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EFFECTS OF WOOD FRAGMENT MULCHES AND DIFFERENTIAL SUPPLIES OF NITROGEN ON THE GROWTH AND CHEMICAL COMPOSITION OF *FEIJOA SELLOWIANA*, *LIGUSTRUM JAPONICUM*, AND TWO CLONES OF *CHRYSANTHEMUM MORIFOLIUM*.

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EFFECTS OF WOOD FRAGMENT MULCHES AND DIFFERENTIAL SUPPLIES OF NITROGEN ON THE GROWTH AND CHEMICAL COMPOSITION OF *FEIJOA SELLOWIANA*, *LIGUSTRUM JAPONICUM*, AND TWO CLONES OF *CHRYSANTHEMUM MORIFOLIUM*

A Dissertation

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by

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INTRODUCTION

The benefits attributed to mulching include soil moisture conservation, weed suppression, and modification of physical and chemical soil properties. In the case of decomposable organic mulches, the modification of chemical soil properties is often reported to create a nitrogen deficiency in plants and a consequent reduction in the growth of those plants (5, 35, 36). Because of this, recommendations about mulching plants with a decomposable organic mulch usually stress the importance of applying fertilizer nitrogen along with the mulch (14, 44, 48, 49). However, the limited amount of literature on the subject indicates the need for more factual data upon which to base these recommendations.

The objective of this study, therefore, was to determine the effects on the nutrient element composition and the growth of four indicator plants when mulched with two decomposable organic mulches and fertilized with differential levels of nitrogen. One mulch was woodshavings from lumber of the coniferous tree *Pseudotsuga menziesii*; the other was woodchips (Figure 1), derived primarily from prunings of the broad-leaved evergreen tree *Eucalyptus camaldulensis*.

Figure 1.--A typical woodchips mulch being examined by the author.

LITERATURE REVIEW

Even though relatively little research has been reported on the specific mulches used in this study, the voluminous amount of basic literature applicable to plant residue mulches in general provides valuable points of reference for interpreting the principal findings of this study.

Physical Properties of Soil

Temperature

The effects of mulching on soil temperature is well described in the literature (17, 32, 38). According to Jacks et al. (32), the usual temperature effect of a mulch, regardless of type, is to keep soil cooler in summer and warmer in winter. A leveling of fluctuations is also an effect of mulches on diurnal soil temperatures (17, 47).

In Israel, Lavee (38) found that mulch with a three-inch layer of medium-sized woodshavings resulted in a reduction of soil temperature in early August by as much as 20° F at a soil depth of one and one-half inches. Medcalf (47) found that mulch treatments lowered soil temperature around coffee plants in Brazil as much as 36° F (88° compared with 124° F).

Burrows and Larson (17) described how a mulch diminishes the amplitude of variation of temperature ordinarily found in bare soil. They also noted that the temperature differences between mulched and bare soil is greatest at the maximum temperature (day time) and least at the minimum temperature (night time). These conditions may be accounted for because of an interrelated source of heat energy from the sun during the day time and a lower conductivity of this heat by plant residues than by soil particles.

In studying the affect of temperature and moisture on nitrification in soil in Iowa, Parker and Larson (52) found that early in the growing season when soil temperature is in the range of 61-68° F, mulched soil was about two degrees cooler than bare soil. They indicated that this temperature differential contributed to greater activity of the nitrifying bacteria in the warmer soil and thus a greater accumulation of nitrate nitrogen. Such differences in nitrate accumulation were less evident where the temperature of the two soils was in the range of 77-86° F.

Shaller and Evans (61) and Moody et al. (50) noted that corn yields in the North Coastal United States were much smaller under mulch tillage than under a tillage system where the residues were incorporated into the soil. One might initially infer that the cause of this phenomenon was a lack of nitrate production under the mulch. However, these workers reported no significant improvement with application of fertilizer, especially of nitrogen. Later, Willis et al. (83) showed that equivalent corn growth resulted if soil temperature under a mulch is maintained at or near the temperature of the bare soil. They concluded that their results agreed in a general way with data of Lehenbauer (39) who found that for a range of temperatures from about 50 to 86° F there was an increase in oat seedling growth rate as the temperature increased, whereas from 86 to 90° F there was a decrease.

Van Wijk et al. (76) carried out uniform mulching experiments in Iowa, Minnesota, Ohio, and South Carolina. From these investigations, they showed that the lower soil temperature due to mulching was near the minimum for corn growth in the northern states, where the temperatures are cooler, but well above the minimum in South Carolina, where warmer temperatures prevail. The result was reduced corn growth everywhere but in South Carolina, the most southerly state in the study.

More severe frost injury has been reported on coffee plants by Medcalf (47) in mulched plots than in bare soil plots. This resulted from the mulched soil absorbing and storing less solar radiation during the day and consequently a lesser amount of outward radiation or transmission of the heat from the soil during the nocturnal hours, resulting in the development of a colder layer of air directly above the mulch. Despite this, only those kinds of plants that are of borderline hardiness in a particular area would ordinarily be affected by this slightly lower ambient temperature in the vicinity of the mulches.

Moisture

Well-documented evidence has been presented by Jacks et al. (32) that one of the important effects of an organic mulch is in conserving moisture by increasing water infiltration into and storage within the soil. Typical of the results often reported are the data of Table 1, which show the percentage of moisture conserved in mulched and unmulched soil. The value of mulching as a means of conserving moisture is further illustrated by a Puerto Rican study by Vicente-Chandler (77) in which the average monthly losses of water by evaporation from bare soil and soil mulched with sugar cane trash was 2.12 and 0.90 inches, respectively. The savings of water was estimated to equal three inches of irrigation water per month.

TABLE 1.--Effect of wheat straw and different tillage treatments on storage of water in the soil during one growing season (Data of Duley and Russel, 19)

Treatment	Rainfall conserved	
	Surface inches	Percent
Land disked, no straw	3.49	19.5
Fresh straw, 2 tons, disked	6.92	38.7
Fresh straw, 2 tons, on the surface	9.72	54.3

It is apparent that an essential quality of a mulch is that its physical texture must be course enough to permit rain or irrigation water, as the case may be, to penetrate it freely. Medcalf (47) demonstrated that moisture conserving effects of a mulch was considerably greater in the upper 6-inch soil horizon, tapering off to practically no effect in the 24- to 36-inch horizon.

Chemical Properties of Soil and Plants

Physiology and Biochemistry of Organic Matter Decomposition

The physical and chemical changes which mulches or any organic matter undergoes when degradated to simple compounds by soil organisms is termed decomposition (49, p. 230). A study of the physiology and biochemistry of this process is fundamental to a review of literature in succeeding sections. It logically begins with a consideration of some basic principles involved in the biological system.

Life on earth is an equilibrium between the storing of energy through photosynthesis and the release of that energy through biological oxidation.[1] In photosynthesis, solar energy splits water into hydrogen and oxygen whereupon the hydrogen is utilized in reducing carbon dioxide, (CO_2) to the level of carbohydrates. In the process, oxygen is liberated. Biological oxidation is essentially the reverse of photosynthesis. It is accomplished by a union between the hydrogen of carbohydrates (or any other organic substrate) and gaseous oxygen to form water, in which process carbon dioxide is liberated (19, p. 284).

The *primary reservoir* of photosynthetic energy ordinarily assumes morphological forms which we identify as green plants. Upon death, this reservoir of energy undergoes "reassignment," by biological oxidation in the presence of enzymatic catalysts, either to a *secondary reservoir*, in this case animals or lower plants, or else into the earth's atmosphere as heat.[2] Mulches derived from previously living plants constitute a portion of the primary reservoir of photosynthetic energy; *soil microorganisms*[3] that decompose mulches a portion of the secondary reservoir. During the energy-reassignment process, the by-products, especially

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[1] This basic concept, known as the carbon cycle, is represented by the chemical equation:

$$6\ CO_2 + 6\ H_2O \underset{\text{Biological oxidation (energy released)}}{\overset{\text{Photosynthesis (energy stored)}}{\rule{16em}{0.4pt}}} C_6H_{12}O_6 + 6\ O_2$$

[2] Except for conditions where new cellular material is formed, most of the energy released on biological oxidation appears as heat (21, p. 929).

