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THESIS

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Factors Affecting Leaf Scorch and Root Rot
Disease of Lilium longiflorum thunb. cv. Ace

presented by

Carol J. Bornstein

has been accepted towards fulfillment
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M.S. degree in Department of
Horticulture

Ronald L. Spangler
Major professor

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FACTORS AFFECTING LEAF SCORCH AND ROOT
ROT DISEASE OF LILIUM LONGIFLORUM THUNB. CV. ACE

By

Carol J. Bornstein

A THESIS

Submitted to
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ABSTRACT

FACTORS AFFECTING LEAF SCORCH AND ROOT ROT DISEASE OF LILIUM LONGIFLORUM THUNB. CV. ACE

By

Carol J. Bornstein

Lilies grown in perlite-amended and superphosphate-fertilized media had more scorched leaves than those grown in dicalcium phosphate/Turface. Three day/night temperature regimes indicated leaf scorch generally decreased as temperature increased.

Soil F content, highest in superphosphate/perlite medium at the lowest temperature, was positively correlated to scorch. Leaf Na and Zn levels were highest in plants grown in perlite-amended and superphosphate-fertilized media, respectively. These nutrients were positively correlated to scorch.

Lilies grown in soil-less media were severely scorched; soil-grown control plants had no scorch. Medium and leaf F content correlated positively to scorch, and soil-less media had high media F levels. The soil medium had the highest soluble salts, N, K and Ca levels. Porosity of these media correlated

positively to scorch. Root-rotting fungal infection differed significantly among media.

Fresh weights of scales, shoots, stem roots and basal plate plus roots were monitored and showed significant weight changes over time.

To Ambyr, Martha, Nancy, Patty and Sally.

And to Ned.

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I. LITERATURE REVIEW

Introduction

The Easter lily, Lilium longiflorum Thunb. is a major floricultural crop in the United States which is grown primarily as a pot plant for the Easter holidays. The extensive research that has been conducted on this crop has focused on the commercial grower's key goals, which are: (a) To time the crop for Easter, (b) to develop as many flowers as possible, and (c) to control plant height (De Hertogh, 1974). Additional investigations have focused on nutritional, physiological, insect and disease problems.

Two cultivars - 'Ace' and 'Nellie White' - comprise the bulk of Easter lilies used by the commercial industry today. The appearance of leaf scorch on 'Ace' has recently been a major concern of the industry and has stimulated renewed investigations into the cause of this problem.

Forcing Program

Commercial Easter lily cultivars require a warm-cool-warm temperature cycle for growth and development (Stuart, 1967). The forcing procedure accelerates and mimics this cycle. Field-

grown bulbs are harvested in late summer, at which time the apical meristem is vegetative (De Hertogh, 1974). Following harvest, bulbs are placed under cool, moist conditions (2°C - 10°C) for six weeks. This cold requirement can be satisfied in one of three ways: Natural cooling, precooling or controlled temperature forcing (De Hertogh and Carlson, 1969). After this requirement has been met, the bulbs are placed in a warm (16°C - 18°C) greenhouse to promote floral initiation, organogenesis, maturation and anthesis (De Hertogh, 1974). To successfully force Easter lilies, De Hertogh and Wilkins (1971) devised a three-phase schedule that is based upon the natural developmental cycle. The phases are: (1) Production - propagation and field-growing of the bulbs, (2) programming - to satisfy the cold temperature requirement, and (3) greenhouse - a follow-up phase that takes the vegetative bulb to anthesis within a certain period of time in order to meet an annually fluctuating Easter date.

During the greenhouse phase, growers must contend with a number of Easter lily problems. These include leaf scorch, diseases, insect predation, excessive plant height, flower abortion, variable maturity within the crop and undesirably low light intensity. Research indicates growers can avoid or effectively eliminate these problems by selecting a good planting medium, using proper fertilizer formulations and

rates, practicing preventive disease control, watering carefully, using long-day photoperiod treatments when necessary, and using growth regulators to control plant height.

Leaf Scorch

In the 1940's and 1950's the 'Croft' lily was the most widely used cultivar for forcing. Growers, however, experienced a great deal of leaf scorch with this lily. Stuart (1949) first reported this injury, and described scorch as a semi-circular necrosis at the leaf margin close to the tip. Initial symptoms appear during the twelfth week of forcing in the greenhouse, the "buds visible stage" on the cultivar 'Ace' (Carlson, et al., 1976).

This disorder was intensively studied and numerous factors were implicated, including low humidity, high temperature and deficient soil moisture (White, 1940), mineral deficiencies and nutrient imbalances (Seeley, 1950, 1951; Seeley and Velazquez, 1952; Haney, 1952; Stuart, 1949; Stuart, et al., 1952), low soil pH (Shanks and Link, 1959; Stuart, et al., 1952), high soluble salts (Kohl, et al., 1960), excess boron (Kohl, et al., 1960; Roberts, et al., 1951), lithium toxicity (Furuta, et al., 1973) and disease (Bald, et al., 1955, 1957).

Seeley (1950) grew 'Croft' lilies in sand to determine their response to various mineral nutrient deficiencies and the relationship of these deficiencies of leaf scorch. He found scorch was not directly caused by a deficiency of nutrients

in the solution; plants grown in complete solution had as much or more injury than those grown with deficiencies. He postulated the concentration and ratio of nutrients in the solution may have an important influence on the occurrence of scorch. In addition, fertilizer conditions in the field may influence the response of lilies to nutrient deficiency treatments and the occurrence of burn in subsequent forcing. Work by Roberts, et al. in 1951 supported Seeley's hypothesis.

Several studies have shown applications of nitrogen during forcing will decrease the incidence of scorch on 'Croft' lilies (Roberts, et al., 1952; Seeley, 1951; Seeley and Velazquez, 1952). Haney's work (1952) revealed high N fertilization effectively controlled scorch only in the presence of adequate calcium. Bald, et al. (1955) supported Haney's findings. Widmer (1957) showed the importance of the initial N content of the soil medium. Soils high in N produced minimal scorch, even without subsequent N fertilization, whereas lilies grown in low N soil had much scorch. Addition of ammonium sulfate reduced symptoms in the latter case.

A nutritional study conducted by Shanks and Link (1959) revealed the importance of relationships between soil pH, liming and fertility on scorch incidence of 'Croft' lilies. By reducing soil acidity and maintaining high N fertility, scorch was reduced. Soil applications of Ca also reduced the amount of scorch. The use of high levels of N reduced scorch in limed

soil or in low acidity soil with adequate Ca present. Low N or P levels were associated with yellowing and browning of lower leaves. These findings indicated there was no marked correlation of either scorch or the breakdown of lower leaves with the concentrations of several elements found in the leaves; i.e. leaf damage was not directly related to any one of the elements studied.

Evidence on the role of pH is contradictory. In Seeley and Velazquez' study (1952), some N fertilization treatments completely eliminated leaf burn, even though the soil pH dropped from an initial 6.6 to 4.5 - 4.9 at the end of the experiment. Stuart, et al. (1952) showed scorch was most severe in very acid soils and was largely eliminated by increasing pH with heavy Ca applications. They were not sure whether scorch was due to toxic amounts of Al or Mn in acid soil or to a deficiency of Ca or Mg, which are usually present in such soils. Applications of Mg alone, however, did not alleviate scorch symptoms and actually increased the amount of scorch in another study (Seeley and Velazquez, 1952).

Although Li toxicity has been shown to cause leaf scorch on 'Croft' lilies (Furuta, et al., 1973), contradictory evidence exists on the effect of excess B. Kohl, et al. (1960) concluded plants are relatively sensitive to B during forcing, whereas Furuta, et al. (1973) stated typical scorch symptoms did not develop when toxic levels of B were applied.

None of the reported research on 'Croft' lilies has demonstrated a conclusive causal relationship for leaf scorch. However, recommendations for control were made (Boodley, 1967; Stuart, 1952; Seeley, 1951; Shanks and Link, 1959). These included regular fertilization with N and P-containing minerals and increasing the pH of acidic soils with heavy applications of Ca. The severity of the problem, though, eventually led to replacement of 'Croft' by 'Ace' and 'Nellie White' cultivars.

In recent years, growers have experienced leaf scorch injury on 'Ace' lilies. Renewed investigations revealed a number of possible causes, some of which were implicated on 'Croft' lilies. An interaction between soil pH and phosphate fertilization has shown low pH (5.0) coupled with regular or triple superphosphate causes severe scorch, whereas at higher pH (6.5), scorch is significantly reduced. The use of di-calcium phosphate at either pH resulted in no scorch (Marousky and Woltz, 1975). Similar results were reported on gladiolus (Woltz and Marousky, 1975) when superphosphate was used.

Other studies have also implicated regular and triple superphosphate (Widmer and Wilkins, 1976; Marousky and Woltz, 1977; Carlson, et al., 1976) and perlite (Carlson, et al., 1976) as causes of lily leaf scorch. These substances all contain relatively high levels of fluorine: Superphosphate - 1.0 to 1.6% F; triple superphosphate - 1.3% F; perlite - 17 ppm F

(Widmer and Wilkins, 1976). German peat also has a high F level, 3.9 ppm (Conover and Poole, 1976). This data has led to investigations of the role of F in leaf scorch of Easter lilies and other floriculture crops in the Liliaceae family.

Applications of superphosphate, triple superphosphate and aqueous hydrofluosilicic acid to soil media produced necrotic leaf margins and tips of Freesia hybrida (Gilbertson-Ferriss and Wilkins, 1978). Fluoridated irrigation water, growing media containing F-contaminated soil amendments, and superphosphate fertilizer all significantly increased foliage F concentration and leaf tip necrosis on Chlorophytum comosum (Wilkerson and Lingamon, 1978). In the latter study, necrosis and foliage F concentration were reduced by increasing Ca and soil pH levels, and by decreasing temperature and light intensity. Leaf scorch in Chlorophytum, Dracaena and Cordyline was induced by root-absorbed F (Conover and Poole, 1974; Poole and Conover, 1973). At low pH, plants fertilized with superphosphate had leaves with more scorch and higher F content than plants grown without superphosphate. Woltz (1964; et al., 1953) had similar results with gladiolus.

In experiments on 'Ace' Easter lilies, Marousky and Woltz (1975) made direct applications of F as NaF to bulbs grown in sand. Plants with NaF had scorch closely correlated with levels of NaF. Bulbs grown without NaF had no scorch. The same pattern of scorch was observed from NaF as from superphosphate.

'Ace' lilies fertilized with superphosphate, NaF and $\text{NO}_3\text{-N}$ or $\text{NH}_4\text{-N}$ developed similar numbers of scorched leaves (Tizio and Seeley, 1976). In treatments lacking NaF, plants fertilized with $\text{NH}_4\text{-N}$ still developed some scorch, whereas those receiving $\text{NO}_3\text{-N}$ had no scorch.

In a recent study (Marousky and Woltz, 1977), soil and plant analysis showed a high positive correlation between superphosphate and leaf scorch. Soil-borne F was influenced by the source of N fertilizer and lime rate. The most severe scorch occurred on plants grown in soils that had the lowest pH and highest F concentration.

The research cited above presents definitive evidence of the harmful effects of F on many plants in the Liliaceae family. Both soil- and air-borne F can induce leaf scorch symptoms, with slight differences in the pattern of necrosis (Woltz, 1964; Fires, 1976b). Peterson (1976) described the incorporation of F into the plant from the soil: Soluble F is absorbed through the basal portion of cuttings or via roots of actively growing plants. It is then translocated in the vascular system to the leaves, where it accumulates. When toxic levels are reached, marginal burn or foliar chlorosis followed by necrosis result.

The effectiveness of maintaining high Ca levels in the soil medium in order to control leaf scorch is based upon the hypothesis (MacIntire, et al., 1942) that additive F compounds

pass into the relatively insoluble CaF form after soil incorporation. Work by Poole and Conover (1973) on Cordyline indirectly confirms this conversion. They demonstrated the amount of soluble F is influenced by pH and Ca levels of the soil; F decreased as pH increased, with Ca possibly playing a role in rendering the F insoluble. Hurd-Karrer (1950) found the addition of CaF to limed and unlimed soil resulted in no injury to collard plants, whereas addition of HF_2 to unlimed soil severely stunted the plants. Her work showed liming greatly reduced the uptake of F when applied as HF_2 and NaF . Sheldrake, et al. (1978) confirmed these results.

To control leaf scorch on 'Ace' Easter lilies, commercial growers are presently advised to adjust the soil pH to 6.0 to 6.5 using limestone or dolomitic limestone, and to replace the N portion of liquid feed with CaNO_3 (Peterson, 1976); avoid using perlite (Carlson, et al., 1976; Rathmall, 1975) and superphosphate (Rathmall, 1975; Carlson, et al., 1976; Peterson, 1976); use water which has less than 0.25ppm F (Rathmall, 1975); and avoid environments which accelerate the rate of transpiration and subsequent uptake of F (i.e. high light intensity, excessive air movement and extremely high temperatures) (Rathmall, 1975; Peterson, 1976). For growers who still wish to use perlite, Henley and Poole (1976) suggest two to three heavy leachings to remove F, plus the addition of lime to adjust the pH of the medium to 5.5 to 6.8.

Planting Medium

In recent years, commercial growers of ornamental container crops have increasingly utilized soil amendments (perlite, vermiculite, calcined clays, rice hulls, bark, peat, sawdust, etc.) and manufactured soil-less media instead of preparing their own soil mixes. Quality, cost and availability of soil components are the major factors involved in choosing a particular growing medium, along with specific requirements of the crop being grown.

Poole and Tayama (1976) reported in 1973, the average grower's costs for making one cubic yard of growing medium was \$33 (\$43/m³). This figure includes: (a) Cost of ingredients, (b) labor preparation and handling, (c) specialized equipment involved, (d) soil sterilization, and (3) cost of fertilizers and amendments. Manufactured soil-less mixes ranged in price from \$32 to \$54 per cubic yard (\$44 to \$61/m³).

The higher price of soil-less media is offset by the potential shortcomings of field soil. The latter is becoming more scarce, and container-crop growers must watch for possible contamination from herbicides, insects, weed seeds and pathogens (White, 1975). Steam sterilization, needed to control these pests, can release potentially toxic amounts of Mn, Al and other salts (White, 1975).

The choice of planting medium for Easter lily forcing is an important one due to leaf scorch injury and diseases that can severely reduce the quantity and quality of the final market product. The basic growing medium for Easter lilies should provide good drainage and aeration, yet have a high moisture holding capacity (Boodley, 1967). The initial nutrient content should be low to avoid burning the roots (Kohl, et al., 1960).

While several studies have analyzed the effects of various fertilizer treatments on the incidence of leaf scorch, few have been conducted on performance of lilies in different growing media. Boodley and Sheldrake (1963) grew 'Ace' lilies in four media and found 50% peat : 25% vermiculite : 25% perlite produced the most flowers/plant, whereas soil-grown plants had the fewest number. They concluded light weight media were equal or superior to the soil mix (9 loam : 6 sphagnum peat : 4 perlite : 2 coarse sand).

'Ace' lilies grown in media amended with rice hulls had more flower buds than those grown in soil:sand:peat, but flowering was delayed 2 - 3 days (Einert, 1972). Rice hull media was lighter in weight and had improved drainage, but moisture retention was lower, thus needed more frequent watering. Einert concluded the influence of hulls on lily growth was either due to the indirect result of improved soil aeration or the possible contribution of nutrient elements, or both.

White (1975) studied growth of 'Nellie White' lilies in various ratios of mushroom casing soil and sphagnum peat. Osmocote 14:14:14 or Peters 14:7:7 fertilizer was incorporated into the media, and no additional fertilization was made. Results indicated nearly equal parts of the two components provided the best combination of physical and chemical properties for lily production.

These studies have illustrated the value of soil-less mixes for growing Easter lilies. However, there are a number of drawbacks that should be considered by the grower before utilizing these mixes. One of the benefits claimed by manufacturers of soil-less media is their uniformity with respect to proportions of ingredients and fertility levels. Fires (1976a) examined the fertility levels of several packaged media and found variations up to 1000% between bags of the same mix. Research conducted at the Pennsylvania State Soil and Forage Testing Laboratory (Anon, 1977) indicated that in twenty commercial mixes tested, one out of five were capable of killing or injuring plants. Some mixes had excessive soluble salts, N and/or K levels. Others contained low P and/or K levels. The pH of several samples was under 5.5, which would affect the availability of various fertilizer elements.

