alone and in combination with IBA + NAA. This is in contrast to the results reported by Krishnamoorthy (13).

The fact that Ethrel alone often promoted rooting and the fact that Ethrel in combination with IBA or NAA was often detrimental may indicate that Ethrel does not act directly but rather that the Ethrel-induced ethylene causes the production of endogenous hormones which, in turn, promote rooting. When exogenous hormones such as IBA and NAA were added with Ethrel, the "proper" hormone balance appeared to be altered to the extent that in most instances death of the cutting occurred. It is intriguing to think that perhaps an application of ethylene could better control this delicate endogenous hormone balance than can be accomplished by the exogenous application of specific hormones.

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CHARLIE PARKERSON: Thank you, Dr. Swanson. I'm real excited about our next speaker because we've been having problems for the past 4 or 5 years with the subject he will be discussing. The paper deals with root-rot of rhododendrons and will be presented by Dr. Harry Hoitink.

RECENT DEVELOPMENTS IN CONTROL OF RHODODENDRON ROOT ROT[1]

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Rhododendron root rot has been a serious disease in both landscape planting and nurseries for decades. Several *Phytophthora* spp. can cause this disease; however, *P. cinnamomi* is encountered most frequently. The disease typically occurs on plants in poorly-drained soils or container media. Differences in susceptibility exist among cultivars, but only a few hybrids are resistant. Most popular hybrids are susceptible (3). Moderately resistant cultivars are available, however these become infected and die after prolonged exposure to high tempera-

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