[3] Soil microorganisms include bacteria, such as *Bacillus subtilis* and *B. mycoides*, which are cosmopolitan in nature; fungi; actinomycetes (molds); protozoa; and higher animal forms such as nematodes, earthworms, and insect larva (79, p. 34-38). Of the bacteria, only the heterotrophic kind derives the carbon and energy from the oxidation of organic compounds: the autotrophic kind derives these two items from the oxidation of inorganic material (79, p. 60).

nutrient elements, may also be utilized in the secondary reservoir or, if in extra supply, utilized anew in the primary reservoir (79, p. 101).

According to Bollen (10), "microbial decompositions of organic matter are ultimately more or less complete oxidations carried on by the organisms primarily to secure growth energy." The rate and extent of the decomposition is influenced by seven factors of the environment: moisture, temperature, aeration, pH, biotic factors, inhibiting factors, and nature of the organic matter (12, p. 6). Since the nature of the organic matter was one of the controlled variables in this study, two characteristics of it, the carbon-nitrogen ratio and the decomposability, will be considered in more detail, starting with the carbon-nitrogen ratio.

Organic matter consists of three basic constituents; carbohydrates, lipids, and proteins.[4,5] While the elements of carbon, hydrogen, and oxygen are common to all of them, only the proteins and their derivatives contain nitrogen. The amount of nitrogen in comparison with carbon in organic matter is commonly referred to as the carbon-nitrogen ratio.

In higher plants, the carbon-nitrogen ratio ranges between as little as 10 to more than 1,000 on a dry weight basis (Table 2).

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[4] In general, the degradation and synthesis of carbohydrates and lipids are a function of the actinomycetes; the bacteria are correspondingly active with proteins (14, p. 40).

[5] Krebs and Kornberg (36) have presented a concise yet comprehensive survey of the energy transformations from these basic organic materials.

TABLE 2.--Carbon-nitrogen ratios of some plant residues (Data of Bollen, 11)

Material	Total carbon, %	Kjeldahl nitrogen, %	C/N
Alfalfa hay	43.15	2.34	18
Bentgrass clippings	43.22	3.23	13
Corn cobs	46.87	0.45	108
Douglas-fir			
420-year-old tree			
Cones	49.17	0.37	133
Needles	55.75	0.96	58
Bark	53.97	0.11	491
Sapwood	49.36	0.09	548
Heartwood	51.51	0.12	429
Sawdust, mill run			
Weathered 2 months . . .	49.84	0.08	623
Weathered 3 years	47.01	0.33	142
Moss peat	48.29	0.83	58
Western hemlock sawdust . . .	49.74	0.04	1244
Wheat straw	44.70	0.12	373

As for the decomposibility of organic matter, compounds such as sugars, starches, and simple proteins are known to be easily decomposed,- while lignins, fats, and waxes are the least readily decomposed by microorganisms (16, p. 131). Since CO_2 and water, along with energy, are the final products of microbial decomposition, workers often assess the decomposibility or rate of decomposition of organic matter by measuring how much CO_2 evolves from it (13, 31).[6] Using this method, Allison et al. (2,4) found wide differences in the decomposition rate of 28 kinds of woods during a 60-day period. On the basis of milligrams of CO_2 evolved per kilogram of wood decomposed, they obtained such CO_2 values as follows: redwood, 5.3; douglas-fir, 11.2; shortleaf pine, 50.0;

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[6] This is essentially a measure of the amount of energy that has been released for "reassignment" since the carbon content of organic matter is indicative of the energy potential therein.

white oak, 49.1; and hickory, 48.1 (4). They attributed these wide differences to variations in the chemical composition, especially the lignin, alpha-cellulose, and resins of the woods.

As pointed out above, there may be pronounced differences in the carbon-nitrogen ratio and the decomposibility of organic matter. We shall now consider how these differences may be reflected in soil nitrogen and in growing plants. Again, the carbon-nitrogen ratio will be considered first.

As energy undergoes "reassignment" to the microorganisms, usually proportionately more nitrogen to carbon is utilized in the growth of the microorganisms than is available from the organic matter. This is because the protoplasm of the decomposing microorganisms comprises 45 to 55 percent carbon and 5 to 10 percent nitrogen on a dry weight basis; carbon-nitrogen ratios of between 10 and 5. In such cases the microorganisms acquire nitrogen elsewhere to supplement that available from the organic matter. Usually this is the nitrogen from the soil, the result of which is the "tying up" or immobilizing of mineralized or soil nitrogen so that it is no longer available for absorption by higher plants.

Bollen (11) stated that the optimum decomposition of organic matter in soils results when the carbon-nitrogen ratio of the organic matter is approximately 20. That ratio is also recognized as the practical value below which immobilization of the soil nitrogen is usually minimal (5). Thus, alfalfa hay, which Bollen found to have a carbon-nitrogen ratio of 18, apparently would be decomposed without the microorganisms requiring any soil nitrogen.

An estimation of the amount of soil nitrogen that may be immobilized during decomposition of an organic material must take into consideration not only the carbon-nitrogen ratio of a material but also the decomposibility of that material. Decomposition of organic matter with a wide carbon-nitrogen ratio ordinarily should result in the immobilization of much soil nitrogen. However, the extent of immobilization is usually less than would be expected because many such wood residues, especially those from coniferous trees, consist of as much as 60 to 70 percent of inherently resistant lignocelluloses (44). For example, Allison et al. (4) found that the amount of soil nitrogen that was immobilized was somewhat proportional to the ease of decomposition, based on the amount of CO_2 evolved during decomposition (Table 3).

TABLE 3.--Nitrogen requirements of microorganisms in the decomposition of various woods in soil (Data of Allison et al., 4)

Wood	Composition C (%)	Composition N (%)	Nitrogen immobilized for the indicated time period in days: 10 (% of weight of wood)	20	40	80	160	CO_2 evolved in 60 days
Redwood	49.9	0.06	0.13	0.22	0.21	0.31	0.34	5.3
Douglas-fir	48.1	0.05	0.17	0.21	0.07	0.14	0.30	11.2
Shortleaf pine	45.0	0.13	0.78	1.00	1.27	1.30	1.13	50.0
White oak	46.9	0.10	0.62	0.96	1.19	1.15	1.09	49.1
Hickory	46.8	0.10	0.78	1.00	1.12	1.17	1.07	48.1

It is revealing to compare other data relationships of Table 3, also. For one thing, while the carbon-nitrogen ratio for the pine, oak, and hickory woods is about one-half as wide as it is for the redwood and douglas-fir woods, the amount of CO_2 that evolved in 60 days was at least five times more for the former three woods than for the redwood and douglas-fir woods. Had the decomposition rate of each wood corresponded to its carbon-nitrogen ratio, the CO_2 should have been about half as much for the redwood and douglas-fir woods as for any of the other three. Thus, it is reasonable to conclude that, of the five woods, the former two are less readily decomposed than the others.

Incidental to the above considerations, during the initial period of decomposition of these five woods there was a step by step increase in the amount of nitrogen that was immobilized (Table 3). This is an indication of the increase in the population of the decomposing microorganisms. Presumably, as decomposition progressed, the microorganism population peaked after which the amount of immobilized nitrogen declined and the soil nitrogen increased. Allison and Klein (3) found that sucrose and wheat straw were markedly different in terms of the rate of microorganism population increase during decomposition of each. Peaking of the microorganism population was reached 2 days after the beginning of decomposition of the sucrose and 20 days for the wheat straw.