Peat is a widely used component of soil-less media. A study of plant pathogens in peat (McCain, 1976) discovered that products labelled "no fungi", "sterilized", and/or "weed free" were in fact contaminated. Five species of Pythium were isolated from various peats, some of which were pathogenic, and Fusarium was found in all the samples tested.

Sterility of the growing medium is not always beneficial. Another study on peat (Glynn, 1972) showed tomatoes grown in Fusarium oxysporum-inoculated peats had less fungal infection as the previous cultivation period of the media increased. This effect may have been due to an increase in competitive microflora population with successive cropping.

Work by Hoitnik, et al. (1975, 1977a, 1977b) on composted hardwood bark has shown this medium to be superior to peat-sand and uncomposted bark media for growing ornamentals that are susceptible to root rot diseases. Leachates from fresh bark composts lysed Phytophthora cinnamoni zoospores and cysts, and sporangium production was reduced (1977a). Since leachates from two-year-old composted bark lacked these inhibitors, the authors hypothesized that its suppressive effect was due to chemical and biological rather than physical factors. The absence of root diseases on plants produced in bark compost was also attributed to antagonistic microorganisms in the bark (1977b). Control of Fusarium in composted bark was equal to

control in sterilized peat after two soil drenches with Benlate (1977b). The composting process is also valuable because it destroys phytotoxins contained in the bark.

Bolton (1977) studied disease development in several growing media. Results showed that in soil-less media, both root rot disease severity on geranium cuttings and persistence of Pythium splendens were high when compared to unsterilized soil:sand:peat. This was due to a lack of antagonistic and competitive organisms in the soil-less mixtures.

Soil reaction can also affect the microbial population. Marshall and Alexander (1960) found in acidic soils there was little or no inhibition of Fusarium by other microorganisms. In higher pH soils, inhibition was due to competition for available N. By adding inorganic N, this inhibition was overcome. The authors suggested incorporating organic matter low in N to sterile soils so that bacteria can out-compete Fusarium.

Easter Lily Root Rot Disease Complex

Easter lilies are susceptible to several diseases, caused by fungi, bacteria and viruses. Forsberg (1975) and Wescott (1971) have published lists of lily diseases and their respective causal agents. The most troublesome diseases for commercial growers are the root, bulb and stem rots. A complex

of fungi and bacteria are responsible, consisting of Fusarium oxysporum Schlecht f. lilii Imle, Cylindrocarpon radicola Wollenw., Pythium splendens Braun, Pythium ultimum Trow, Rhizoctonia solani Kuehn, Phytophthora parasitica, Phytophthora cactorum, and Pseudomonas spp. (Raabe and Hurlimann, 1970; Wescott, 1971; Forsberg, 1975; Bald, et al., 1973). Three species of mites have also been implicated: Rhizoglyphus echinopus Fumouze and Robin (Baker and Wharton, 1952), R. hyacinthi Bdv. (Latta, 1939), and R. robini (Lindquist, 1976).

Pathogenicity and virulence of these causal organisms have been investigated (Baker, 1957; Bald and Solberg, 1960; Bald, et al., 1969, 1971, 1973; Raabe, 1975). Interactions between microorganisms were observed and found to be highly important. Raabe (1975) found that 'Georgia' and 'Harson' lily roots infected with necrotic flecks virus complex (Brierly and Smith, 1944) were more severely damaged by Pythium splendens than roots without virus symptoms. Bald, et al. (1960, 1969, 1973) discovered a number of antagonistic and synergistic interactions among lily pathogens. Certain isolates of Cylindrocarpon, barely capable of tissue invasion, prevented Pseudomonas from infecting bulb scales (1960, 1969). Mild or severe variants of Fusarium, when combined with Pseudomonas, caused very severe rotting (1960, 1969, 1973). Trichoderma, a fairly ubiquitous saprophyte, can invade dead tissues and compete with one or more lily pathogen in lesions (1969).

One source of these pathogens is field soil. When lily bulbs are harvested from the field, some soil usually remains on the scales and roots. The pathogens may have already invaded the bulbs. In order to eradicate these organisms, growers dip the bulbs in fungicides prior to planting. Fusarium, Cylindrocarpon and Rhizoctonia are all ubiquitous parasites, and necessitate sterilization of any soil- or peat-containing mixture.

In addition to bulb treatments, growers should follow rigid sanitation measures to prevent development of rot diseases. Reliance upon fungicides has been heavy. Raabe and Hurlimann (1970) found a combination of soil drench and bulb dip provided better control than either alone. Benlate was effective against Rhizoctonia and Fusarium, whereas Dexon and Terrazole (Truban) controlled Pythium. In 1973 they reported monthly soil drenches gave better control than pre-plant treatments alone.

During shipping from field grower to greenhouse forcer, bulbs are kept cool, but growth and development may continue. This activity produces heat, and temperatures may rise inside the container to levels favorable to pathogenic fungi on or in the bulbs (Bald, et al., 1973). If so, dipping the bulbs upon arrival and prior to planting may be too late. Bald, et al. (1973) dipped bulbs in Benlate prior to shipping and found this procedure to be worthwhile. Resistance to Benlate, however, has been observed in Penicillium corymbiferum, which

causes a storage rot of lilies (Duineveld and Beijersbergen, 1975). In 1975, some cases were also noted where Benlate did not effectively control Fusarium oxysporum on hyacinth and gladiolus, members of the Liliaceae family.

The control of bulb mites is an important aspect of good sanitation. Lindquist (1976) found that the amount of root rot in untreated lily plants was essentially the same as in fungicide-treated plants. He suggested bulb mites may have been damaging the roots and lower stems so extensively that the rate and frequency of the fungicide applications was incapable of preventing root rot. By applying both fungicide and miticide, less rot occurred, indicating that mite control can improve root rot control and the performance of fungicides.

Porosity

The importance of planting media to successful Easter lily production has been noted. One of the main considerations in selecting the proper medium is porosity, as lilies require good drainage and aeration, coupled with high moisture holding capacity (De Hertogh, et al., 1977; Boodley, 1967). The ideal medium satisfies these contradictory needs by holding as much moisture as possible without reducing aeration.



Several investigations have pointed out the moisture holding capacity of container media is quite different from that of field soils (Bunt, 1961; Hendrickson and Veihmeyer, 1941; Joiner and Conover, 1965; Matkin, et al., 1969). Containers have a limited depth; a boundary exists at the bottom, in contrast to a continual soil column in the field. This boundary constitutes a barrier to free drainage.

Container size and depth affect the porosity of the medium (White and Mastalerz, 1966; Hendrickson and Veihmeyer, 1941; Green and Adams, 1977; Spomer, 1976; Hanan and Langhans, 1963). Due to this limited depth, soils which provide adequate aeration in the field may not necessarily do so when placed in containers. This inadequacy is partially explained by a loss of natural porosity after digging and compaction in the container (Wildon and O'Rourke, 1964). Compaction is often accompanied by reduced water holding capacity, drainage, aeration, water infiltration rate and possibly root penetration (Poole, et al., 1968). For these reasons, numerous organic and inorganic amendments have either been added to or substituted for field soils in order to increase the number of large pores and improve drainage and aeration (Mastalerz, 1977).

There is considerable literature on the physical and chemical properties of various media components (Self, 1976; Koths, 1976; Self, et al., 1967; Waters, et al., 1970; Wildon

and O'Rourke, 1964; Cappaert, et al., 1974; de Boodt and Verdonck, 1972; Goh and Haynes, 1977; Poole and Waters, 1972; Matkin, 1968).

A satisfactory planting medium for container-grown crops should have 10-25% air space after drainage and 35-50% water holding capacity by volume (Conover, 1967; Self, 1976). According to Matkin (1968), lilies require 5-10% air space after drainage for adequate root growth. It is therefore important that the chosen medium's porosity be determined. Buscher and van Doren (1973) and Gessert (1976) outline simple measurement procedures.

Particle size of the medium is extremely important in container production. The larger and more uniform the particles, the greater the effect of depth on water removal and O_2 supply (Hanan and Langhans, 1963). The smaller the particle size, the greater the depth necessary to achieve the minimum O_2 supply of the particular plant (Hanan and Langhans, 1963). As Paul and Lee (1976) noted, it is possible that plants grown in two different media having the same porosity will respond differently because the distribution of air-filled pores and the fineness of the pores may differ.

The addition of perlite, rice hulls, vermiculite, calcined clays, sphagnum peat or bark will improve the porosity of a soil-based medium (Matkin, 1968; Mastalerz, 1977; Koths, 1976; Self, et al., 1967). Again, particle size of the amendment

is a critical factor. If fine bark, peat, sand or vermiculite are used, aeration will decrease (Self, 1976; Mastalerz, 1977). Another important consideration is decomposition of the organic amendments (peat, bark, sawdust, wood shavings) which causes shrinkage of the medium. This shrinkage reduces the air spaces, resulting in decreased aeration and an increase in water holding capacity (Self, 1976).

Porosity of the Easter lily medium is also important in relation to the root rot disease complex. Several investigators have studied the effect of O_2 - CO_2 levels in the rhizosphere on fungal growth and disease development in plants (Bergmann, 1959; Papavizas and Davey, 1961, 1962; Stolzy, et al., 1966; Klotz, et al., 1965, 1968; Curtis and Zentmeyer, 1949; Newcombe, 1960; Raney, 1965; Wiersum, 1977). Bergmann (1959) stated that low O_2 or accumulation of CO_2 or both may affect the activity of soil microorganisms and thus cause changes in the mineral nutrient supply. Grable (1966), however, claimed that gaseous transfer through air spaces within the plant may make it independent of soil aeration status if nutrients and water supply are adequate. These air spaces may become saturated with water, requiring O_2 levels above 21% for normal growth to occur.

Transpiration by plants causes water to flow from microorganisms as well as from soil particles (Raney, 1965). The first change that occurs when soils are drained is emptying

of the large pores. Raney postulated that discontinuous moisture changes affect microorganisms well before an appreciable change in gross moisture content of the soil occurs.

The moisture content of the soil directly affects the growth of fungi. Rhizoctonia develops best under moderate moisture conditions, whereas Pythium and Phytophthora prefer very wet soils (Baker, 1957). Papavizas and Davey (1961) found saprophytic activity of Rhizoctonia was higher when soil moisture was maintained at 20-50% of its moisture holding capacity than at 60-90%. The former range is quite similar to the suggested range (Conover, 1967; Self, 1976) for growing container crops. Therefore Rhizoctonia can be a problem even in a well-drained medium.

Papavizas and Davey (1962) later found that Rhizoctonia's saprophytic activity was inhibited by 10-20% CO₂. Degree of inhibition depended upon CO₂ concentration, type of soil and inoculum potential. This decreased activity could not be attributed to O₂ deficiency. The authors also discovered that the pathogenic phase of the fungus was more sensitive to CO₂ than its active saprophytic phase.

Production of Fusarium oxysporum f. cubense chlamydospores is inhibited by CO₂ and soil flooding (Newcombe, 1960). These factors initially increase conidial production, but a colonizable substrate must be present for fungal survival since

conidia are short-lived in soil. Long-term survival of Fusarium is dependent upon chlamydospore production (Newcombe, 1960).

In their studies of bean root rot, Miller and Burke (1965, 1977) found plants grown in Fusarium solani f. sp. phaseoli infested soil were more severely damaged by the pathogen when subjected to short periods of O_2 deprivation than plants grown in well-aerated soil. Root rot, which is aggravated by low oxygen diffusion rates (ODR), is the principal cause of yield reduction and plant stunting that result from temporary excessive wetting of soil in Fusarium-infested fields (Miller and Burke, 1977). Even though O_2 may be adequate in air-filled pores, it can be deficient at the root surface if the ODR is low.

Klotz, et al. (1965) studied the distribution of root-rotting fungi in soils and concluded the O_2 concentration is an important factor. Their work also supported previous reports that Phytophthora spp. thrive under low O_2 levels.

In a study on Phytophthora root rot of citrus, Stolzy, et al. (1966) found root decay was caused mainly by inadequate O_2 . Infection of citrus roots by Phytophthora is a function of zoospore production and ability to reach the roots. In fine-textured soils, root damage was attributed to low O_2 , because the small pores blocked zoospore motility. In coarse-textured soils, injury was due to the fungus; large pores filled with water allowed for rapid zoospore transport.

Klotz, et al. (1968) also investigated Phytophthora root rot of avocado seedlings by varying watering regimes and O_2 levels. Results indicated at low O_2 levels, all watering treatments had much root rot whether inoculated with the fungus or not. At high O_2 concentrations, the effect of Phytophthora on root rot damage was more apparent. These results contradict earlier work by Curtis and Zentmeyer (1949), who reported that fungal attack of avocado seedlings was most rapid at the highest O_2 level. They performed their study in nutrient solutions, however, as opposed to soil.

II. OBJECTIVES

Commercial bulb production is a major portion of the floriculture industry. The Easter lily and other bulbous species grown for holidays and particular seasons require rigid forcing procedures. To improve bulb production and forcing, research has focused on the cold requirement needed for bulbing and floral development. Photoperiod, an important factor in Easter lily production, has also been studied extensively.

Leaf scorch and root rot diseases have been major problems for Easter lily growers. Although several factors have been implicated as causal agents of leaf scorch, results are incomplete. Costly, time-consuming and sometimes ineffective use of fungicides has been the method for controlling the root rot diseases.

The trend toward increased usage of manufactured soil-less media has created problems for the commercial floriculturist. Researchers have suggested components of these media contribute to leaf scorch of Easter lilies. The major objective of this study was to investigate the role of fluorine, found in some soil amendments and fertilizers, on leaf scorch of Lilium longiflorum Thunb. cv. Ace. The combined

effect of growing medium, temperature and fertilizer on the amount of scorch was analyzed.

Previous work by Laemmlen (unpublished data, 1976) indicated a significant difference between several soil-less media on lily growth and root rot development. A second objective was to further study the effects of these media on fungal diseases and growth of 'Ace' Easter lilies.

III. MATERIALS AND METHODS

Bulbs of Lilium longiflorum Thunb. cv. Ace were received from United Bulb Company (Mt. Clemens, Michigan) in late October 1976 and 1977. Upon arrival, the bulbs were precooled at 5°C for six weeks in moist peat.

All growing media were analyzed before and after each experiment by the Michigan State University Soil Testing Lab in East Lansing, Michigan and by Dr. Frank Marousky at the USDA Southern Region Federal Research Service in Bradenton, Florida. Both laboratories used the saturation paste extract method. Soil flouride (F) content was measured only at the Florida lab. Leaf tissue analysis was performed by the Michigan State University Plant Analysis Lab, and leaf F content was measured by Dr. Marousky. Nitrogen content was determined by the Kjeldahl method, K by flame photometer, F by the procedure of Woltz and Marousky (1975) and all other elements by a direct reading spectrograph.

Effect of Media, Fertilizer and Temperature on Leaf Scorch

On December 9, 1977, 240 20.3 - 22.9cm bulbs were planted in 15cm clay pots. A 2.5cm layer of gravel covered the bottom of each pot. Bulbs were planted nose-up. Prior to planting, bulbs were dipped in a benomyl-diazoben mixture for 30 minutes.

The bulbs were planted in one of the following media/fertilizer combinations: (a) 1:1:1 soil:peat:Turface (BASF Wyandotte Corporation; Wyandotte, Michigan) plus dicalcium phosphate (0-41-0 with 23% Ca), (b) 1:1:1 soil:peat:Turface plus superphosphate (0-20-0 with 20% Ca), (c) 1:1:1 soil:peat:perlite plus dicalcium phosphate, or (d) 1:1:1 soil:peat:perlite plus superphosphate. Dicalcium phosphate was incorporated at the rate of 1.5kg/m^3 , and superphosphate at 3kg/m^3 .

During greenhouse stages I and II (DeHertogh, 1974), the bulbs were grown at 17°C night/20°C day temperature. The greenhouse had no temperature modification system other than automatic vents controlled by thermostats and cooling fans, thus fluctuations occurred. One application of Osmocote 14-14-14 (Sierra Chemical Company; Newark, California) at 9g/pot was made as a top dress on December 28, 1977. Weekly fertilization with 120ppm Peters 20-20-20 (Allentown, Pennsylvania) was provided for the duration of the experiment. At

four-week intervals, the pots were drenched with diazobenzopentachloronitrobenzene. Plants were hand-watered as needed.