The above findings and those of many other investigators indicate the difficulty in predicting the amount of soil nitrogen that would be immobilized during the decomposition of organic matter.[7] In a study of the carbon-nitrogen ratio in organic materials in relation to the availability of the nitrogen therein, Rubins and Bear (59) concluded

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[7] With a few organic materials, decomposibility may be secondary to their phytotoxic properties in affecting plant growth. Allison et al. (1) tested woods and barks of 28 kinds of trees for toxicity to garden peas grown in limed soil-sawdust mixture under conditions of adequate nitrogen. Douglas-fir, as well as most other kinds showed no significant toxicity either to germination or early growth when used at rates of 1 and 2 percent. Toxicity symptoms were observed only with woods and/or bark of California incense-cedar, eastern white pine, red-cedar, ponderosa pine, loblolly pine, and yellow poplar. Apparently, Baldsiefen (7) also recognized the phytotoxicity of eastern white pine wood.

that the principle of the carbon-nitrogen ratio may be applied in interpreting the availability of water-soluble fractions of organic nitrogen. But with water-insoluble fractions they said:

> Ease of decomposition and relative abundance of the associated carbonaceous material must be considered as well as decomposibility of the insoluble nitrogenous material itself, before a rigid application of carbon-nitrogen ratios to availability can be made.

Bollen (11) reached the same conclusion. He stated:

> The practical application of the carbon-nitrogen ratio to problems involving organic matter decomposition requires consideration of qualitative as well as quantitative factors.

Speaking about such plant residues as douglas-fir sawdust, he said:

> Although . . . exceptionally low in nitrogen and high in carbon, the additional nitrogen necessary to offset microbial requirements during decomposition is much lower than indicated by the overall carbon-nitrogen ratio.

Humus

The final stage of decomposition of organic matter is termed humification. Of it Bollen (12) said:

> This stage is characterized by the formation and gradual continual decomposition of the humus complex. Nitrogen assimilated by microorganisms is reassimilated by succeeding generations and repartitioned until much of it accumulates as protein of dead bacterial cells. Bacterial protein is resistant to decomposition and most of the nitrogen of humus is in this form. The non-nitrogenous portion of humus is composed largely of lignin, hemicellulose, and various other resistant substances . . . Only actinomycetes and certain non-sporeforming bacteria can attack ligno-proteinate and other humus complexes. As a result the nitrogen is only slowly but continuously liberated, maintaining for higher plants a supply of available nitrogen that bridges the intervals between additions of fresh organic residues.

The amount of humus remaining in the soil following decomposition of plant residues depends, therefore, upon the chemical makeup of the material.

Soil Reaction

In the decomposition process, various kinds of intermediate acidic compounds are produced. This has led to the supposition that soil acidity is increased with the addition of organic material. Contrary to this common belief, it is well established in the literature that the addition of fresh organic matter to the soil does not lower the soil pH (28, 33, 35, 43, 44, 47, 57, 60, 71, 75). According to Salomon (60), the decomposition products, ordinarily termed ash, have a greater effect on soil reaction than do mulches *per se*. He stated:

> Since the ash of plants contains more basic than acidic constituents, the ultimate effect should be towards a less acidic pH. If organic acids are initially in excess of bases, a temporary increase in soil acidity may be expected. However, organic acids decompose readily.

Medcalf (47) reported that three years after initial mulching of coffee shrubs in Brazil, the soil was appreciably more alkaline than at the beginning. The pH increased the greatest amount in the 0-2-inch soil horizon, the change being apparent, however, down to 6 inches.

Nutrient Elements

Determining the amount of nutrient elements in the soil is a sedulous method of evaluating cultural practices. The effect of mulching on the concentration of these elements in the soil, and the alteration of the availability of them to growing plants, has received substantial study (6, 28, 32, 35, 71, 82).

Within the past two to three decades soil evaluations of cultural practices have been supplemented with determinations of the concentration of the nutrient elements within the plants grown under such cultural practices (65). This technique, known as *plant* or *tissue* analysis and sometimes more specifically as foliar analysis when foliage of the plant is used as is ordinarily the case, has been shown to "reflect what the plant has obtained from the soil in relation to its growth up to the time of sampling the plant" (74).

Such information may provide a picture of the adequacy of a nutrient element or it may provide, as it does in this study, a means of comparing the affects of various cultural practices on the growth and the concentration of various nutrient elements within the plants.

Comprehensive reviews of plant analysis have been prepared by Macy (45), Goodall and Gregory (25), Lundegårdh (42), Smith (65), and Ulrich (72). Selected excerpts, with citations usually omitted, from the more recent of these reviews, that by Smith (65), follows, in order to provide additional orientation for the interpretation of the results of this study.

> The physiological basis of tissue analysis is dependent on two general processes: (a) the absorption and distribution of minerals by plants and (b) a quantitative relation between absorbed nutrients and growth . . .
>
> In the early work on foliar analysis emphasis was placed on nutrient balance and the intensity of nutrition (63, 69). While the logic behind this concept is reasonable, no one has ever shown that maximum growth or yield occurs only upon the coincidence of a specific intensity of each element within a plant . . .
>
> Nearly all recent work hinges on a more flexible concept of nutrition having as its starting point an area, or narrow range, separating deficiency amounts from adequate amounts of each element . . . Ulrich (called this) the "critical nutrient level." . . .
>
> The mineral composition of a tissue is dynamic since it is subject to the physio-chemical changes manifest in growth processes. Some elements are present in high concentration in young tissue and are diluted as the tissue enlarges. Others are present in low concentrations in young tissue and gradually increase. The accumulation of dry weight dilutes all elements unless an influx of mineral offsets this effect.

> Plants of different types differ widely in both nutrient requirements and the ability to absorb the various elements from a common medium . . .
>
> Next to the supply of elements, the physiological age of tissue is probably the most important factor affecting the mineral composition of a given species. The preponderance of data show that each element has a characteristic pattern that accompanies the aging of tissue. The trend is not altered fundamentally by soil or cultural factors, but may be displaced upward or downward by the level of supply . . . the concentration of N, P, K, Cu, and Zn are greater in young tissues than in old while the reverse tends to be true for (Ca, Mg, Mn, Fe, Al, and B) . . . Leaves formed in the spring and those developed later during the summer or fall, are fairly similar in composition if they are of the same chronological age . . .
>
> Tissue analysis frequently shows reciprocative effects between pairs of anions and pairs of cations. One effect that has been widely reported from various parts of the world is the decrease in leaf P resulting from an increase in N supply. Another effect is that which occurs among the various base elements--K, Ca, and Mg. Fe and Mn antagonism has long been recognized . . .
>
> An opposite effect wherein the increase of one element results in a simultaneous increase in a second, has been termed synergism . . . Examples . . . are: simultaneous increases in Na and K from applied K, increases in Ca and Mg from applied Ca . . . or increases in N and Mg from applied N . . .
>
> Table (4) illustrates how extensively and in what direction, the mineral pattern of leaves may be modified by increasing the supply of one essential element.

The uptake of nutrient ions, i. e. the net movement of them into the plant regardless of the particular method (intake and absorption also used in the same meaning), and accumulation (movement of ions against a concentration gradient, generally as a result of active transport) are affected, in part, by the interaction between ions. In _Mineral Salts Absorption in Plants_, Sutcliffe (68) describes the interrelationship of the different kinds of ions, noting that when two or more of them with the same electrical charge are present in the external medium, there may be either antagnostic or synergistic affects. For this reason, the concentration of a nutrient in the soil has considerable relevance if influenced by mulching practices.

TABLE 4.--General effect of an applied element on the mineral composition of citrus leaves (Data of Smith, 65)[1]

Element added	Elements measured in the leaves						Total number
	N	P	K	Ca	Mg	Mn	
N	+	-	-	+	+	-	6
P	0	+	+	-	-	0	4
K	-	0	+	-	-	0	4
Ca	0	0	-	+	0	?	2
Mg	0	0	-	-	+	+	4
Mn	0	0	+	0	-	+	3
Total number	2	2	6	5	5	3	23

[1] Increased concentration in leaf is indicated by (+); decrease by (-); no change by (0).

Nitrogen

More than any other element, the concentration of available nitrogen in the soil is profoundly affected by mulches. Roberts and Stephenson (57) reported less nitrate nitrogen for as long as four years following incorporation in the soil of from three to four inches of douglas-fir sawdust. With alder sawdust, however, the depressive effects lasted no longer than 3 years. The depression was least pronounced when these two materials were used as surface mulches although fertilizer nitrogen was still necessary for satisfactory tomato growth.

Within 12 to 18 months after mulching coffee shrubs with hay, Medcalf (47) observed definite trends during the next two years of less nitrogen in the leaves of plants for all mulch amounts. The least foliar nitrogen (about 15 percent less than control plants) was in the plants that were mulched the heaviest.