On February 27, 1978, the "buds visible stage", the plants were separated into the following greenhouse temperature regimes: (a) 13°C NT/16°C DT, (b) 17°C NT/20°C DT, (c) 20°C NT/23°C DT. All four media/fertilizer treatments were represented at each temperature. The experimental design was a split plot in a completely randomized arrangement, with temperature as the main plot and media/fertilizer as the sub-plot. There were four blocks within each main plot and five observations per block.

Due to the three temperature regimes, flowering occurred over a several-week period, at which time the experiment was terminated. The following data were recorded: Number and type of flower buds, height to pedicel and total plant height measured from the soil line, total leaf count, number of scorched leaves/plant, and scorch rating. For the latter measurement, 0 designated no scorch, 1 = slight, 2 = moderate and 3 = heavy scorch. In determining scorched leaves, only those with marginal necrosis were counted.

For leaf tissue analysis, thirty leaves were removed from the lower-middle zone of each plant, dried in a forced air drying oven at 80°C, and ground in a Wiley mill.

Effect of Soil-less Media on Lily Growth and Root Rot Disease Development

On December 8, 1976, 288 16.5 - 17.8cm bulbs were planted as outlined above. Plants did not receive a pre-plant fungicidal dip. The bulbs were planted in one of the following media: (a) 1:1:1:1 soil:peat:sand:Turface, (b) Ball Growing Mix (Ball Seed Company; West Chicago, Illinois), (c) Jiffy-Mix (Jiffy Products of America; West Chicago, Illinois), (d) Jiffy-Mix Plus, (e) Metro-Mix 200 (W.R. Grace and Company; Cambridge, Massachusetts), (f) Metro-Mix 300, (g) Pro-Mix BX (Premier Brands, Inc.; New York, New York), or (h) Redi-Earth (W.R. Grace and Company). Pots were placed in an 18.3°C greenhouse in a randomized complete block arrangement. Due to the greenhouse's environmental control system, temperatures fluctuated throughout the experiment. Fluctuations ranged from 16.5°C to 29°C. Osmocote 14-14-14 at 9g/pot was applied as a top dress on January 6, 1977. Plants were hand-watered as needed.

Samples consisting of two pots/block/treatment (total = 48 bulbs) were collected at 30-day intervals over a four-month period. The following data were collected: Fresh weights of scales, shoots, stem roots and basal plate plus roots; shoot length; leaf number; percent live roots; meristem diameter (first month only); bud count; and disease rating. The rating scale (1 - 10) reflected the amount of lesions present on the roots, with 1 signifying 0-10% infection, 2 = 11-20%, etc.

Only dying roots and live roots with lesions were considered. Plant segments were cultured on various media at each sampling date to determine what fungi were present.

In 1976, the final sampling was conducted on March 29. In addition to the above parameters, yellow and scorched leaves were counted and root production and root rot were evaluated. A 16-square grid consisting of 12mm squares was pressed against the root ball at two locations. For root production, the number of squares containing visible roots were recorded. For root rot, those squares with dead and/or rotted roots were recorded. Scorched leaves were collected, dried and analyzed for F content only by Dr. Marousky.

The experiment was repeated with the following modifications. Lilies were potted up and placed in a 17°C NT/20°C DT greenhouse on December 6, 1977. Osmocote was applied on December 28. At the end of the experiment, leaf samples were collected from the top and bottom halves of the shoot, and analyzed for complete nutrient content. All other aspects of the trial were similar to the 1976-77 experiment.

Porosity Determination of Soil-less Media

The porosity of the seven soil-less media and the soil control were measured. The procedure of Gessert (1978) was used, with slight modifications. Eight 15cm plastic pots, with corked drainage holes, were filled with the dry media to the

inner rim. The media were slowly wetted, using warm water, until saturated. The volume added to each pot represented the total porosity of the medium.

The pots were then set in trays and the corks removed. Then the pots were covered with aluminum foil and the trays with plastic sheeting to reduce evaporation from the media surfaces and drained water, respectively. The pots were allowed to drain for twelve hours, and the collected water was measured. This volume was equivalent to the air space in the drained media. The total volume of the pot was also determined. By using the following formula, the percent air space (percent of the total volume of the drained medium that is occupied by air) of each medium was calculated:

$$\text{Percent Air Space} = \frac{\text{volume of drained water}}{\text{total volume of pot}} \times 100$$

The procedure was replicated four times.

Measurement of Fungal Growth in Soil-less Media

Phytophthora, Fusarium, Cylindrocarpon and Rhizoctonia isolated from Lilium longiflorum Thunb. cv. 'Ace' bulbs were used. A Pythium species and a second Phytophthora isolate from lily were supplied by Dr. Robert Raabe (Department of Plant Pathology, University of California, Berkeley). Due to contamination problems with the Pythium and Phytophthora species, these fungi were eliminated from the experiment.

To increase the inoculum supply, flasks containing barley grain were inoculated with the fungi, according to the procedure outlined by Dr. Charles Schneider (personal communication, 1977). 1500mls of barley were soaked overnight in 860mls of distilled water. The excess water was removed, and the barley was placed in 250ml flasks and autoclaved for 45 minutes. The next day the flasks were re-autoclaved for 90 minutes, then inoculated with fungus-permeated agar pieces. Flasks were plugged with aluminum foil-covered sterile cotton and incubated in a dark location for 30 days at room temperature.

The seven soil-less media and one soil control were placed in clay pots, saturated with sterile distilled water and allowed to drain 24 hours to reach field capacity. The media were not watered again. 50mls of each medium were placed in individual sterile glass petri plates with covers. One fungus propagule (= one barley grain) was centered on top of each medium. Two sets of plates were prepared, one for each temperature. A 5°C and a 17°C incubator were used; these temperatures correspond to the cold requirement and greenhouse forcing temperatures, respectively, used for Easter lilies. In addition, a non-inoculated petri plate of each medium was incubated as a control. To serve as indicators of fungal growth, each fungus was plated onto potato dextrose agar and incubated at the two temperatures. In sum, there were 35 plates per incubator (3 fungi x 9 media + 8 controls).

IV. RESULTS AND DISCUSSION

Effect of Media, Fertilizer and Temperature on Leaf Scorch

Initial symptoms of scorch appeared in late January 1978 on a few plants. As this was quite early (Carlson, et al., 1976), the possibility of fungal infection was investigated, with negative results.

Temperature and fertilizer/amendment influenced the amount of leaf scorch. Plants grown in the superphosphate/perlite medium at 16°C DT had the greatest number of scorched leaves (Figure 1), whereas those in dicalcium phosphate/Turfacer at the same temperature had the least scorch. In general, the amount of scorch decreased as temperature increased. Regardless of soil amendment, plants fertilized with superphosphate had more scorched leaves and greater scorch per leaf than those receiving dicalcium phosphate (Figure 2). These findings on superphosphate and perlite concur with previous studies (Widmer and Wilkins, 1976; Marousky and Woltz, 1977; Carlson, et al., 1976; Widmer and Woltz, 1976).

Leaf tissue nutrient analysis revealed the temperature and fertilizer/amendment treatments affected the concentration of several elements, and the interaction was significant at or above the 5% level for N, P, Ca, Mg, Mn, Fe, B and Al (Table A8).

Figure 1. Effect of temperature and fertilizer/amendment on scorch count of 'Ace' Easter lily, 1978.

Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite

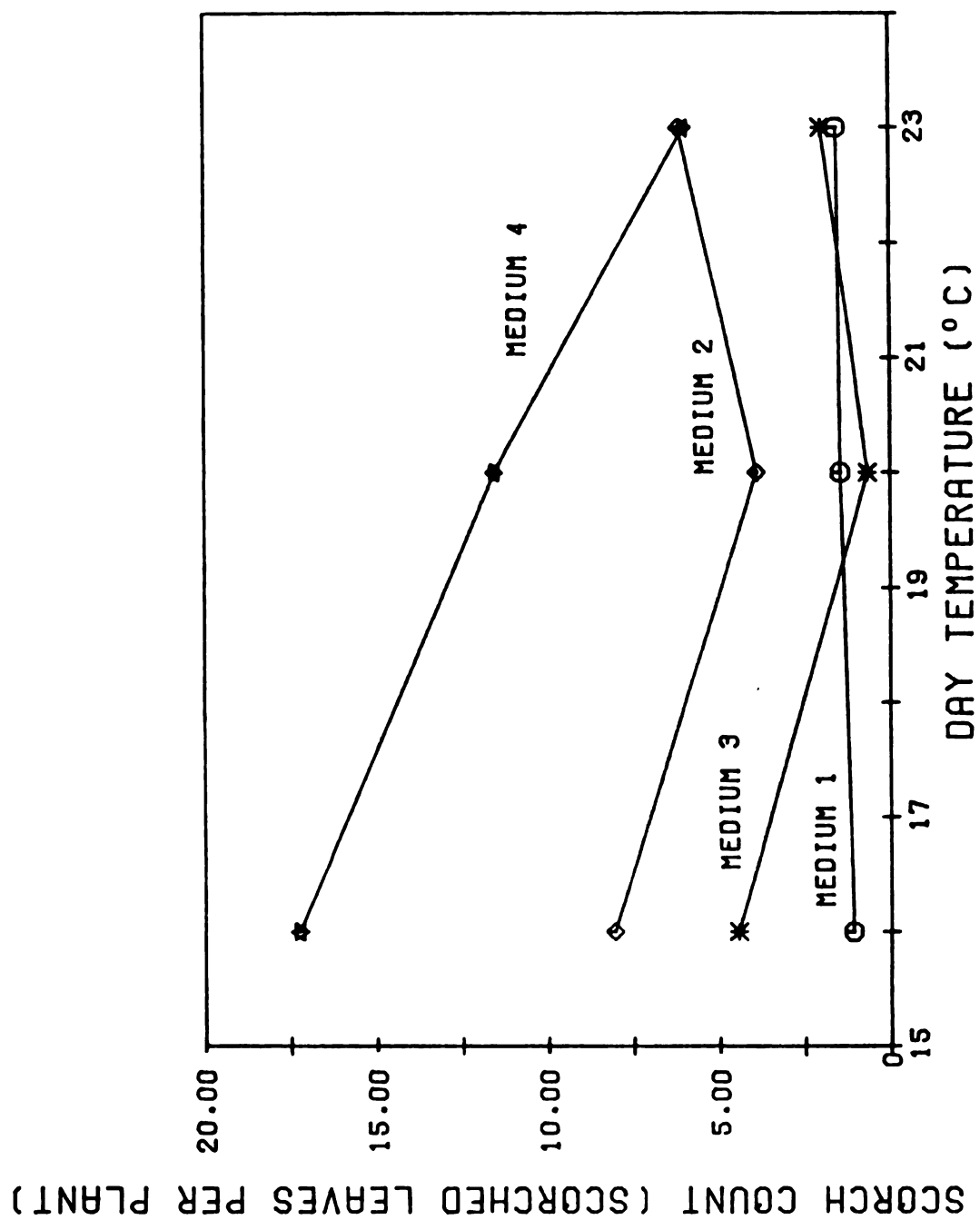


FIGURE 1

Figure 2. Effect of temperature and fertilizer/amendment on scorch rating of 'Ace' Easter lily, 1978.

Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite

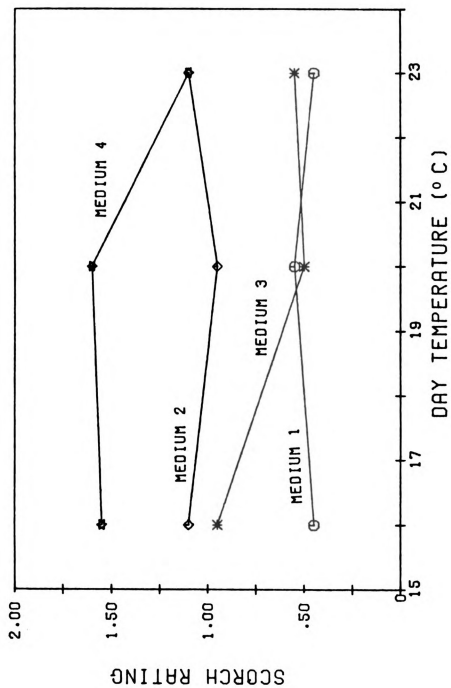


FIGURE 2

Fluoride content was significant only between temperature treatments, and levels were not high enough to cause severe scorch. However, there was a high linear correlation between scorch and Na and Zn concentrations (Table 1), which has not been mentioned in past scorch investigations. Shanks and Link (1959) found a high negative correlation between Na content and scorch on 'Croft' lilies. Plants grown in media fertilized with superphosphate had higher Zn levels than those receiving dicalcium phosphate, and perlite-grown plants had higher Na levels than Turface-grown plants (Table 2). There was also a high correlation between fertilizer/amendment treatment and scorch (Table 1).

Fluoride levels in the soil media were low, but differences between treatments did exist (Table 3). Several nutrient levels, soluble salts and pH significantly differed between temperatures and/or fertilizer/amendments (Table 3); however, only F content had a high positive correlation to scorch count and rating (Table 4). The lower the temperature, the higher the F level in the soil (Table 3). F content was also higher in soils amended with perlite and in soils fertilized with superphosphate. Contrary to a report by Marousky and Woltz (1975), use of dicalcium phosphate did result in some scorched leaves, as opposed to no scorched leaves (Figure 1).

Table 1 : Linear correlation coefficients for scorch count and rating in relation to leaf analysis, 'Ace' Easter lily scorch experiment 1978.

INDEPENDENT VARIABLE	DEPENDENT VARIABLE			
	Scorch Count		Scorch Rating	
	F-test	r	F-test	r
Replicate	0.29 NS	0.08	0.01 NS ^x	-0.01
Fertilizer/Amendment	19.87 ****	0.55	22.10 ****	0.57
Temperature	3.94 **	-0.28	1.59 NS	-0.18
N (%)	0.34 NS	-0.08	0.06 NS	0.04
K (%)	0.52 NS	0.11	0.30 NS	-0.08
P (%)	0.29 NS	-0.08	0.23 NS	-0.07
Na (ppm)	8.99 ***	0.40	7.11 ***	0.37
Ca (%)	0.001 NS	-0.005	0.32 NS	0.08
Mg (%)	0.22 NS	-0.07	0.64 NS	-0.12
Mn (ppm)	1.29 NS	-0.16	0.21 NS	-0.07
Fe (ppm)	1.69 NS	0.19	0.75 NS	0.13
Cu (ppm)	2.72 *	0.24	2.16 NS	0.21
B (ppm)	2.82 *	0.24	1.82 NS	0.20
Zn (ppm)	5.03 **	0.31	5.66 **	0.33
Al (ppm)	1.37 NS	0.17	0.24 NS	0.07
F (ppm)	0.46 NS	0.10	1.70 NS	0.19
All	3.57 ****	-	2.95 ***	-

^x F-test * significant at 10% level.
 ** significant at 5% level.
 *** significant at 1% level.
 **** significant at 0.1% level.
 NS not significant

Table 2 : Effects of temperature and fertilizer/amendment on nutrient content of 'Ace' Easter lily leaves, scorch experiment, 1978.^z

Temperature (T) (°C)	Fertilizer /Amendment (F/A)	N (%)	K (%)	P (%)	Na (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Zn (ppm)	Al (ppm)	F (ppm)
13°NT/16°DT	Dicalcium phosphate/Turf	3.6 ^y	4.0 ^x	0.64 ^w	1584 ^v	1.04 ^u	0.73 ^t	121 ^s	166 ^y	8.0 ^r	35.2 ^q	69 ^p	130 ^o	5.6 ⁿ
13°NT/16°DT	Superphosphate/Turf	4.0	4.0	0.71	1743	1.49	0.82	122	167	10.6	37.0	84	138	5.6
13°NT/16°DT	Dicalcium phosphate/Perlite	3.6	4.2	0.63	2047	1.59	0.74	136	190	11.0	32.9	81	184	6.2
13°NT/16°DT	Superphosphate/Perlite	3.6	4.0	0.57	1885	1.61	0.66	114	208	10.8	44.7	72	204	5.6
17°NT/20°DT	Dicalcium phosphate/Turf	3.7	4.2	0.67	1588	1.64	0.78	138	157	9.2	42.6	70	108	6.5
17°NT/20°DT	Superphosphate/Turf	3.6	4.2	0.65	1523	1.76	0.70	133	218	12.2	34.3	68	220	7.1
17°NT/20°DT	Dicalcium phosphate/Perlite	3.7	4.1	0.56	1777	2.44	0.59	128	138	2.4	33.1	66	44	5.2
17°NT/20°DT	Superphosphate/Perlite	3.7	4.1	0.61	2109	2.31	0.60	112	184	7.8	48.7	78	115	7.6
20°NT/23°DT	Dicalcium phosphate/Turf	3.7	4.1	0.63	1661	1.62	0.72	112	152	9.3	49.4	63	103	5.0
20°NT/23°DT	Superphosphate/Turf	3.8	4.3	0.63	1601	1.68	0.74	137	166	12.0	49.0	85	116	5.2
20°NT/23°DT	Dicalcium phosphate/Perlite	3.8	4.0	0.58	1698	2.67	0.67	138	207	8.4	36.1	67	215	5.3
20°NT/23°DT	Superphosphate/Perlite	3.1	3.9	0.58	1744	2.82	0.63	147	160	11.8	41.7	85	120	5.0

z Values are means of four replications.

y T x F/A significant at 5% level.

x T x F/A significant at 10% level.

w T significant at 5% level, F/A significant at 0.1% level, T x F/A significant at 1% level.

v F/A significant at 0.1% level, T x F/A significant at 10% level.

u T, F/A, T x F/A significant at 0.1% level.

t T significant at 1% level, F/A significant at 0.1% level,

s T x F/A significant at 5% level.

r T, F/A significant at 10% level, T x F/A significant at 0.1% level.

q F/A significant at 5% level.

p T, T x F/A significant at 5% level, F/A significant at 0.1% level.

p Not significant.

o T x F/A significant at 0.1% level.

n T significant at 1% level.