Lunt (44) found only the first crop of beets following mulch treatments of oak-hickory, ash-birch, or pine woodchips required fertilizer nitrogen to prevent nitrogen deficiency.

Kirch (35) studied the effect of a soil-incorporated 3-inch volume of douglas-fir sawdust on corn growth in Oregon. All plots, sawdust-treated and check, were irrigated simultaneously by automatic sprinkler. He reported that the foliar nitrogen of the corn was 2.55 percent in the check plots and 2.10 percent in the sawdust-treated plots when averaged over 0, 400, 800, and 1600 pounds of nitrogen per acre. Moreover, the corn plants in the sawdust-treated plots were much smaller throughout the period of growth.

Burrows and Larson (17) reported that the concentration of nitrogen in the middle of June in corn in an Iowa experiment varied indirectly with the amount of chopped corn stalks applied to the soil.

Phosphorus

The affect of organic matter on the availability of phosphorus in soil has been the subject of numerous investigations. Gerretson (24) found microbial activity in rock phosphate increased the availability of phosphate phosphorus. Several investigators (24, 64, 78) have reported that phosphorus added to the soil with organic matter has greater availability than the same amount of phosphorus added without organic matter.

Other investigators (26, 57, 71, 80, 82) have shown pronounced increases in available phosphorus in the soil with the application of organic mulches; these effects being apparent for as long as 10 years following mulching.

Dalton et al. (18) and Weeks et al. (82) attributed the greater availability of phosphorus in the presence of organic matter to certain metabolic products of microbial decomposition forming stable complex molecules with the iron and aluminum that, in acid soils, are responsible for phosphate fixation.

Fuller et al. (23) reported that the rate of availability of the phosphorus of crop residues was inversely related to the stage of growth-maturity of the residues. That is, growing plants derived more phosphorus from succulent than from more aged residues.

Wander and Gourley (80) reported a slight increase in phosphorus in the foliage and fruit of apples grown under hay mulch in comparison with clean cultivation.

Gerretson (24) studied the influence of soil microorganisms on the amount of phosphorus absorbed into plants. He found a substantial increase in the uptake of this nutrient in the presence of soil microorganisms. This increase resulted primarily from the solubilizing of the phosphate compounds by the microorganisms.

In field plot trials with coffee shrubs in Brazil, Lott et al. (40) found that the quality of phosphorus in foliage increases directly with the increase in quantity of grass mulch applied (0.095, 0.114, and 0.147 percent phosphorus on a dry weight basis for 0, 21, and 85 tons per acre of applied mulch).

Not all of the workers have reported increased phosphorus in plants following mulching. Burrows and Larson (17) found no significant change in the concentration of phosphorus in corn plants as a result of mulching with chopped corn stalks at rates of 0, 1, 2, 4, and 8 tons per acre. They attributed the much smaller size of the mulched plants to lower soil temperatures during the initial growth phase of the corn.

In an experiment of mulching tung trees with what the authors called alyce clover, Sitton et al. (64) indicated that fertilizer nitrogen did not significantly alter the average amount of foliar phosphorus although for three of the five years of the experiment the foliar phosphorus trended downward with a corresponding rise in foliar nitrogen.

Potassium

There is general agreement in the literature, with one exception, that decomposable organic residue mulches increase the availability of available potassium (26, 47, 57, 64, 71, 80, 81, 82). The exception was where there was no change in the available potassium with the application of a 3-inch layer of douglas-fir sawdust (35).

In reference to orchard soil mulching, Sitton et al. (64), Wander and Gourley (81), and Wander et al. (82) reported that, with clean cultivation, there was much less exchangeable potassium in unmulched than in mulched soil. Wander and Gourley (81) found 113, 23, and 63 ppm of available potassium at depths of 0-6, 6-12, and 12-18 inches, respectively. At comparable depths, the available potassium with wheat straw mulch was 137, 102, and 125 ppm.

Tukey and Schoff (71) investigated the affects of decomposable and non-decomposable mulches in comparison with check treatments of grass sod and clean cultivation in Indiana. Maintaining a 6-inch mulch depth during the course of the experiment, after a 5-year period they found that the soil beneath sawdust and other decomposable organic mulches had significantly more potassium than the soil in the check plots. No significant differences were observed in their data between glass fiber or other non-decomposable mulches and the check treatment.

None of the foregoing literature indicated whether the difference in amounts of potassium was of sufficient magnitude to result in other than desirable concentrations of potassium within plants.

In general, any increase in potassium in the soil following mulching results in a corresponding increase of potassium in the foliage of plants growing therein (6, 47, 64, 80). However, workers have reported that foliar potassium of corn plants was unchanged with applications of mulches of either sawdust or chopped corn stalks (17, 35).

Sitton et al. (64) reported that a mulch of alyce clover in a Mississippi tung orchard substantially increased potassium uptake in the tung trees without seriously lowering magnesium uptake. Baker (6) found a pronounced and comparable increase in foliar potassium of apple trees that had been mulched with either decomposable materials, such as straw, manure, and sawdust, or such non-decomposable materials as cinders and glass-wool. He decided that, on the basis of these results, the utilization of soluble potassium from the mulching material--the usual reason given for higher foliar potassium due to mulching--is less important than the probability that mulches per se result in a more extensive development of the plant feeder roots into the upper soil.

Baker also suggested that less drying out of the soil under a mulch may render the potassium more constantly available than would be the case otherwise.

Sodium

The affects of mulches on the availability of sodium in soil has seldom been reported. Nor is there any indication in the literature about the affects of mulches on foliar sodium.

Calcium

Medcalf (47) and Wander and Gourley (80) found increases in available calcium as a result of mulching. Sitton et al. (64) and Tukey and Schoff (71) found no significant difference in available calcium between decomposable and non-decomposable mulches and check treatments throughout a 5-year period, nor did the former workers find any change in foliar calcium.

Magnesium

No clear-cut pattern emerges in the literature concerning the differential availability of magnesium in soil due to mulching. Wander and Gourley (80) found a concentration of approximately 100 ppm at 3- and 9-inch depths in cultivated soil whereas soil mulched with wheat straw had approximate values of 175 ppm at all depths.

In comparison with no-mulch treatment, a Savannah very fine sandy loam soil in Mississippi mulched with alyce clover and native grass was reported by Sitton et al. (64) to have had a greater amount of exchangeable magnesium in the 0-6 inch depth but not deeper. Similar effects were reported by Latimer and Percival (37). Tukey and Schoff

(71) found no difference in magnesium availability in soil under decomposable and non-decomposable mulches and clean cultivation after 5 years.

In England, Goode and White (26) reported a depression in soil magnesium under straw mulching at the end of 5 years. Likewise a decrease in foliar magnesium of apples under grass mulch compared with trees under clean cultivation was reported by Wander and Gourley (80).

Although Sitton et al. (64), as previously noted, reported no appreciable decrease in foliar magnesium as foliar potassium increased in tung trees in the presence of an alyce clover mulch, Robinson and Chenery (58) found that mulching with either napiergrass (Pennistemon purpureum) or coffee husks had a strong tendency to induce magnesium in coffee plants. They attributed this to an antagonistic effect of the exchangeable potassium in the soil.

Manganese

Parker (51) made an extensive review of the literature about the influence of mulching on manganese in plants. From the evidence he presented, it appears reasonably conclusive that mulching can cause a reduction in the availability of manganese in the soil. This may be due, among other things, to the lower soil temperature and the greater amount of soil moisture that often are associated with a mulching program. Fujimoto and Sherman (22) and others (47, 51) indicated that the maintenance of a higher moisture level in mulched soil, compared with clean cultivation, results in there being comparatively less foliar manganese in the mulched plants. This, they suggested, is because of less availability of manganese in the hydrated form (22).

Fifteen days from the date of corn planting in an experiment in Iowa, Parker (51) found that the mulched plants had 85 ppm manganese compared with a manganese level of 145 ppm in unmulched plants. Indicative of the fact that the 85 ppm represented a deficiency was the 1.50 milligrams per gram of a-amino-nitrogen compared with 1.26 milligrams per gram in unmulched plants. According to Steward et al. (67) a manganese deficiency in a plant blocks protein synthesis resulting in an accumulation of a-amino-nitrogen.