Table 3 : Post-scorch experiment soil analysis, 1978.^z

Temperature (T) (°C)	Fertilizer/Amendment (F/A)	pH	Soluble Salts (mmhos)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	F (ppm)	N (%)	K (%)	Ca (%)	Mg (%)
13°NT/16°DT	Dicalcium phosphate/Turf	5.3 ^y	12.00 ^x	1249 ^w	120 ^v	814 ^v	1047 ^u	291 ^x	0.66 ^t	14.6 ^s	9.6 ^r	12.4 ^q	3.4 ^p
13°NT/16°DT	Superphosphate/Turf	5.1	11.75	1302	122	852	994	256	0.65	15.8	10.2	12.1	3.2
13°NT/16°DT	Dicalcium phosphate/Perlite	5.5	9.30	742	142	801	703	194	0.71	11.2	12.3	10.7	3.0
13°NT/16°DT	Superphosphate/Perlite	5.4	11.62	1066	162	967	950	262	0.83	13.0	12.2	11.7	3.2
17°NT/20°DT	Dicalcium phosphate/Turf	5.4	8.50	803	84	635	800	211	0.50	13.4	10.7	13.5	3.6
17°NT/20°DT	Superphosphate/Turf	5.2	10.00	1023	89	635	980	213	0.58	14.4	9.1	14.1	3.1
17°NT/20°DT	Dicalcium phosphate/Perlite	5.2	9.11	650	158	758	780	219	0.54	10.2	11.8	12.2	3.4
17°NT/20°DT	Superphosphate/Perlite	5.4	9.75	743	185	948	675	215	0.84	10.7	13.8	10.0	3.2
20°NT/23°DT	Dicalcium phosphate/Turf	5.4	8.37	928	59	526	93	220	0.46	15.7	9.0	1.6	3.8
20°NT/23°DT	Superphosphate/Turf	5.1	9.25	1021	70	605	97	239	0.50	15.3	9.3	1.5	3.8
20°NT/23°DT	Dicalcium phosphate/Perlite	5.2	10.75	864	192	1114	675	195	0.56	11.4	14.7	9.0	2.6
20°NT/23°DT	Superphosphate/Perlite	5.0	11.50	1001	191	1011	825	210	0.61	12.4	12.5	10.2	2.6

^z Values are means of four replications.^y T, F/A, T x F/A significant at 0.1% level.^x T significant at 5% level, F/A significant at 10% level.^w T, F/A significant at 5% level.^v F/A significant at 0.1% level, F/A x T significant at 5% level.^u T, T x F/A significant at 0.1% level, F/A significant at 5% level.^t T, F/A significant at 0.1% level.^s F/A significant at 0.1% level.^r F/A significant at 0.1% level, T x F/A significant at 10% level.^q T, T x F/A significant at 0.1% level, F/A significant at 1% level.^p F/A, T x F/A significant at 0.1% level.

Table 4 : Linear correlation coefficients for scorch count and rating in relation to soil analysis, 'Ace' Easter lily scorch experiment, 1978.

INDEPENDENT VARIABLE	DEPENDENT VARIABLE			
	Scorch Count		Scorch Rating	
	F-test	r	F-test	r
Replicate	0.29 NS	0.08	0.01 NS ^x	-0.01
Fertilizer/Amendment	19.87 ****	0.55	22.10 ****	0.57
Temperature	3.94 **	-0.28	1.59 NS	-0.18
pH	1.75 NS	0.19	0.04 NS	0.03
Soluble Salts (mmhos)	0.44 NS	0.10	0.08 NS	0.04
N (ppm)	0.001 NS	0.005	0.01 NS	-0.04
P (ppm)	2.74 *	0.24	2.36 NS	0.22
K (ppm)	2.45 NS	0.22	0.57 NS	0.11
Ca (ppm)	0.27 NS	0.08	0.94 NS	0.04
Mg (ppm)	0.10 NS	0.05	0.17 NS	-0.06
Nitrate N (%)	0.35 NS	-0.09	0.59 NS	-0.11
K(%)	3.82 *	0.28	1.31 NS	0.17
Ca (%)	0.07 NS	0.04	0.05 NS	0.03
Mg (%)	0.33 NS	-0.08	0.83 NS	-0.13
F (ppm)	13.55 ****	0.48	9.42 ****	0.41
All	3.10 ***	-	2.42 **	-

x F-test

* significant at 10% level.
 ** significant at 5% level.
 *** significant at 1% level.
 **** significant at 0.1 level.
 NS not significant.

Soil analysis run by Michigan State University's Soils lab and by Dr. Marousky indicated soluble salts levels (mmhos) were extremely high (Table 3), with no visible effect on plant growth or vigor.

Bud count generally decreased as temperature increased (Figure 3). Stage II in greenhouse forcing, the time from floral initiation to buds visible in the foliage, is critical in establishing the number of flowers that will be developed (De Hertogh, 1974). All lilies were grown at 17°C NT/20°C DT during Stage II, and this is considered the best setting for optimum bud count. Results of this experiment indicate that Stage III temperatures, from buds visible to anthesis, are also important in terms of ultimate bud count and development.

Plants grown in superphosphate/Turface at 20°C DT had the highest bud count; those grown in dicalcium phosphate/perlite at the same temperature had the lowest (Figure 3). Turface-grown plants had more buds than perlite-grown plants.

In general, leaf count decreased as temperature increased (Figure 4). Highest leaf count occurred in dicalcium phosphate/perlite medium at 16°C DT, whereas lowest count was found on plants grown in the same medium at 23°C DT.

Both pedicel height and total plant height increased with increasing temperatures (Figures 5 & 6). These results concur with previous findings (De Hertogh and Wilkins, 1971).

Figure 3. Effect of temperature and fertilizer/amendment on bud count of 'Ace' Easter lily, 1978.

Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite

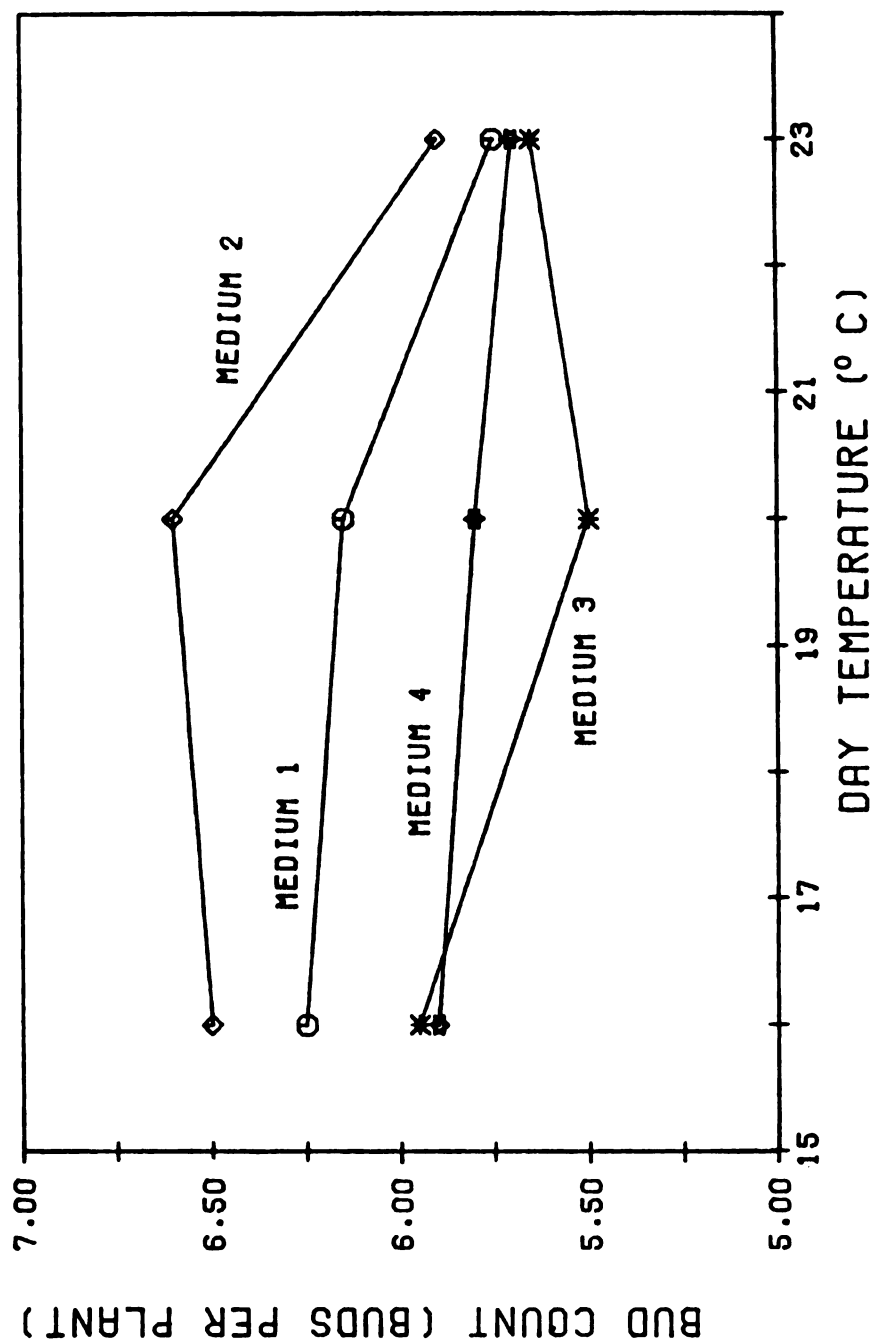


FIGURE 3

Figure 3. Effect of temperature and fertilizer/amendment on bud count of 'Ace' Easter lily, 1978.

Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite

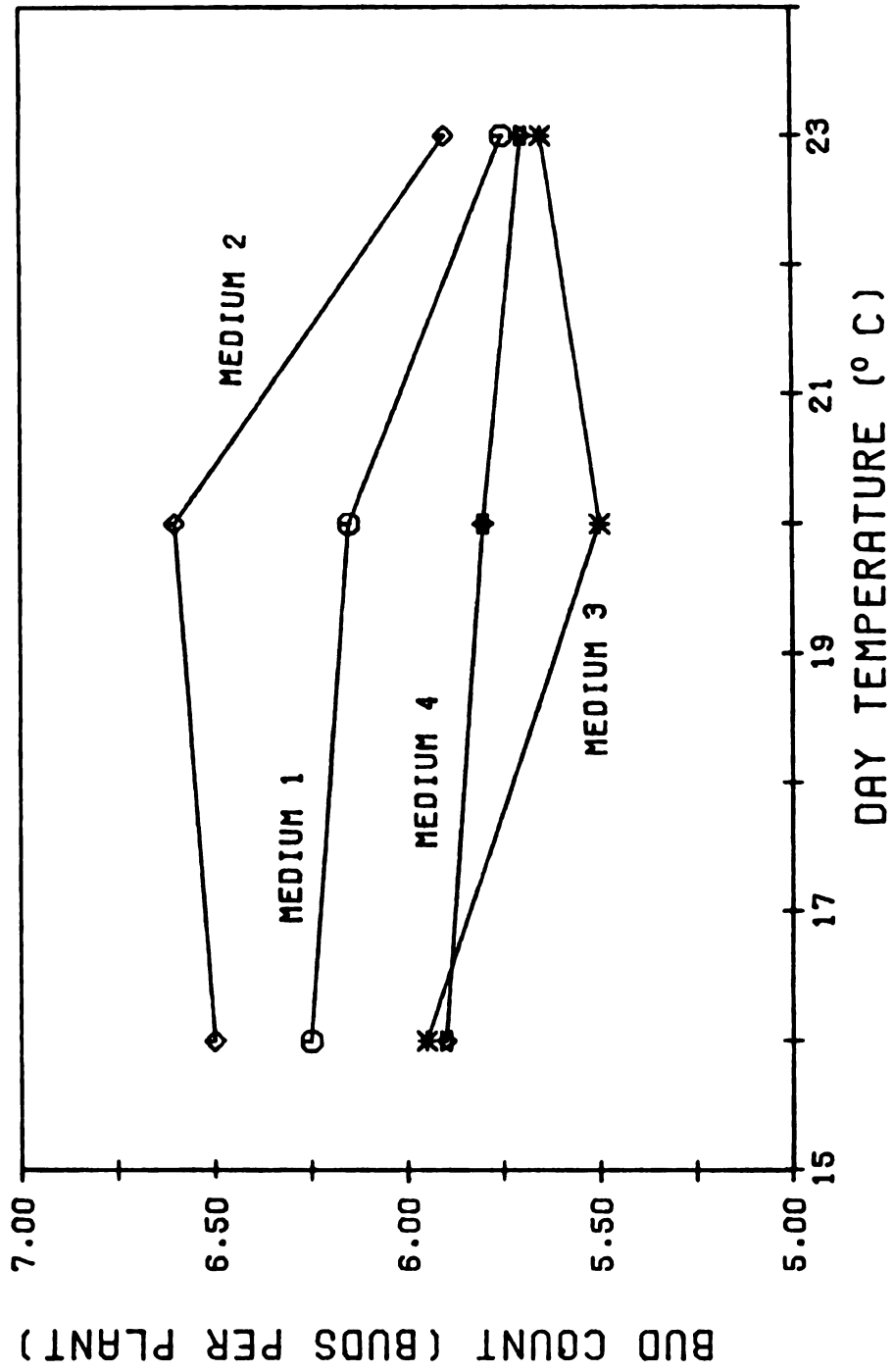


FIGURE 3

Figure 4. Effect of temperature and fertilizer/amendment of leaf count of 'Ace' Easter lily, 1978.

Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite

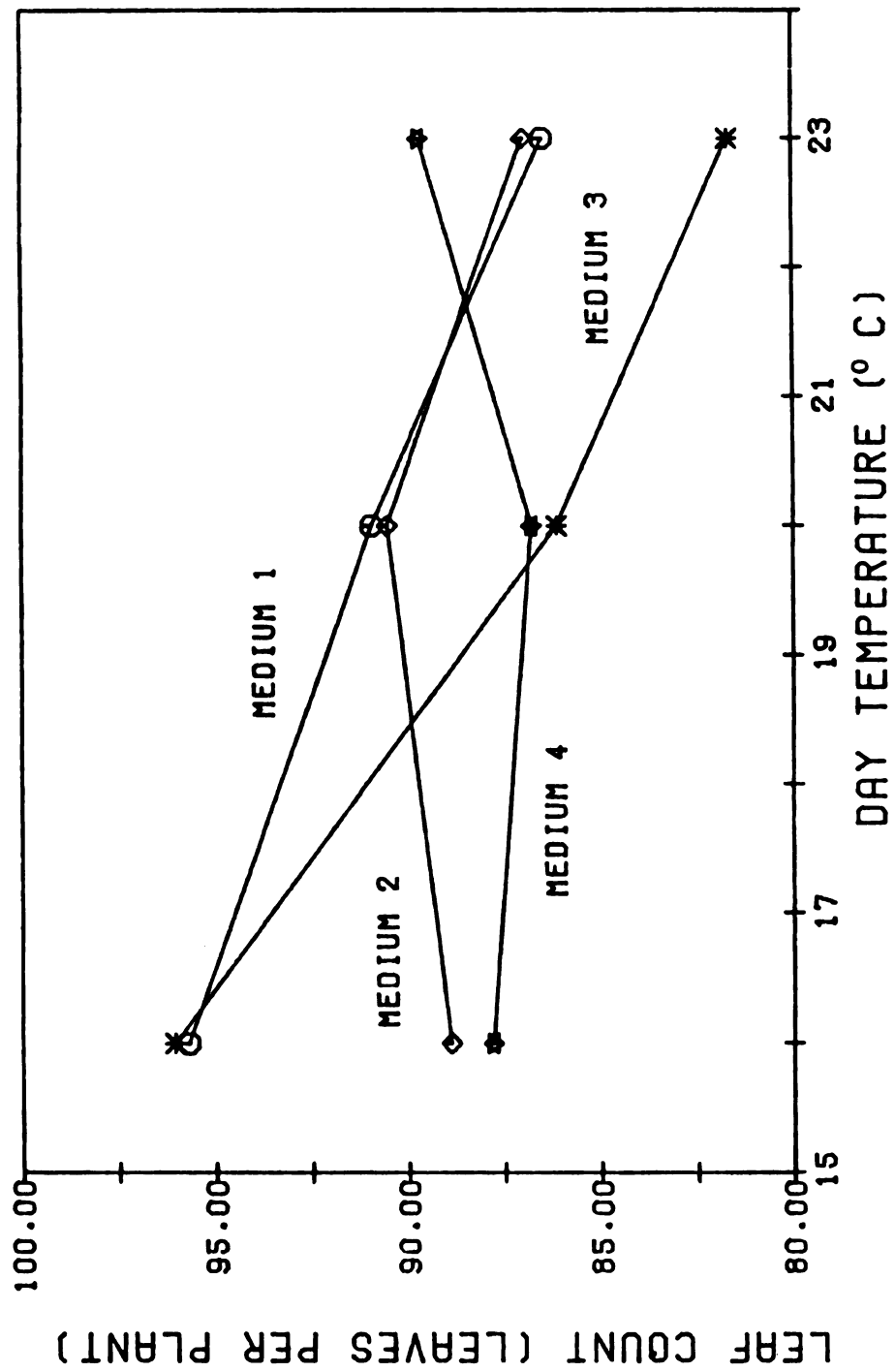


FIGURE 4

Figure 5. Effect of temperature and fertilizer/amendment of total plant height of 'Ace' Easter lily, 1978.

Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite

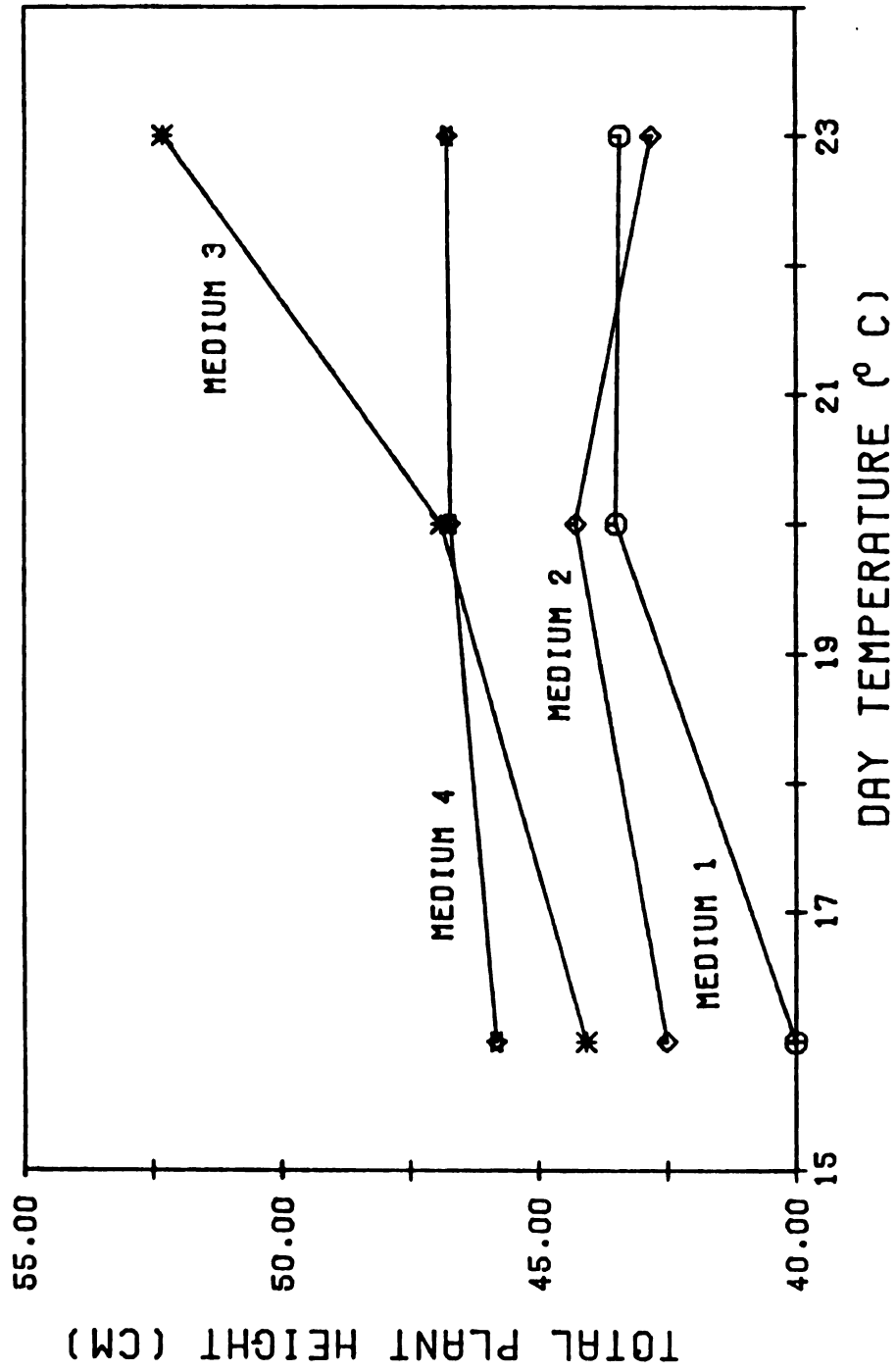


FIGURE 5

**Figure 6. Effect of temperature and fertilizer/amendment
on pedicel height of 'Ace' Easter lily, 1978.**

**Medium 1 - Dicalcium phosphate/Turface
Medium 2 - Superphosphate/Turface
Medium 3 - Dicalcium phosphate/Perlite
Medium 4 - Superphosphate/Perlite**

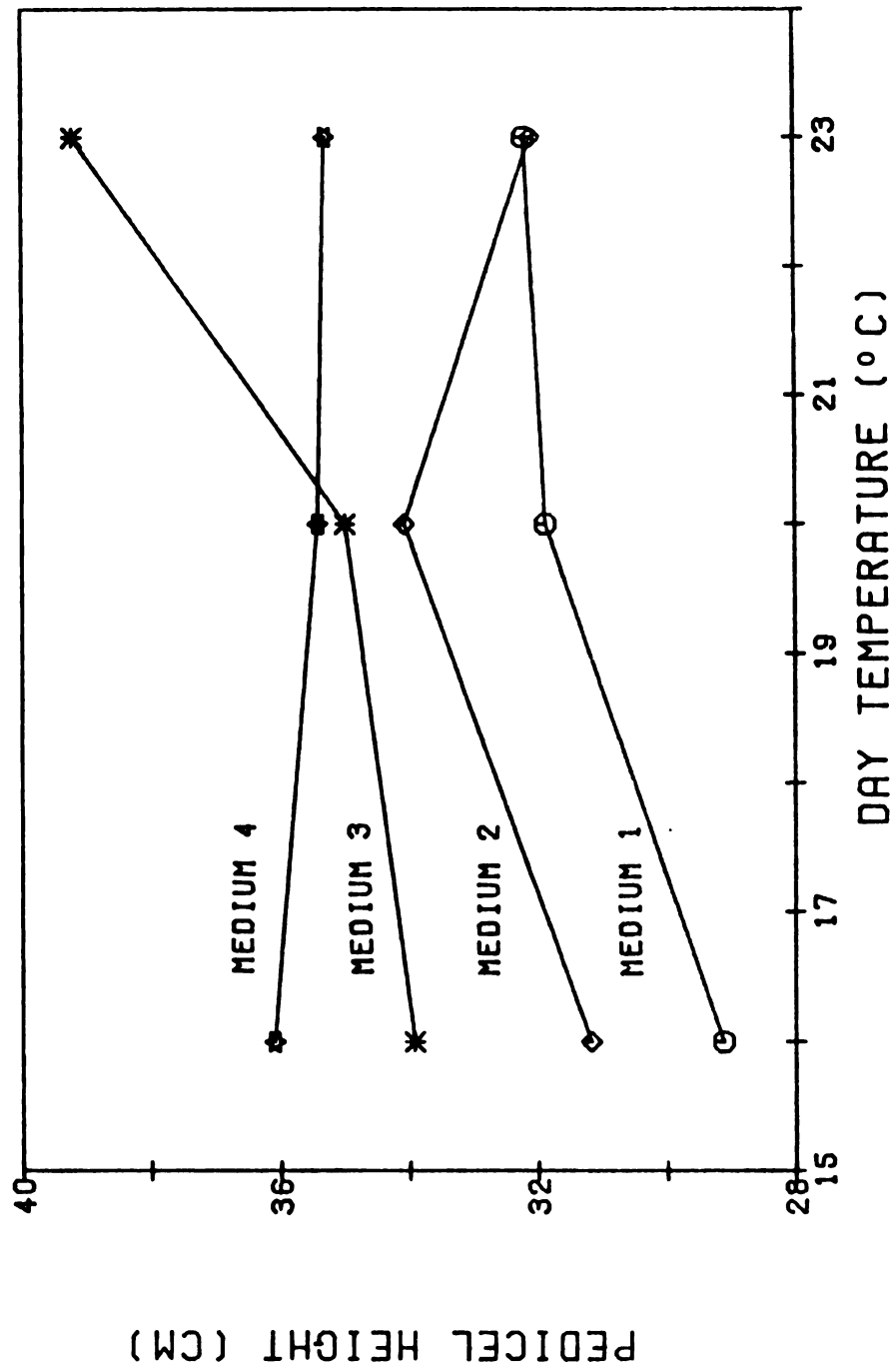


FIGURE 6

Plants grown in perlite were generally taller than those grown in Turface, irrespective of fertilizer used.

Effect of Soil-less Media on Lily Growth and Root Rot Disease Development

In 1976-77, the number of scorched leaves was significantly different between the eight media, with no scorch in the control and the most in Pro-Mix BX. This medium also had the highest leaf count, whereas Metro-Mix 200 had the lowest (Table 5).

Fresh weight data revealed the media-time interaction was significant at the 1% level for scales, shoot and stem roots. For basal plate plus roots, only the main and subplot effects were significant, again at the 1% level (Table A10). In general, shoot and stem root weights increased from January to April (Figure 7). Basal plate plus root weights increased over the first three months, then dropped slightly by April. Scale weight decreased steadily over the four-month period.

In 1977-78 media again affected the number of scorched leaves. The crop was more severely scorched in this trial than the previous year (Table 6). All soil-less media produced heavily scorched plants, whereas control plants had none. Results of soil analysis revealed a positive correlation of medium and the nutrients Mg (% of total salts), P and F to

Table 5 : Influence of growing medium on leaf count and scorch count of 'Ace' Easter lily, 1977 soil-less media experiment.^V

Medium ^W	Leaf Count ^{X**}	Scorch Count ^{Y**Z}
Control	75.8 ab	0.0 a
Ball Growing Mix	70.5 ab	28.5 b
Jiffy-Mix	76.2 ab	21.7 ab
Jiffy-Mix Plus	75.3 ab	13.3 ab
Metro-Mix 200	67.8 b	24.2 b
Metro-Mix 300	76.7 ab	12.2 ab
Pro-Mix BX	77.3 a	31.8 b
Redi-Earth	74.5 ab	22.2 ab

^V Values are means of 2 observations/rep. with 3 reps.

^W Mean separation within columns by Duncan's multiple range test. Numbers followed by the same letter are not significantly different at the 5% level.

^X Indicates number of leaves/plant.

^Y Indicates number of scorched leaves/plant.

^Z F-test * significant at 5% level.
 ** significant at 1% level.

Figure 7. Fresh weights over time, 1977 soil-less media experiment.

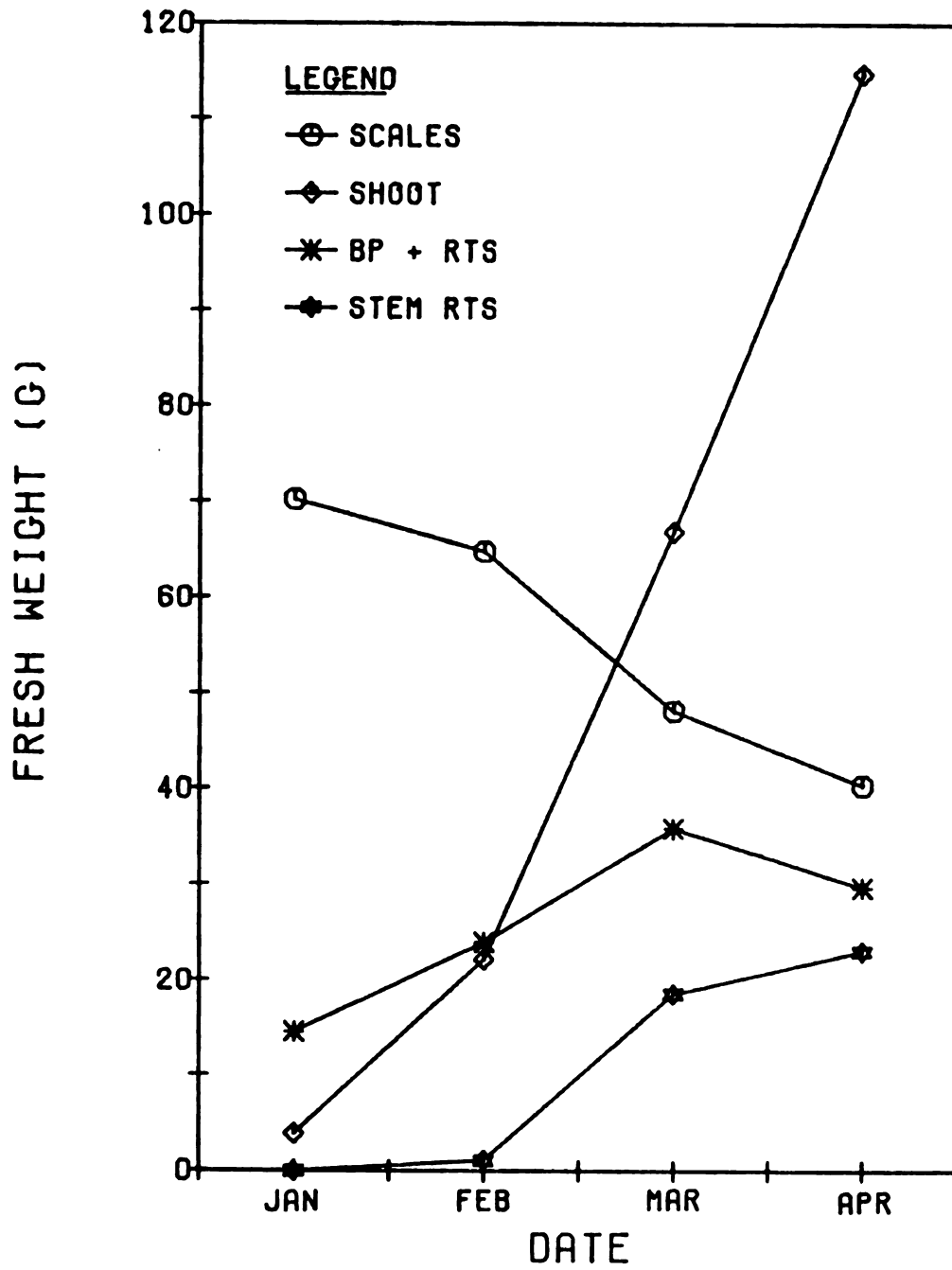


FIGURE 7

Table 6 : Influence of growing medium on disease and leaf scorch of 'Ace' Easter lily, 1978 soil-less media experiment.^z

Medium ^t	Leaf Loss ^{u**}	Scorch Count ^v ***	Scorch Rtg ^w ***	Root Rot ^x ***y
Control	6.2 c	0.0 a	0.0 a	10.8 abc
Ball-Growing Mix	9.8 bc	36.2 b	2.8 b	7.1 c
Jiffy-Mix	10.7 abc	45.0 b	3.0 b	10.1 bc
Jiffy-Mix Plus	24.7 abc	47.2 b	3.0 b	14.2 ab
Metro-Mix 200	14.5 abc	35.5 b	2.8 b	11.4 abc
Metro-Mix 300	6.8 c	38.8 b	2.8 b	10.8 abc
Pro-Mix BX	28.8 a	50.0 b	3.0 b	15.0 a
Redi-Earth	26.8 ab	55.7 b	3.0 b	13.2 ab

^t Mean separation within columns by Duncan's multiple range test. Numbers followed by the same letter are not significantly different at the 5% level.