Medcalf (47) reported that two years after applying a grass mulch to coffee shrubs, the control plants had a mean concentration of 515 ppm of manganese compared with 188 ppm or less than one-half as much manganese as in the unmulched plants.

MATERIALS AND METHODS

Location of the Experiment

The experiment was carried out at the Davis campus of the University of California. The mean annual rainfall for the area is 16.65 inches (90-year average) with about 75 percent of it occurring within the winter period of December through March. July and August are usually rainless.

The temperature ranges from an average monthly maximum of about 103° F in June to a minimum of about 25° F in December and January. Frosts are of infrequent occurence and snows are rarely recorded.

The topography of the area of the experiment was level. The soil was an alluvial fine sandy loam of the Yolo series. Its geological origin was from sedimentary rock sources in the Coast Range mountains about 20 miles west of Davis. The soil profile was of uniform material several feet deep. Drainage was good. For many years prior to establishing the experiment, the land had been under uniform cropping practices; most recently alfalfa and before then a peach orchard operation.

The values of six chemical properties of each of 10 soil samples that were taken at random from within the experiment area a few days before making any treatments are shown in Table 5.

TABLE 5.--Chemical composition of the soil in the area of the experiment prior to treatment

Sample	Organic matter	pH	Nitrate nitrogen	Total nitrogen	Available phosphorus	Available potassium
	%		ppm	%	ppm	ppm
1	4.3	6.7	25.6	0.08	31.5	420
2	4.6	6.8	30.4	0.09	29.7	420
3	4.9	6.9	29.6	0.10	28.8	420
4	5.3	6.8	32.0	0.13	30.6	480
5	4.2	6.8	26.4	0.08	28.8	470
6	4.5	6.7	24.0	0.08	28.8	500
7	4.9	6.7	24.0	0.08	29.7	430
8	5.1	6.8	24.0	0.10	27.9	450
9	4.5	6.8	28.2	0.12	27.0	420
10	4.9	6.7	28.0	0.09	27.9	430
Mean	4.7	6.8	27.1	0.10	29.1	454

The weight of soil is ordinarily expressed as 2,000,000 pounds per acre plow-share or 6 2/3-inch depth. The weight in pounds of some of the soil constituents of Table 5 in that amount of soil would be as follows:[8]

Organic matter	94,000
Nitrate nitrogen	135
Total nitrogen	1,920
Available phosphorus . .	58
Available potassium . .	908

Assuming that as much as 95 percent of the total nitrogen of the soil was in organic form, the composition of the organic matter would have been approximately 2 percent nitrogen (1920 x 0.95 ÷ 94,000). This is somewhat low since the amount indicated for organic matter is usually 5 to 10 percent (10, 11, 17).

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[8] The nitrate nitrogen value is for the top 15-inch horizon of soil; the volume estimated to have been penetrated by irrigation water.

Treatments and Experiment Design

The treatments were bare soil, representing the check, and mulches of woodshavings and woodchips upon which was superimposed a broadcast application of calcium nitrate fertilizer at elemental nitrogen rates of 0, 1, and 2 pounds per 1000 square feet, the equivalent of 0, 45, and 90 pounds per acre, respectively. This comprised nine different mulch-fertilizer treatments, all of which were arranged in a complete-block factorial design with six replications for each; a total of 54 plots (3 mulch levels x 3 fertilizer levels x 6 replications = 54 plots). Each plot was 143 square feet in area; 13 feet long in a north-south direction and 11 feet wide. The plot plan is shown in Figure 2.

The bare soil or no mulch treatment was never cultivated and was kept weed-free by occasionally spraying any weed seedlings with a dinitro-in-oil contact herbicide.

The woodshavings consisted of locally available planing mill residue from new kiln-dried lumber of douglas-fir, Pseudotsuga menziesii. It will be recalled that various workers (2, 4, 11, 13) have shown that although douglas-fir wood has an unusually wide carbon-nitrogen ratio of as much as 700, it is not readily decomposed because of a high ligno-cellulose content.

The woodchips were derived from branches and limbs recently pruned from an assortment of landscape trees, but primarily from the broad-leaved evergreen Eucalyptus camaldulensis. These prunings were passed through a portable mechanical chipper[9] which reduced them to chips.

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[9] Since the introduction of portable mechanical wood chippers about 1950, an increasing number of arborists and others concerned with trees have been reducing tree prunings to woodchips thereby reducing the bulk about five times (34).

Composition data of material believed to be reasonably comparable to the mulch material are shown in Table 6. On the basis of these data and the foregoing estimated composition of woodchips of the *Eucalyptus*,

TABLE 6.--Amount of certain nutrients in woodshavings of *Pseudotsuga menziesii* and various fractions of prunings of *Eucalyptus camaldulensis*

Material[1]	Composition, estimated percentage dry weight basis	Nutrient element percentage dry weight basis[2]					
		Nitrogen		Phosphorus		Potassium	
		Observed	Weight equivalent per 100# material[4]	Observed	Weight equivalent per 100# material[4]	Observed	Weight equivalent per 100# material[4]
Pseudotsuga menziesii Wood (woodshavings)	100	.04	.04	.02	.02	.05	.05
Eucalyptus camaldulensis Wood	70	.29	.203	.04	.028	.09	.063
Bark	12	.50	.060	.05	.006	.38	.046
Leaves	15	1.52	.228	.08	.012	.66	.099
Fruit	3	1.15	.034	.14	.004	.82	.025
TOTAL (Woodchips)	100		.52		.05		.23

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[1] Obtained July 17, 1965; the newly-produced Pseudotsuga woodshavings from the same source as the woodshavings used in the experiment, the *Eucalyptus* fractions from trees growing near Davis, California. Prepared and analyzed according to the methods described later.

[2] Underlining is for comparison convenience.

[3] Each datum is a mean of four observations.

[4] Observed datum x composition datum / 100

inference may be made that, compared with the woodshavings mulch, the woodchips mulch contained about 12 times more nitrogen, 2 times more phosphorus, and 4 times more potassium (Table 6).

The mulches were applied during the week of June 22, 1959, a few days after the soil had been disk-cultivated.[10] Both mulches were applied in a layer-depth of about 2½ inches or about one cubic yard per plot (7 cubic yards per 1000 square feet or 300 cubic yards per acre). This was a per acre application of about 25 tons of woodshavings and 40 tons of woodchips since the respective dry weight of each was 165 and 270 pounds per cubic yard. Alternately, it constituted a nitrogen application of about 20 pounds per acre from the woodshavings and 400 pounds per acre from the woodchips.

The mulch/fertilizer treatment combinations, the factor symbols, and the amount of nitrogen supplied by each are shown in Table 7.

Application of the calcium nitrate fertilizer was delayed until September 9, 1959, since it was thought that applying it earlier might have an adverse affect on the young chrysanthemum plants, particularly the unmulched ones. The fertilizer was broadcast directly upon the mulch or, in the unmulched plots, upon the bare soil.

Each of the 54 plots was planted with 8 plants each of two clones of Chrysanthemum morifolium ('Arlora' and 'Chris Columbus') and one plant each of Ligustrum japonicum (Japanese privet) and Feijoa sellowiana

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[10] It should be noted that mulching preceeded the planting. The convenience in spreading the mulches far outweighed the slight effort of temporarily displacing the mulches during planting.

pineapple-guava).[11] These plants were used for various reasons. For one thing the chrysanthemum plants are herbaceous; the other two are broad-leaved evergreen shrubs. Furthermore, it was of interest to determine how variable any of the effects might be between two closely related plants, thus the two clones of chrysanthemum. In a study of the performance of 10 garden-type chrysanthemums the previous summer, the 'Arlora' and 'Ohio State' clones were rated the best.[12] Consequently,

TABLE 7.--Treatment combination, factor symbols, and amount of nitrogen (pounds per acre) supplied to the soil by the treatments[1]

Cultural treatment and Factor symbol		Nitrogen from indicated source		Total nitrogen
Mulch, A	Fertilizer[2], B	Mulch[3]	Fertilizer[4]	
None, a_1	None, b_1	0	0	0
None, a_1	One, b_2	0	45	45
None, a_1	Two, b_3	0	90	90
Woodshavings, a_2	None, b_1	20	0	20
Woodshavings, a_2	One, b_2	20	45	65
Woodshavings, a_2	Two, b_3	20	90	110
Woodchips, a_3	None, b_1	400	0	400
Woodchips, a_3	One, b_2	400	45	445
Woodchips, a_3	Two, b_3	400	90	490

[1] Data for the mulch are calculated values; for the fertilizer, rounded values.