^u Indicates number of dead or dying leaves/plant.

^v Indicates number of scorched leaves/plant.

^w Indicates degree of scorch. 0= none, 1= slight, 2= moderate, 3= severe.

^x Measured by a 16-square grid. Values indicate number of squares containing diseased or dead root tissue.

^y F-test ** significant at 1% level
*** significant at 0.1% level

^z Values are means of 2 observations/rep. with 3 reps.

scorch count and rating (Table 7). Pro-Mix BX had the highest F content and the control the lowest, which agrees with the resultant degree of leaf scorch on plants grown in these media (Tables 6 & 8). Comparison of P and Mg content to the number of scorch leaves per medium is not a direct relationship. Soluble salts (mmhos), N (ppm), K (ppm) and Ca (ppm and % of total salts) all showed a high negative correlation to scorch. One-on-one comparison of these parameters to leaf scorch is inconclusive. It appears that leaf scorch is influenced by a complex interaction of various soil nutrient levels.

Leaf tissue analysis results also showed a high positive correlation of medium and F to scorch (Table 9). Fluoride content was higher in lower leaves than upper (Table 10), but levels were inconsistent with actual leaf scorch. Plants grown in the control mix had no scorch (Table 6), yet their F content was higher than plants grown in Metro-Mix 300, which had 38.8 scorched leaves (Table 6).

Leaf boron content was also highly correlated to scorch (Table 9); however, a direct relationship between concentration and number of scorched leaves does not exist (Tables 6 & 10). Phosphorus and Zn were negatively related to scorch (Table 9). In contrast, Shanks and Link (1959) reported a positive relationship between scorch and P content. Again, a complex interaction of leaf nutrients seems to influence scorch.

Table 7 : Linear correlation coefficients for scorch count and rating in relation to soil analysis, 'Ace' Easter lily soil-less media experiment, 1978.

INDEPENDENT VARIABLE	DEPENDENT VARIABLE			
	Scorch Count		Scorch Rating	
	F-test	r	F-test	r
Replicate	0.63 NS	-0.17	0.015 NS ^x	-0.03
Medium	16.27 ****	0.65	11.61 ***	0.59
pH	5.22 **	-0.44	5.10 **	-0.43
Soluble Salts (mmhos)	35.10 ****	-0.78	40.00 ****	-0.80
N (ppm)	24.44 ****	-0.72	30.51 ****	-0.76
P (ppm)	3.17 *	0.36	4.54 **	0.41
K (ppm)	11.69 ***	-0.59	11.53 ***	-0.59
Ca (ppm)	34.03 ****	-0.78	59.79 ****	-0.86
Mg (ppm)	2.85 *	-0.34	1.60 NS	-0.26
Nitrate N (%)	3.76 *	-0.38	4.56 **	-0.41
K (%)	0.056 NS	0.05	0.10 NS	0.07
Ca (%)	13.44 ****	-0.62	25.34 ****	-0.73
Mg (%)	6.24 **	0.47	10.04 ***	0.56
F (ppm)	27.49 ****	0.74	32.81 ****	0.77
Al	5.54 ***	-	16.08 ****	-

x F-test

- * significant at 10% level
- ** significant at 5% level
- *** significant at 1% level
- **** significant at 0.1% level
- NS not significant.

Table 8 : Post-soil-less media experiment soil analysis, 1978.^x

Treatment	pH (**)	Soluble Salts mmhos (***)	N ppm (***)	P ppm (***)	K ppm (**)	Ca ppm (***)	Mg ppm (**)	F ppm (***)	N % (**)	K % (NS)	Ca % (***)	Mg % (***) ^y
Control	6.0	4.30	548.6	34.4	252.6	459.3	113.6	0.34	18.1	8.4	15.0	3.7
Ball Growing Mix	5.3	3.00	379.6	103.8	214.0	276.0	127.3	2.53	18.1	10.1	13.1	6.0
Jiffy-Mix	5.1	2.50	292.0	56.5	166.6	177.0	82.6	2.05	16.3	9.4	9.9	4.6
Jiffy-Mix Plus	5.1	2.40	179.0	154.2	110.6	174.0	122.3	2.75	10.5	6.5	10.2	7.2
Metro-Mix 200	5.9	2.30	238.0	54.1	120.0	145.0	85.0	2.49	14.2	6.8	8.7	5.1
Metro-Mix 300	5.8	2.90	338.6	76.0	195.0	212.6	118.0	2.03	16.1	9.5	10.4	5.7
Pro-Mix BX	5.7	2.10	213.6	76.8	138.6	174.0	69.3	4.02	14.1	9.1	11.6	4.7
Redi-Earth	5.5	1.90	191.6	55.0	128.0	135.3	68.0	3.08	14.3	9.6	10.2	5.1

^x Values are means for three replications

^y F-test ** significant at 1% level.
 *** significant at 0.1% level.
 NS not significant

Table 9 : Linear correlation coefficients for scorch count and rating in relation to leaf analysis, 'Ace' Easter lily soil-less media experiment, 1978.

INDEPENDENT VARIABLE	DEPENDENT VARIABLE			
	Scorch Count		Scorch Rating	
	F-test	r	F-test	r
Medium	16.27 ****	0.65	11.61 *** ^x	0.59
Replicate	0.63 NS	-0.17	0.01 NS	-0.03
N (%)	0.17 NS	-0.03	0.82 NS	-0.19
K (%)	0.10 NS	0.07	0.46 NS	0.14
P (%)	10.14 ***	-0.56	33.03 ****	-0.78
Na (ppm)	0.23 NS	0.10	0.11 NS	0.07
Ca (%)	0.11 NS	0.07	0.86 NS	0.19
Mg (%)	1.47 NS	0.25	3.76 *	0.38
Mn (ppm)	4.08 *	-0.40	3.80 *	-0.38
Fe (ppm)	3.57 *	0.37	3.28 *	0.36
Cu (ppm)	0.08 NS	-0.06	2.67 NS	-0.33
B (ppm)	10.13 ***	0.56	10.84 ***	0.57
Zn (ppm)	3.50 *	-0.37	6.21 **	-0.47
Al (ppm)	0.65 NS	0.17	0.67 NS	0.17
F (ppm)	16.49 ****	0.65	8.96 ***	0.54
All	8.12 ***	-	40.50 ****	-

x F-test * significant at 10% level
 ** significant at 5% level
 *** significant at 1% level
 **** significant at 0.1% level
 NS not significant

Table 10 : Effect of growing medium on nutrient content of 'Ace' Easter Lily leaves, soil-less media experiment, 1978.^z

Medium (M)	Position ^y (P)	N (%)	K (%)	P (%)	Na (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Zn (ppm)	Al (ppm)	F (ppm)
Control	Upper	3.5 ^x	3.8 ^w	0.52 ^v	1357 ^v	1.13 ^v	0.61 ^v	123 ^u	151 ^t	5.9 ^s	31.2 ^r	92 ^q	61 ^p	4.5 ^w
Ball Growing Mix	Upper	3.1	3.7	0.31	1294	1.23	0.79	93	155	1.7	57.1	97	37	7.1
Jiffy-Mix	Upper	2.9	3.8	0.33	1469	1.20	0.89	142	197	3.4	41.8	57	90	9.5
Jiffy-Mix Plus	Upper	3.2	4.1	0.28	1191	1.50	0.70	89	184	5.4	49.0	71	60	10.0
Metro-Mix 200	Upper	3.1	3.9	0.38	1461	1.22	0.85	98	175	3.1	47.4	66	81	7.0
Metro-Mix 300	Upper	3.4	4.3	0.36	1587	1.23	0.91	91	199	3.1	39.9	52	272	5.7
Pro-Mix BX	Upper	3.2	3.7	0.36	1316	1.21	0.61	62	161	2.0	57.7	73	54	8.5
Redi-Earth	Upper	3.0	4.0	0.34	1504	1.05	0.71	72	200	4.2	46.8	65	243	11.1
Control	Lower	3.0	3.9	0.61	1692	0.75	0.70	118	220	5.6	30.9	103	120	13.2
Ball Growing Mix	Lower	2.9	4.5	0.41	1647	0.99	1.04	103	163	4.8	76.7	133	58	14.5
Jiffy Mix	Lower	2.9	4.4	0.41	1955	0.96	1.16	169	197	8.6	48.9	78	111	28.4
Jiffy Mix Plus	Lower	2.9	4.5	0.38	1642	1.58	0.98	107	181	10.0	63.7	77	130	19.5
Metro-Mix 200	Lower	2.8	4.1	0.54	2120	1.05	1.21	124	160	12.7	63.1	81	163	14.8
Metro-Mix 300	Lower	3.1	4.6	0.45	2137	1.00	1.16	108	161	10.3	45.2	57	181	12.4
Pro-Mix BX	Lower	2.8	4.2	0.47	1811	1.13	0.82	63	118	7.3	81.8	48	143	15.2
Redi-Earth	Lower	2.8	4.5	0.37	1563	1.00	0.77	69	142	8.1	44.6	38	166	17.8

^z Values are means of three replications.^y Plant shoots were divided into upper and lower halves.^x P significant at 5% level.^w M significant at 1% level, P significant at 0.1% level.^v M and P significant at 0.1% level.^u M and P significant at 0.1% level, M x P significant at 5% level.^t M significant at 5% level, M x P significant at 0.1% level.^s M significant at 5% level, P significant at 0.1% level.^r M and P significant at 0.1% level, M x P significant at 1% level.^q M, M x P significant at 0.1% level.^p M significant at 0.1% level.

The 1977-78 lily crop was more severely infected by root-rotting fungal pathogens than the previous year. Many plants were severely stunted, had aborted flower buds, and lost several lower leaves. There was a significant difference in the amount of root rot between the various media (Table 6). Ball Growing Mix had the fewest dead or infected roots, and Pro-Mix BX the most. Leaf loss, the number of dead or dying leaves per plant, was also significant. This parameter is a visual indication of root rot, improper fertility and spacing and possibly soil aeration problems. A comparison of root rot values to leaf loss supports this cause-effect relationship somewhat.

Analysis of fresh weight data showed all organs had significant weight changes over time (Tables A10 - A13). The time/media interaction was significant for scale fresh weight, and the development of stem roots was significantly affected by growing media. Plants grown in Redi-Earth and Jiffy Mix developed the most stem roots, whereas those grown in Pro-Mix BX and the control had the fewest such roots. Stem root fresh weights gradually increased with time (Figure 8). Shoots increased through March but dropped by April, which was to be expected due to the early Easter date. This could also be seen by the turnaround in scale fresh weight (as compared to 1977), which decreased from January to March, then increased during the last month. Plants had completed flowering and were beginning to channel their energies into vegetative reproduction.

Figure 8. Fresh weights over time, 1978 soil-less media experiment.

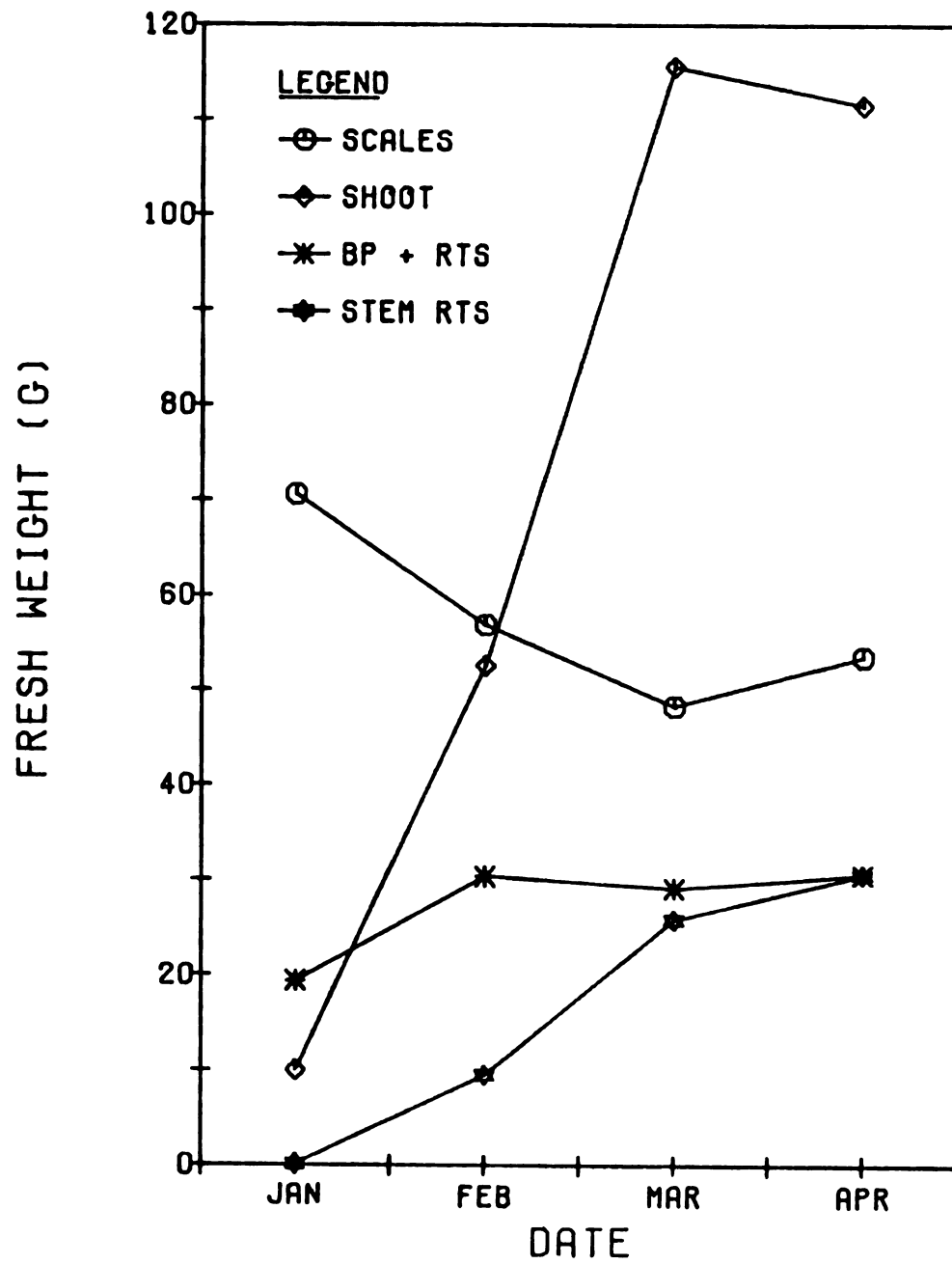


FIGURE 8

i.e. bulbing. Basal plate plus root growth was strong only between January and February, probably due to successful infection by fungal pathogens in the later months.

Porosity Determination of Soil-less Media

The percent air porosity of the soil-less media and soil control are given in Table 11. Figure 9 illustrates the variability within and between media with respect to aeration. There was a significant difference in porosity between the eight media. Porosity was also found to be positively correlated to leaf scorch count and rating (Table 12). The control had the lowest porosity and no scorch, whereas Redi-Earth had the highest porosity and the most scorch in 1978 (Tables 6 & 11). One possible explanation for this is stress; plants grown in the more porous Redi-Earth dried out quickly due to its large pore spaces and rapid drainage. This, combined with warm, sunny days could have increased the transpiration rate more so than on control mix-grown plants. According to Rathmall (1975) and Peterson (1976), high transpiration should be avoided in order to lessen the likelihood of scorch.