[2] Pounds of elemental nitrogen applied per 1000 square feet.

[3] Available upon decomposition of the mulch.

[4] Immediately available as nitrate nitrogen

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[11] Herein frequently referred to as indicator plants; a term often used in reference to plants that serve as biological indicators.

[12] Author's unpublished data.

use of these two was planned but the supplier's shortage of the latter necessitated the substitution of the comparable 'Chris Columbus' clone. The two woody plants were chose because they are extensively used in landscaping in Western United States.

The chrysanthemum plants, compliments of Neal Bros., Toledo, Ohio, were planted on July 7, 1959, after being grown in a greenhouse in 2-inch Jiffy peat pots from June 15, 1959, when they had been received as rooted cuttings. The next spring, on March 11, 1960, the Ligustrum plants were planted; the Feijoa plants 10 days later.[13] At planting time, the required number of each of the two woody shrubs had just been received as 15- to 18-inch-high 1-gallon stock from Oki Nursery, Sacramento, California. Both shrubs had been vegetatively propagated by cuttings and grown under a routine production schedule over an 8-month period prior to planting.

A description of the arrangement of all the plants in each plot follows. Each chrysanthemum clone was located in two adjacent north-south rows of four plants each. In other words, there were two 4-plant rows of each of two clones; totals of 4 rows and 16 chrysanthemum plants per plot. Collectively, the plants were in the central portion of the plot with square-grid spacing of 30 inches between plants. By random choice, the plants of one clone were planted in two adjacent rows in either the east or the west half of a plot; those of the other clone in the other half of the plot.

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[13] It was thought that planting the Feijoa and Ligustrum plants during the 1959 growing season might affect the growth of the chrysanthemum plants that would be nearest them.

Interplanted between the two inside rows of chrysanthemum plants was one plant each of Feijoa and Ligustrum (Figures 2 and 3). There were no guard plants in the experiment since the spacing between plants and between plots was designed to avoid any overlapping effects of the treatments.

During the term of the experiment, all of the plots were sprinkler irrigated about once every two weeks to a depth of approximately 15 inches when the moisture supply in any of the plots was considered low. Also, the area was similarly irrigated immediately after the applications of mulches and fertilizer.

Sampling Procedures

Soil Evaluations

Temperature

Soil temperature, as related to soil surface conditions (mulch versus no mulch) was determined on September 12, 1960; March 21, 1961; and May 27, 1961. These measuring dates were considered to represent fall, spring, and summer conditions, respectively. The weather on the foregoing dates was clear and calm between midafternoon and about 5:00 p. m. when the soil temperatures were taken. A dial-type Rochester thermometer, with a 20-centimeter-long stem was used in recording the temperatures. The full length of the stem was inserted into the soil and the thermometer left in place for about one minute until the needle had stabilized before reading the temperature. The soil temperature for each plot was an average of three observations made at random locations within a plot.

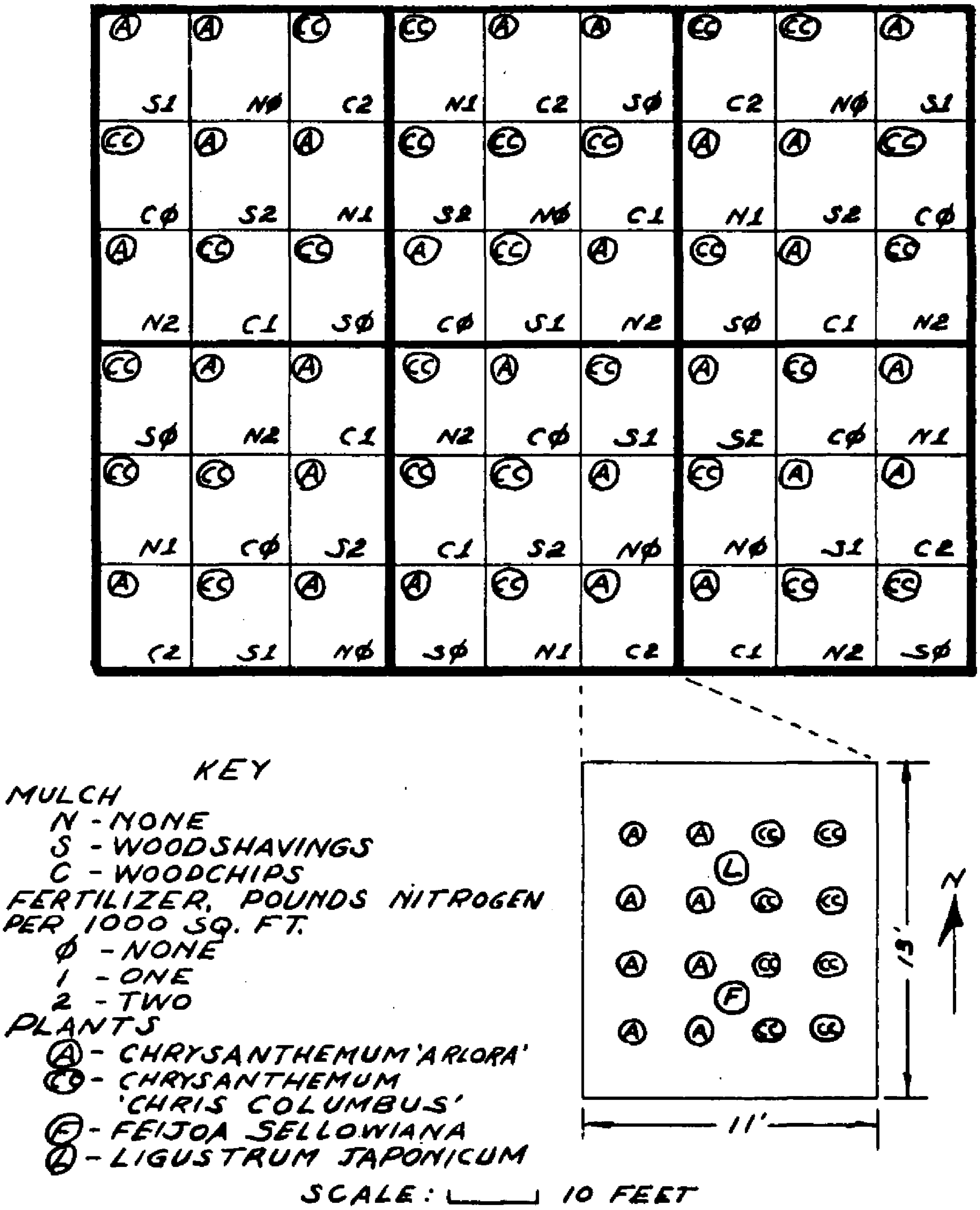

Figure 2.--Plot plan of the experiment. All treatments were randomly replicated in each of the six blocks delineated by the heaviest boundary lines. The symbol in the upper left corner of each plot indicates which chrysanthemum clone was on that side of the plot. The blown-up plot illustrates the arrangement of the plants in a plot.

Figure 3.--The area of the experiment as it was in 1961. By then, the chrysanthemum plants had been eliminated from the plots with a dinitro-in-oil contact herbicide and only the Feijoa and Ligustrum plants remained. The view is to the east.

Moisture

Soil samples were collected from each of the 54 plots on September 8, 1960, two weeks after all plots had been sprinkler irrigated, to determine the percentage of soil moisture on a dry weight basis. Each sample consisted of a composite of soil from three random locations within a plot; all three being at least 12 inches beyond the periphery of any indicator plant. Immediately before taking a sample, the soil surface was spot cleared of all mulch material. The samples were weighed, dried to a constant weight at 105° C in a forced draft oven for four days and then weighed again to determine moisture loss.