Table 11 : Percent air porosity of soil-less media.

Medium	Mean ^y
Control	6.3 e ^x
Ball Growing Mix	21.7 bc
Jiffy-Mix	24.4 ab
Jiffy-Mix Plus	24.3 ab
Metro-Mix 200	12.7 dc
Metro-Mix 300	15.4 cd
Pro-Mix BX	19.1 bcd
Redi-Earth	30.8 a

x Numbers followed by same letter are not significantly different at 5% level, by Duncan's multiple range test.

y Values are means of four replications.

Figure 9. Percent air porosity of soil-less media and soil control, 1978.

Medium 1 - Control
Medium 2 - Ball Growing Mix
Medium 3 - Jiffy-Mix
Medium 4 - Jiffy-Mix Plus
Medium 5 - Metro-Mix 200
Medium 6 - Metro-Mix 300
Medium 7 - Pro-Mix BX
Medium 8 - Redi-Earth

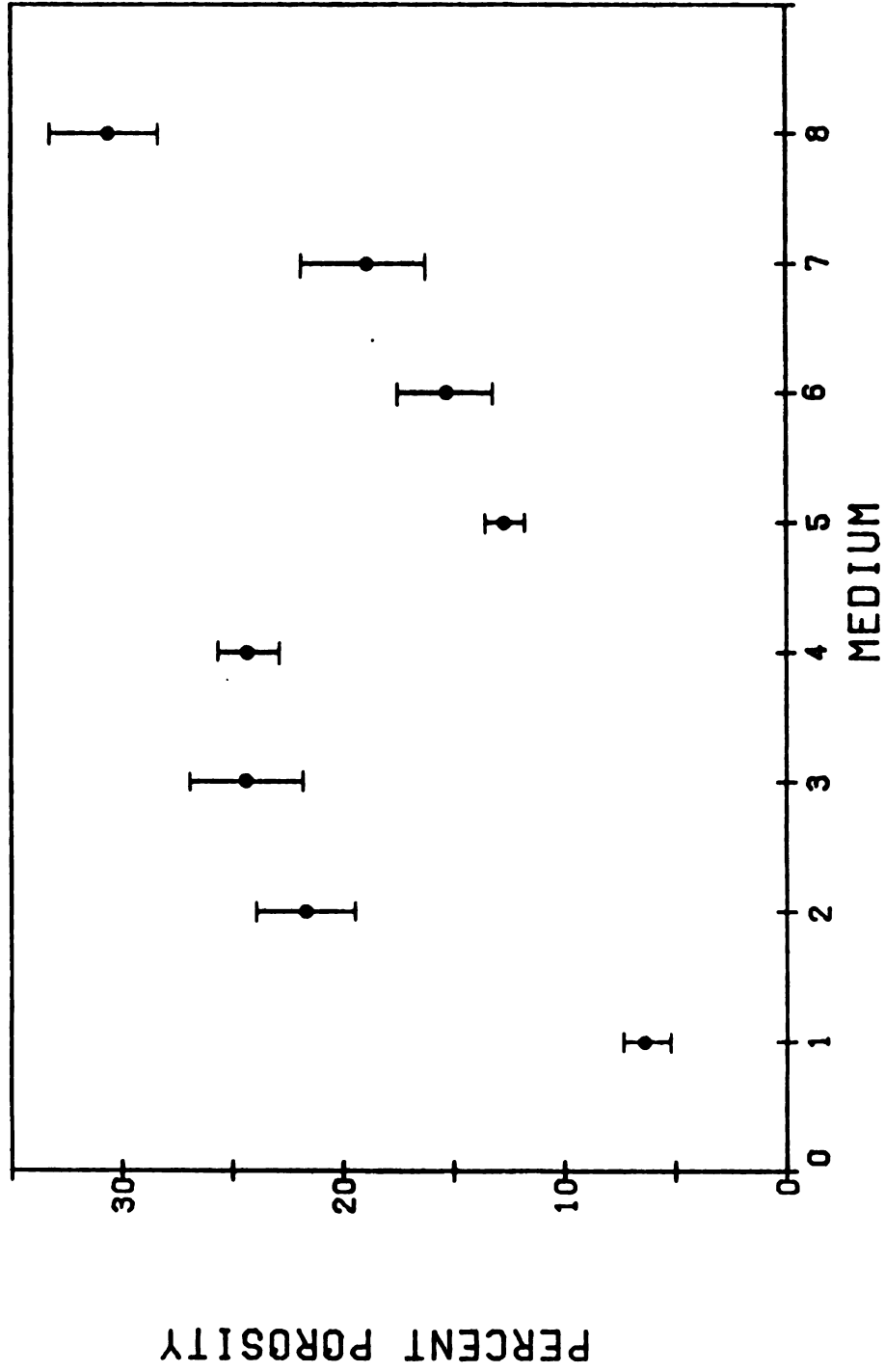


FIGURE 9

Table 12 : Linear correlation coefficients for root rot, leaf loss, scorch count and rating in relation to porosity, 'Ace' Easter lily soil-less media experiment, 1978.

PARAMETERS	POROSITY	
	F-test	r
Medium	1.55 NS ^x	0.45
Root rot	0.25 NS	0.20
Leaf loss	3.20 NS	0.59
Scorch count	15.83 ***	0.85
Scorch rating	6.80 **	0.73
All	13.45 *	-

x F-test * significant at 10% level
 ** significant at 5% level
 *** significant at 1% level
 NS not significant.

Measurement of Fungal Growth in Soil-less Media

The results of this investigation were inconclusive, as only one successful trial was completed. Data are located in the Appendix (Tables A21 - A23). The main problem confronted in this experiment was measuring fungal growth accurately. Mycelial strands were difficult to see with the unaided eye, especially if they wove above and below the medium's surface. No satisfactory method was devised to chart the daily progress of a particular strand without interfering with or contaminating the culture.

V. SUMMARY AND CONCLUSIONS

Leaf scorch was greater in plants grown in superphosphate/perlite than the other fertilizer/amendment treatments. The amount of leaf scorch generally decreased as temperature increased, possibly because plants grown under the lowest temperatures had a longer exposure to F in the soil, as data on these plants was not recorded until anthesis occurred. This is supported by the fact that soil F levels increased as temperature decreased.

Soil F content was positively correlated to scorch. As expected, soils amended with perlite and/or fertilized with superphosphate had higher F levels than soils amended with Turface or fertilized with dicalcium phosphate. Plants fertilized with superphosphate also had higher leaf Zn levels, and those grown in perlite had higher leaf Na levels, both of which were positively correlated to scorch. Based on these findings, growers should avoid using perlite or superphosphate when forcing 'Ace' Easter lilies if leaf scorch is a major concern.

Most of the variability of scorch was accounted for by soil F levels, with some due to leaf Na and Zn concentrations. It appears, therefore, that F is the main factor responsible for Easter lily leaf scorch, although other nutrients also play a significant role.

Plants grown in soils amended with Turface had higher bud and leaf counts than those grown in perlite. Perlite also produced taller plants than Turface, which can be undesirable, especially if high temperatures are being utilized to accelerate forcing time in order to meet the Easter marketing date. This evidence further supports using Turface instead of perlite.

Lower temperatures are desirable in terms of bud count, leaf count and plant height; but the greater incidence of scorch negates using lower temperatures.

The soil-less media used all produced severe leaf scorch on Easter lilies in both 1977 and 1978. Medium and leaf tissue F content were positively correlated to scorch; however, a direct relationship between concentration and actual scorch count existed only for medium F levels. All seven soil-less media had high F levels due to the incorporation of F-contaminated perlite, peat or superphosphate. Fluoride again accounted for a majority of the variability of scorch.

The control medium had the highest level of soluble salts, N, Ca and K and the lowest F concentration. The first four parameters had high negative correlations to scorch. It seems plausible, therefore, that the interaction of these factors, combined with the low F level, was responsible for the complete absence of scorch on plants grown in this medium. Media which produced severely scorched plants had concentrations of these nutrients and soluble salts at the opposite extreme to the control. Unfortunately, the relationship between leaf nutrient levels and scorch was not as straightforward. With respect to scorch, based on the results of this experiment, media containing F-contaminated amendments or fertilizers should be avoided.

Root rot infection was severe in the 1977-78 lily crop, with some media more conducive to fungal growth and survival than others. In terms of visible disease symptoms, plants grown in Ball Growing Mix, Metro-Mix 300 and the control lost the fewest lower leaves. However, the former two media produced heavily scorched plants, negating their favorable disease ratings. If growers elect to use these soil-less media, an intensive disease prevention program using fungicides will be necessary, due to a lack of competitive, antagonistic microorganisms often present in soil-based media.

Fresh weight data for both trials revealed certain trends in lily organogenesis over time. In order to feed and support a rapidly growing shoot, the plant expands its bulb root system and initiates a stem root system in mid to late January. Stem roots become increasingly important as the root-rotting complex invades the basal plate and roots, as was the case in 1977-78.

Scale fresh weight gradually decreased over time, due to a depletion in stored carbohydrates which were used to nourish the growing shoot. Once anthesis and subsequent senescence occur, the flow of carbohydrates reverses, the scales are replenished, and bulbing occurs.

Porosity of the soil-less media and soil control may account for the difference in stem root fresh weights between these media. Plants grown in more porous media (Jiffy-Mix, Jiffy-Mix Plus and Redi-Earth) developed more extensive stem roots than plants in the other media. The greater pore space provided both sufficient room and adequate gas exchange to stimulate root growth.

These same media also produced the most severely scorched plants in 1977-78, partly due to high porosity and drainage. The correlation between porosity and leaf scorch was highly positive. The explanation here could be due to greater water stress for plants grown in the more porous media, a factor which has been linked to scorch. Plants grown in the control

medium had no scorch, and its porosity fell within the recommended 5-10% range for Easter lilies. Evidently, porosity above 10% is not advantageous to lily growth in terms of leaf scorch, or root rot occurrence. There was no correlation between root rot and porosity. It was expected that the more porous media would provide unfavorable environments for the root rot pathogens, especially Phytophthora and Pythium spp.

The preliminary investigation to measure fungal growth in the soil-less media and soil control was inconclusive. Of the soil-less media tested here, the two which contained bark, Metro-Mix 300 and Ball Growing Mix, had relatively low leaf loss and root rot values, compared to the control. This trend was not evident in the experiment. Other media/disease studies have shown that bark suppresses fungal growth. Further work needs to be done to determine specifically what causes one soil-less medium to be more conducive to or suppressive of fungal growth than another.

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APPENDIX
TABLES

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Table A1 : Influence of temperature and fertilizer/amendment treatments on leaf scorch (number/plant) of 'Ace' Easter lily, 1978.

Fertilizer/ Amendment	TEMPERATURE (°C)			Fertilizer/ Amendment Means
	13°NT/16°DT	17°NT/20°DT	20°NT/23°DT	
Dicalcium Phosphate/ Turface	1.10	1.45	1.55	1.37
Super phosphate/ Turface	8.05	3.90	6.15	6.03
Dicalcium phosphate/ Perlite	4.45	0.65	2.00	2.37
Superphosphate/ Perlite	17.25	11.55	6.00	11.60
Temperature Means	7.71	4.39	3.92	

Table A2 : Influence of temperature and fertilizer/amendment treatments on scorch rating^x of 'Ace' Easter lily, 1978.

Fertilizer/ Amendment	Temperature (°C)			Fertilizer/ Amendment Means
	13 ⁰ NT/16 ⁰ DT	17 ⁰ NT/20 ⁰ DT	20 ⁰ NT/23 ⁰ DT	
Dicalcium phosphate/ Turface	0.45	0.55	0.45	0.48
Super phosphate/ Turface	1.10	0.95	1.10	1.05
Dicalcium phosphate/ Perlite	0.95	0.50	0.55	0.67
Superphosphate/ Perlite	1.55	1.60	1.10	1.42
Temperature Means	1.01	0.90	0.80	

x Scorch rating: 0= no scorch, 1= slight, 2=moderate, 3= severe.

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Table A3 : Influence of temperature and fertilizer/amendment treatments on bud count (number/plant) of 'Ace' Easter lily, 1978.

Fertilizer/ Amendment	Temperature ($^{\circ}\text{C}$)			Fertilizer/ Amendment Means
	13 $^{\circ}\text{NT}$ /16 $^{\circ}\text{DT}$	17 $^{\circ}\text{NT}$ /20 $^{\circ}\text{DT}$	20 $^{\circ}\text{NT}$ /23 $^{\circ}\text{DT}$	
Dicalcium phosphate/ Turface	6.25	6.15	5.75	6.05
Superphosphate/ Turface	6.50	6.60	5.90	6.33
Dicalcium phosphate/ Perlite	5.95	5.50	5.65	5.70
Superphosphate/ Perlite	5.90	5.80	5.70	5.8
Temperature Means	6.15	6.01	5.75	

Table A4 : Influence of temperature and fertilizer/amendment treatments on leaf count (number/plant) of 'Ace' Easter lily, 1978.

Fertilizer/ Amendment	Temperature ($^{\circ}\text{C}$)			Fertilizer/ Amendment Means
	13 $^{\circ}$ NT/16 $^{\circ}$ DT	17 $^{\circ}$ NT/20 $^{\circ}$ DT	20 $^{\circ}$ NT/23 $^{\circ}$ DT	
Dicalcium phosphate/ Turface	95.70	90.95	86.50	91.05
Superphosphate/ Turface	88.90	90.55	87.00	88.82
Dicalcium phosphate/ Perlite	96.05	86.15	81.70	87.97
Superphosphate/ Perlite	87.80	86.80	89.70	88.10
Temperature Means	92.11	88.61	86.22	

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Table A5 : Influence of temperature and fertilizer/amendment treatments on total height^x(cm) of 'Ace' Easter lily, 1978.

Fertilizer/ Amendment	Temperature (°C)			Fertilizer/ Amendment Means
	13°NT/16°DT	17°NT/20°DT	20°NT/23°DT	
Dicalcium phosphate/ Turface	40.00	43.50	43.42	42.31
Superphosphate/ Turface	42.52	44.28	42.82	43.21
Dicalcium phosphate/ Perlite	44.08	46.90	52.30	47.76
Super phosphate/ Perlite	45.82	46.72	46.78	46.44
Temperature Means	43.11	45.35	46.33	

^x Measured from soil level to top of plant.

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Table A6 : Influence of temperature and fertilizer/amendment treatments on pedicel height^x (cm) of 'Ace' Easter lily, 1978.

Fertilizer/ Amendment	Temperature (°C)			Fertilizer/ Amendment Means
	13 ⁰ NT/16 ⁰ DT	17 ⁰ NT/20 ⁰ DT	20 ⁰ NT/23 ⁰ DT	
Dicalcium phosphate/ Turface	29.13	31.88	32.20	31.07
Superphosphate/ Turface	31.18	34.08	32.10	32.45
Dicalcium phosphate/ Perlite	33.93	35.00	39.22	36.05
Superphosphate/ Perlite	36.1	35.42	35.30	35.61
Temperature Means	32.58	34.09	34.71	

^x Measured from soil level to base of pedicel.

Table A7 : Analysis of variance. 'Ace' Easter lily scorch experiment, 1978.

Source	df	Pedicle ^z Height	Total ^y Height	Scorch Count	Scorch Rating	Bud Count	Leaf Count
Total	47						
Temperature (T)	2	0.034 *	0.002 **	0.003 **	0.163	0.021 *	<0.0005 ***x
Fertilizer/ Amendment (F/A)	3	<0.0005 ***	<0.0005 ***	<0.0005 ***	<0.0005 ***	0.002 **	0.144
T x F/A	6	0.072	0.028 *	0.018 *	0.227	0.468	0.002 **
Error	36						

x

F-test

* significant at 5% level.
 ** significant at 1% level.
 *** significant at 0.1% level.

y

Measured from soil line to top of plant.

z

Measured from soil line to base of pedicel.

Table A8 : Analysis of variance. Effects of temperature and fertilizer/amendment on nutrient content of 'Ace' Easter lily leaves, scorch experiment, 1978.