Chemical properties

Soil samples, with which certain chemical properties were determined, were collected on two dates. These dates and the analytical uses made of the respective samples are given below.

June 19, 1959

Soil collected on this date was used in the analysis of the before-treatment chemical properties. This collection date was between the time the area was disk-cultivated and the mulch treatments were made. Three samples were collected at random from each of the 54 plots, dried at 65° F in a forced draft oven for 24 hours and stored in manila paper bags. Analysis of the chemical properties as described later was made during the summer of 1962 of 10 samples taken randomly from the lot.

September 11, 1961

After-treatment chemical properties of the soil were determined using samples collected on this date. This was 26 and 24 months, respectively, after the mulches and the fertilizer nitrogen had been applied. Two weeks before collecting the samples, the experiment area had been sprinkler irrigated to bring the soil to field capacity. The next day after irrigating, approximately 1-foot-diameter randomly located spots in each of the mulched plots were cleared of all mulch material. This was done so the soil samples, when collected, would all have comparable moisture.

The soil samples were collected from the o-4-inch depth with a 3-inch-diameter soil auger. They were air dried, sieved, and stored in manila paper bags. Analysis was made for pH, organic matter, nitrate nitrogen, total nitrogen, phosphate phosphorus, and available potassium during the summer of 1962.

Plant Evaluations

Nutrient element composition

Foliar analysis techniques were important tools in this study. They were used, not to determine an optimal range of any nutrient element in the plants, but rather to compare the effect of the various treatments on the nutrient element composition.

Chrysanthemum clones

The nutrient element composition of the chrysanthemum plants was determined from foliage samples collected on May 2 and July 2, 1960. These two collections were from different stems since the plants had been harvested following the May 2 sampling.

Each sample was a composite of about 25 petioled-leaves from a single clone of a plot. Since many workers (65, 73) have pointed out a general pattern of nitrogen, phosphorus, and potassium being highest in young leaves and calcium and magnesium highest in old leaves,[14] an effort was made to select leaves of comparable physiological age. To achieve this, each leaf was taken from about 4 inches below the shoot apex in the vicinity of the most recently fully expanded leaf of a stem. In a few plots, it was necessary to collect a second leaf from some of the stems. This leaf was on the next node below where the first leaf had been selected.

As soon as the foliage samples were collected they were placed in a forced draft oven and dried at between 70° and 75° C for 20 hours.[15] Afterwards they were ground in a Wiley mill to pass a 20-mesh screen and stored in corked glass vials until analyzed for the nutrient element composition.

Feijoa and *Ligustrum* plants

The nutrient element composition of these two shrubs was determined from foliage samples collected in 1960 on October 5 and in 1961 on June 1 and July 21. Each sample consisted of a composite of single leaves collected from 4 to 5 inches below the apex of each of 25 shoots per plant. After collection these samples were handled in the manner described above.

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[14] This pattern generally corresponds to metabolic, shoot elongation, and leaf expansion rates in plants.

[15] None of the leaves were washed when collected because the overhead irrigation for about 6 hours three to four days prior to each sampling date left the leaves relatively clean.

Growth measurements

Chrysanthemum clones

Number of stems.--The stems growing from the root crown of the chrysanthemum plants were counted on April 28, 1960.

Plant size.--The height and spread of the chrysanthemum plants were measured on April 27 and June 30, 1960. The data for the individual plants were converted to volumetric values by the formula (height x spread x 0.7854). The size data constituted the amount of growth of the plants from the time they had been last harvested as described below.

Plant weight.--The harvesting and weighing of the chrysanthemum plants were done in 1959 on November 30 and in 1960 on May 3 and again on July 8. The plants were cut off at ground level and immediately weighed to the nearest 1/10 pound on a spring-type scale. The few leaves that had been taken for foliar analysis purposes just prior to harvesting did not alter the comparative weights of these plants.

Feijoa and Ligustrum plants

Root weight.--In November 1961, two growing seasons after the woody shrubs had been planted in the plots, root samples were taken from a representative number of each of them to assess root growth. Each sample was a composite of five soil borings from around the periphery of each plant. The borings were made to a depth of 9 inches and divided into three 3-inch-deep increments. Thus three composite samples were collected from around an individual plant.

The sampling equipment included a cylindrical soil coring tool having an inside diameter of three inches that was powered by a slow-speed electric drill. Electricity for the drill was available from a wheel-mounted generator described by Lownsbery et al. (41). Prior to sampling, all organic matter was cleared from the soil surface beneath the plants. As the samples were collected, the roots were separated from the soil by sieving. Loss of some of the hair-size roots during sieving was considered comparable for all of the samples and therefore to have had no adverse effect on the comparative interpretation of the data.

Shoot growth of the Feijoa.--The current season's linear shoot growth was measured on the Feijoa plants on September 12, 1961. This included all the primary and secondary shoots of a plant.

Analytical Procedures

Soil Properties

The methods outlined by Rible and Quick (56), comparable to those described by Black (9), were used to analyze various soil properties. These methods are briefly described hereafter. The soil reaction was determined by measuring the pH with a glass electrode Beckman pH meter using the saturated paste method (9, pp. 920-921, 935). Nitrate nitrogen was extracted from the soil samples with calcium sulfate and sodium phosphate, the extract treated with silver sulfate to remove chloride, and analyzed colorimetrically by the phenoldisulfonic method using a Bausch and Lomb colorimeter equipped with a 400-420 millimicron blue filter (9, pp. 1212-1217, slightly modified). Total nitrogen was found by a modified Kjeldahl procedure.

Available phosphorus was extracted by 0.5 molar sodium bicarbonate solution at pH 8.5 and determined colorimetrically by the ammonium molybdate-stannous chloride method using a Bausch and Lomb colorimeter equipped with a 650-700 millimicron red filter (9, pp. 1044-1047). Available potassium was extracted by 1.0 normal ammonium acetate solution at pH 7.0 and determined photometrically with a Beckman DU flame spectropnotometer (9, pp. 1025-1028). Organic matter was determined by loss of weight on ignition.

Nutrient Element Composition of the Indicator Plants

The amount of various nutrient elements in the foliage of the four indicator plants was found by the analytical procedures used in the Pomology Laboratory of the Davis campus of the University of California. The first step in these procedures, applicable for phosphorus, potassium, calcium, sodium, magnesium, and manganese, was digestion in the presence of a solution of ammonium hydroxide and nitric acid followed by ashing in a muffle furnace. The concentration of total potassium, calcium, sodium, magnesium, and manganese was determined by flame photometry using a Beckman Model DU spectrophotometer with flame attachment and modified amplifier. The amount of total phosphorus was determined colorimetrically with a red-filtered Bausch and Lomb colorimeter.

Determination of the total nitrogen in the foliage of the indicator plants was made by a modified Kjeldahl method. It consisted of adding a sulfuric acid-salicylic acid mixture to the ground leaves and then digesting in Kjeldahl digestion apparatus.

The results of all analyses are presented on a dry weight basis. Concentration of the elements is expressed in parts per million for manganese and in percentage for the other elements.

Statistical Procedures

The statistical significance of the differences of all the data was tested by analyses of variance according to methods described by Steel and Torrie (66). Only analyses of variance of the raw data in arithmetic form are reported. Doing log transformations of the data before doing the analyses of variance was not needed.

The analyses of variance of the data for the nutrient elements in the indicator plants consisted of a split-split plot factorial design,[16] by which the mulch and fertilizer factors were analyzed in the whole unit; the plants (either the two chrysanthemum clones or the two woody plants) in the sub-unit, and the sampling dates (two for the chrysanthemum clones and three for the two woody plants) in the sub-sub-unit.[17]

The results are presented in tabular and narrative versions under each of several subject categories. Most of the tables within the narrative are so-called segregated two-way tables.[18] Each such table consists of those data, related to a significant interaction,

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[16] One of the principal reasons for using a factorial design in this study was to detect and measure the interactions of the various treatments. For instance, it was desired to see whether mulching has the same affect on the different kinds of plants. Such a comparison was made of the two chrysanthemum clones and another of the two woody shrubs. With such a design it was possible to interpret the results in more detail where interactions were significant than could have been done by considering main effects only.