Source	df	N (%)	K (%)	P (%)	Na (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Zn (ppm)	Al (ppm)	F (ppm)
Total	47													
Temperature (T)	2	1.48	1.04	3.54**	2.08	72.65****	8.13***	3.16*	0.44	2.28	4.11**	0.9	2.39	8.4***x
Fertilizer/ Amendment (F/A)	3	1.16	1.44	14.37****	7.54****	57.1****	16.34****	2.33*	1.28	3.1**	6.05***	2.12	1.5	0.53
T x F/A	6	2.65**	2.08*	3.99***	2.23*	6.6****	2.98**	5.52****	2.56**	1.8	2.5**	1.4	5.48****	1.82
Error	36													

x F-test * significant at 10% level.
 ** significant at 5% level.
 *** significant at 1% level.
 **** significant at 0.1% level.

Table A9 : Analysis of variance. Effects of temperature and fertilizer/amendment on soluble salts, pH and elemental content of 4 growing media, 'Ace' Easter lily scorch experiment, 1978.

Source	df	pH	Soluble Salts (mmhos)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	F (ppm)	N (%)	K (%)	Ca (%)	Mg (%)
Total	47												
Temperature (T)	2	10.61****	4.74**	3.83**	0.38	1.46	52.03****	4.34**	7.40***	1.82	0.16	165.30****x	0.63
Fertilizer/ Amendment (F/A)	3	11.63****	1.58	3.23**	25.57****	7.57****	2.94**	2.22*	6.12***	7.42****	17.21****	6.09***	8.63****
T x F/A	6	6.18****	1.99*	0.60	3.11**	2.35**	16.08****	1.46	0.72	0.12	2.24*	34.52****	4.70****
Error	36												

x F-test
 * significant at 10% level.
 ** significant at 5% level.
 *** significant at 1% level.
 **** significant at 0.1% level.

Table A10 : Fresh weight (g) of 'Ace' Easter lily basal plate and roots over time^x, soil-less media experiments, 1977 and 1978.

Medium (M)	1977 ^y				1978 ^z			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Control	13.3	19.6	32.2	26.7	16.2	22.9	24.7	20.4
Ball Growing Mix	15.6	23.7	32.1	31.5	16.9	26.2	29.9	30.0
Jiffy-Mix	14.7	29.8	46.0	36.7	17.0	32.1	33.3	31.8
Jiffy-Mix Plus	16.1	26.9	42.0	25.3	21.6	35.3	32.3	32.1
Metro-Mix 200	14.2	23.6	40.7	28.6	21.3	26.1	27.0	24.1
Metro-Mix 300	12.0	19.6	33.5	24.5	23.9	34.7	33.1	30.4
Pro-Mix BX	16.2	25.0	33.3	31.4	19.4	33.4	26.4	32.9
Redi-Earth	14.8	27.0	27.5	33.1	18.8	32.4	26.0	43.5

^x Monthly measurements represent time, T.

^y T, M significant at 1% level.

^z M significant at 10% level, T significant at 1% level.

Table A11 : Fresh weight (g) of 'Ace' Easter lily shoots over time^x, soil-less media experiments, 1977 and 1978.

Medium (M)	1977 ^y				1978 ^z			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Control	5.6	14.9	47.9	83.6	8.3	37.8	108.2	97.2
Ball Growing Mix	3.2	20.6	63.0	105.0	11.1	54.1	134.9	124.9
Jiffy-Mix	4.3	25.0	60.8	123.6	9.4	60.5	122.3	106.7
Jiffy-Mix Plus	4.2	26.0	82.5	116.6	10.3	65.3	116.2	102.6
Metro-Mix 200	3.6	21.5	69.4	104.6	9.9	44.5	107.7	108.8
Metro-Mix 300	3.0	21.5	71.5	131.2	12.7	51.0	118.6	134.6
Pro-Mix BX	4.0	22.1	70.7	130.5	8.8	52.3	103.0	95.4
Redi-Earth	3.6	26.0	69.5	123.6	9.9	55.3	113.7	121.9

^x Monthly measurements represent time, T.

^y M, T x M significant at 1% level.

^z M significant at 10% level, T significant at 1% level.

Table A12 : Fresh weight (g) of 'Ace' Easter lily stem roots over time^x, soil-less media experiments, 1977 and 1978.

Medium (M)	1977 ^y				1978 ^z			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Control	-	0.3	7.5	17.1	0.4	4.5	16.5	16.9
Ball Growing Mix	-	1.6	19.7	16.0	0.0	9.6	20.7	27.8
Jiffy-Mix	-	0.8	19.1	28.8	0.0	11.9	29.1	45.7
Jiffy-Mix Plus	-	1.0	19.4	22.5	0.0	13.5	35.3	29.3
Metro-Mix 200	-	1.2	22.7	20.7	0.1	5.5	23.8	21.1
Metro-Mix 300	-	0.7	18.0	25.5	0.1	10.5	29.9	30.8
Pro-Mix BX	-	1.2	18.3	28.1	0.0	8.7	23.1	19.8
Redi-Earth	-	2.1	24.1	26.0	0.0	11.7	28.1	53.5

^x Monthly measurements represent time, T.

^y M significant at 5% level, M x T significant at 1% level.

^z M, T significant at 1% level.

Table A13 : Fresh weight (g) of 'Ace' Easter lily scales over time^x, soil-less media experiments, 1977 and 1978.

Medium (M)	1977 ^y				1978 ^z			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Control	77.7	69.5	60.8	41.9	70.9	40.4	45.5	45.9
Ball Growing Mix	68.3	63.8	44.0	38.2	67.5	54.7	44.8	51.2
Jiffy-Mix	72.2	60.3	47.1	36.6	63.1	66.2	48.8	56.3
Jiffy-Mix Plus	72.6	69.9	49.2	53.7	67.1	55.5	42.9	47.3
Metro-Mix 200	64.4	62.2	49.1	36.8	69.4	60.6	55.0	53.7
Metro-Mix 300	70.3	61.5	47.7	37.3	81.4	58.1	56.7	56.8
Pro-Mix BX	71.6	67.0	48.0	39.4	70.5	62.2	47.2	51.3
Redi-Earth	64.6	64.4	39.4	39.6	75.3	57.2	45.2	66.6

^x Monthly measurements represent time, T.

^y M x T significant at 1% level.

^z M x T significant at 5% level, T significant at 1% level.

Table A14 : Analysis of variance. Effect of growing medium on leaf loss, leaf scorch, scorch rating, root rot and disease rating of 'Ace' Easter lily, soil-less media experiment, 1978.

MEASUREMENT	ANALYSIS OF VARIANCE			
	Source	df	MS	F
Leaf Loss	Total	47	-	-
	Medium	7	519.94	5.54 *** ^x
	Rep	2	112.02	1.19
	Error	14	93.88	-
	Sampling	24	-	-
Scorch Count	Total	47	-	-
	Medium	7	1749.51	10.18 ***
	Rep	2	392.14	2.28
	Error	14	171.93	-
	Sampling	24	-	-
Scorch Rating	Total	47	-	-
	Medium	7	6.47	105.57 ***
	Rep	2	0.06	1.00
	Error	14	0.06	-
	Sampling	24	-	-
Root Rot	Total	47	-	-
	Medium	7	38.47	6.73 ***
	Rep	2	5.45	0.95
	Error	14	5.71	-
	Sampling	24	-	-
Disease Rating	Total	47	-	-
	Medium	7	13.14	1.07 NS
	Rep	2	0.77	0.63
	Error	14	12.29	-
	Sampling	24	-	-

^x F-test

* significant at 5% level
 ** significant at 1% level
 *** significant at 0.1% level
 NS not significant

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Table A15: Analysis of variance. Effect of growing medium on shoot length, leaf count and bud count of 'Ace' Easter lily, soil-less media experiment, 1978.

MEASUREMENT	ANALYSIS OF VARIANCE			
	Source	df	MS	F
Shoot Length	Total	47	-	-
	Medium	7	132.85	1.69 NS
	Rep	2	2982.15	37.87 **** x
	Error	14	78.75	-
	Sampling	24	-	-
Leaf Count	Total	47	-	-
	Medium	7	145.69	2.14 NS
	Rep	2	189.56	2.79 *
	Error	14	67.99	-
	Sampling	24	-	-
Bud Count	Total	47	-	-
	Medium	7	1.70	1.99 NS
	Rep	2	1.19	1.39 NS
	Error	14	0.85	-
	Sampling	24	-	-

x F-test * significant at 10% level
 ** significant at 5% level
 *** significant at 1% level
 **** significant at 0.1% level
 NS not significant

Table A16 : Analysis of variance. Effect of growing medium on salts, pH and elemental content of 8 growing media, soil-less media experiment, 1978.

Source	df	pH	Soluble Salts (mmhos)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	F (ppm)	N (%)	K (%)	Ca (%)	Mg (%)
Total	23												
Media	7	4.72 **	7.28 ***	8.98 ***	13.28 ***	4.54 **	11.27 ***	5.89 **	27.66 ****	5.95 **	1.95 NS	14.91 ***	32.69 *** ^x
Block	2	0.16	0.01	0.19	0.90	0.94	0.48	0.16	1.30	0.75	0.16	0.51	0.15
Error	14												

^x F-test * significant at 5% level
 ** significant at 1% level
 *** significant at 0.1% level
 NS not significant

Table A17 : Analysis of variance. Effect of growing medium on nutrient content of 'Ace' Easter lily leaves, soil-less media experiment, 1978.

Source	df	N (%)	K (%)	P (%)	Na (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Zn (ppm)	Al (ppm)	F (ppm)
Total	46 ^z													
Medium (M)	7	1.69	3.86**	17.07***	4.76***	13.68***	13.46***	51.39***	2.84*	2.34*	25.27***	27.28***	6.41***	4.35*** ^x
Rep	2	0.38	1.39	1.00	0.40	9.29***	0.38	0.67	1.38	0.04	3.61*	0.35	0.95	0.92
Position ^y (P)	1	5.91*	31.79***	55.60***	62.98***	20.58***	54.91***	16.61***	1.18	46.43***	34.31***	2.95	2.01	47.59***
M x P	7	1.86	1.38	1.02	1.47	1.96	1.53	2.90*	4.73***	2.12	3.31**	6.66***	2.13	1.18
Error	29													

^x F-test * significant at 5% level.
 ** significant at 1% level.
 *** significant at 0.1% level.

^y Plant shoots were divided into upper and lower halves.

^z Lost one degree of freedom due to an out-of-range factor value.

Table

ME

Leaf

Score

Root

Table A18 : Analysis of variance. Effect of growing medium on leaf scorch, leaf loss and root rot of 'Ace' Easter lily, soil-less media experiment, 1977.

MEASUREMENT	ANALYSIS OF VARIANCE			
	Source	df	MS	F
Leaf Loss	Total	47	-	-
	Medium	7	19.33	1.24 NS
	Rep	2	14.25	0.92
	Error	14	15.54	-
	Sampling	24	-	-
Scorch Count	Total	47	-	-
	Medium	7	632.71	4.65 **x
	Rep	2	190.40	1.40
	Error	14	136.09	-
	Sampling	24	-	-
Root Rot	Total	47	-	-
	Medium	7	15.42	1.46 NS
	Rep	2	43.27	4.09 *
	Error	14	10.57	-
	Sampling	24	-	-

x F-test

* significant at 5% level
 ** significant at 1% level
 NS not significant

Table A19 : Analysis of variance. Effect of growing medium on shoot length, leaf count, bud count and root growth of 'Ace' Easter lily, soil-less media experiment, 1977.

MEASUREMENT	ANALYSIS OF VARIANCE			
	Source	df	MS	F
Shoot Length	Total	47	-	-
	Medium	7	77.55	2.28 * x
	Rep	2	705.21	20.74 ****
	Error	14	34.00	-
	Sampling	24	-	-
Leaf Count	Total	47	-	-
	Medium	7	115.07	4.94 ***
	Rep	2	166.02	7.13 ***
	Error	14	23.28	-
	Sampling	24	-	-
Root Growth	Total	47	-	-
	Medium	7	1.47	1.06 NS
	Rep	2	2.36	1.70
	Error	14	1.39	-
	Sampling	24	-	-
Bud Count	Total	47	-	-
	Medium	7	1.50	1.96 NS
	Rep	2	1.31	1.72
	Error	14	0.76	-
	Sampling	24	-	-

x F-test

* significant at 10% level
 ** significant at 5% level
 *** significant at 1% level
 **** significant at 0.1 % level
 NS not significant

Table A20 : Analysis of variance. Percent air porosity of soil-less media.

Source	df	SS	MS	F
Total	23	2047.75	-	-
Treatment (media)	7 ^x	1668.14	238.31	9.42 ** ^y
Error	15 ^x	379.61	25.31	-

^x Loss of one degree of freedom due to one missing plot.

^y Significant at 1% level.

Table A21: Influence of temperature and media on surface growth x (mm) of Rhizoctonia solani.

Table A21: Influence of temperature and media on surface growth $\bar{x}$ (mm) of Rhizoctonia solani.

Medium	DAYS AFTER INOCULATION											
	5°C						17°C					
	1	3	5	7	9	11	1	3	5	7	9	11
Control	-	1.0	3.0	5.0	8.5	13.0	1.0	13.0	22.0	38.0	42.0	44.0
Ball Growing Mix	-	1.0	1.5	2.5	6.0	8.0	1.0	9.0	19.0	23.0	40.0	42.0
Jiffy-Mix	-	1.0	2.0	3.0	3.0	3.5	1.0	1.0	2.0	3.0	5.0	5.0
Jiffy-Mix Plus	-	1.0	1.0	5.0	9.0	9.0	1.0	6.0	20.0	32.0	42.0	43.0
Metro-Mix 200	-	1.0	4.0	5.0	10.0	10.0	1.0	5.0	5.0	9.0	32.0	36.0
Metro-Mix 300	-	0.5	1.0	2.0	6.0	7.0	1.0	10.0	16.0	27.0	40.0	42.0
Pro-Mix BX	-	1.0	3.0	5.0	6.0	6.0	1.0	9.0	13.0	26.0	43.0	44.0
Redi-Earth	-	1.0	1.0	2.5	7.5	7.5	1.0	5.0	6.0	30.0	43.0	44.0

 $\bar{x}$ Measured visible mycelial growth on media surface.

Table A22: Influence of temperature & media on surface growth $\bar{x}$ (mm) of Fusarium oxysporum.

Medium	5°C										17°C				
	DAYS AFTER INOCULATION														
	1	3	5	7	9	11	1	3	5	7	9	11			
Control	-	-	-	-	-	-	-	1.0	1.0	1.5	1.5	1.5	1.5		
Ball Growing Mix	-	-	-	-	-	-	-	1.0	1.5	2.0	1.5	1.5	2.5		
Jiffy-Mix	-	-	-	-	-	-	-	1.0	1.0	1.5	1.5	1.5	1.5		
Jiffy-Mix Plus	-	-	-	-	-	-	-	0.5	1.0	0.5	1.0	1.5	1.5		
Metro-Mix 200	-	-	-	-	-	-	-	1.0	1.0	5.0	5.0	4.5	4.5		
Metro-Mix 300	-	-	-	-	-	-	-	1.0	1.0	0.5	0.5	1.0	1.0		
Pro-Mix BX	-	-	-	-	-	-	-	1.0	2.0	2.0	3.0	3.0	3.0		
Redi-Earth	-	-	-	-	-	-	-	1.0	1.5	2.0	2.0	2.0	2.0		

 $\bar{x}$ Measured visible mycelial growth on media surface.

Table A23: Influence of temperature & media on surface growth $\times$ (mm) of Cylindrocarpon radicola.

Medium	5°C						17°C					
	DAYS AFTER INOCULATION											
	1	3	5	7	9	11	1	3	5	7	9	11
Control	-	-	-	-	-	-	-	-	1.0	1.0	2.0	2.0
Ball Growing Mix	-	-	-	-	-	-	-	-	1.0	1.0	1.0	1.0
Jiffy-Mix	-	-	-	-	-	-	-	-	0.5	1.0	1.5	1.5
Jiffy-Mix Plus	-	-	-	-	-	-	-	-	-	-	0.5	1.0
Metro-Mix 200	-	-	-	-	-	-	-	-	0.5	1.0	1.0	1.5
Metro-Mix 300	-	-	-	-	-	-	-	-	-	-	-	0.5
Pro-Mix BX	-	-	-	-	-	-	-	-	-	-	-	0.5
Redi-Earth	-	-	-	-	-	0.5	-	-	0.5	1.0	0.5	0.5

x Measured visible mycelial growth on media surface.

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