[17] A typical analysis of variance table of mean squares and Fisher (F) ratios, that for foliar nitrogen in the chrysanthemum plants, is presented in Appendix Table 1.

[18] The caption of each segregated two-way table is an abridged version of the caption of the appropriate master two-way table (see footnote 19) from which the data in the segregated two-way table are derived.

that were segregated from a so-called master two-way table.[19] Whenever either data or treatment effects are discussed as being either the same or different it means that that relationship is statistically significant at the level of 5 percent or better. Where data are described as "trending" in a certain direction, it means that their magnitude of difference is not great enough to be significant at the 5 percent level, but that it might be significant at a percentage value greater than that.

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[19] Data of the overall results within most subject categories are presented in respective so-called master two-way tables of the Appendix. These data consist of the treatment or main effect means along with various subtotal means. They apply to the various factors involved in the experiment. For example, in the nutrient element composition categories for the two woody shrubs, the data for each are for a 3 x 3 x 2 x 3 factorial design, meaning 3 levels each of factors A (mulch), B (fertilizer), and D (sampling date) and 2 levels of factor C (plant) as illustrated in Appendix Table 9.

Each datum is identified in the master two-way tables by a superscript of some or all of the letters a, b, c, and d. A datum with a superscript of all four letters--abcd--is a mean of six observations. That is, it is a mean of six replications or one observation from each of the six blocks in the layout of the experiment. A datum with a superscript of fewer than four of these letters is a mean of the product of six replications multiplied successively by the number of levels of each factor not shown as a superscript. For example, a datum with a superscript of "cd" is a mean of the product of six replications x three levels of factor A x three levels of factor B or 54 observations. The data for the treatment or main effects of a particular factor have a common single-letter superscript; those for factor A an "a" superscript, and so forth.

Accompanying most of the master two-way tables is a table of the least significant differences (LSD) for the data of that master two-way table. To find the LSD between any two data having a common superscript, refer to that superscript in the first or Item columnof the LSD table and choose the appropriate datum within one of the one or more rows pertaining to that superscript.

RESULTS AND DISCUSSION

A general discussion of the analyses of variance F-ratios for the various soil and plant properties will preceed presentations of the results and discussion in each of the several subdivisions of any major subject category that follows.

Soil Properties

The significant F-ratios of Table 8 indicate that the mulch factor had an important influence on all properties of the soil that were studied except nitrate nitrogen; the fertilizer factor only on exchangeable potassium.

TABLE 8.--Significance of the relationship between the variation of several soil properties and mulch, fertilizer nitrogen, and sampling date factors (F-ratios are calculated from data of Appendix Table 2)[1]

Factor	Factor code	F-ratio for the indicated soil property			
		Temperature	Moisture	Reaction	Organic matter
Mulch	A	118.88**	41.13**	14.03**	3.97*
Fertilizer	B	< 1	1.52	1.82	< 1
Sampling date	C	7424.74**			

Factor	Factor code	F-ratio for the indicated soil property			
		Nitrate nitrogen	Total nitrogen	Phosphorus	Potassium
Mulch	A	2.45	23.08**	10.89**	9.73**
Fertilizer	B	1.96	< 1	< 1	3.53*

[1] Symbols * and ** indicate significance at the 5- and 1-percent levels respectively.

Only temperature was measured at different dates and, as expected, the sampling date factor, compared with the mulch and fertilizer factors, was by far the most significant for it. Even so, the greatest influence of the mulch factor was on the temperature, too, followed in order by moisture, total nitrogen, available phosphorus, available potassium, and organic matter.

Temperature

On March 21, 1961, the soil temperature under either of the mulches was about one degree warmer than without mulch (50° vs. 49° F). Conversely, the mulched soil was cooler by about two degrees on May 27, 1961 (64° vs. 66° F), and by about nine degrees on August 12, 1960 (74° vs. 83° F), as shown in Table 9.

Even though there were minor differences in soil temperature, the pattern for the different recording dates was as follows: coldest in March, warmer in May, and warmest in August, whether mulched or not.

TABLE 9.—Effect of mulches on soil temperature on a fall, a winter, and a spring day (Data are those with an "ac" superscript of Appendix Table 3; LSD values are from Appendix Table 4)

Mulch treatment	Soil temperature, degrees F		
	8/12/60, c_1	3/21/61, c_2	5/27/61, c_3
No mulch, a_1	83	50	66
Woodshavings, a_2	74	51	64
Woodchips, a_3	75	51	64

LSD for all data (rounded): 5%, 1; 1%, 1

The pattern of these temperatures coincides with the results obtained by numerous other workers as reviewed earlier (17, 32, 38, 49). In essence, the insulation provided by a mulch, whereby temperature changes on the top side of the mulch are tempered on the bottom side, is a principal feature of a mulching practice.

Moisture

The 16-percent moisture content in the top 3-inch horizon of the woodshavings-and the woodchips-mulched soils was about twice the amount found in the unmulched soil (Table 10). The reason for this differential must be because evaporation of moisture was much less for the mulched soil than for the unmulched soil (32, 77).

TABLE 10.--Effect of differentials of mulch and fertilizer nitrogen on the amount of moisture in a Yolo fine sandy loam soil approximately one year after treatment application

Mulch treatment	Soil moisture, percentage, for the indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	9.33	7.95	7.38	8.22
Woodshavings, a_2	16.18	14.58	18.07	16.28
Woodchips, a_3	17.87	15.38	16.27	16.51
Mean	14.46	12.64	13.91	

LSD for the mean values: 5%, 2.23; 1%, 2.95

The slightly slower springtime temperature increase of the mulched soil (Table 9), compared with the unmulched soil, was probably due in part to the greater amount of moisture in the former soil. For this reason, the greater amount of moisture in the mulched soil may not always have been a benefit.

Chemical Composition

The chemical composition of the Yolo fine sandy loam soil on September 11, 1961, 26 months (hereinafter indicated as two years) after mulch-application, as affected by the mulch/fertilizer nitrogen treatments, is discussed below for each of several properties.

Reaction

With either mulch, the soil pH was no less two years later than at the time of treatment application. Without mulch, however, the soil pH was higher (less acid) than at the beginning. These differences may be seen by comparing the data of Tables 5 and 11.

The higher pH value of the unmulched soil two years after treatment application is attributed to soil moisture loss by evaporation resulting in a concentrating of soluble salts in the surface soil. The mulched soil would have been insulated against such moisture loss.

TABLE 11.--Effect of differentials of mulch and fertilizer nitrogen on the reaction of a Yolo fine sandy loam soil two years after treatment application

Mulch treatment	Soil reaction, pH, for indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	7.2	7.2	7.1	7.2
Woodshavings, a_2	6.9	6.8	6.6	6.8
Woodchips, a_3	7.0	7.0	7.0	7.0
Mean	7.0	7.0	6.9	

LSD for the mean values: 5%, 0.2; 1%, 0.2

The preponderance of literature that indicates that mulching does not cause a permanent decrease in soil pH (28,33, 35, 43, 44, 47, 57, 60, 71, 75) should be qualified in light of the results of this study. Even though the soil pH may not become less in the presence of a mulch, in areas of limited rainfall, the presence of a mulch may retard a buildup from evaporative moisture loss of basic compounds in the surface soil.

Organic matter

Whereas the organic matter in the unmulched soil trended lower from its value at the beginning of the experiment, as would be expected, that in the woodshavings-mulched soil was no different while in the woodchips-mulched soil was greater (Tables 5 and 12).

TABLE 12.--Effect of differentials of mulch and fertilizer nitrogen on the organic matter content of a Yolo fine sandy loam soil two years after treatment application

Mulch treatment	Soil organic matter, percentage, for indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	4.7	4.5	4.6	4.6
Woodshavings, a_2	4.5	4.8	4.8	4.7
Woodchips, a_3	5.2	5.0	5.0	5.1
Mean	4.8	4.8	4.8	

LSD for the mean values: 5%, 0.4; 1% 0.5

A change in the amount of organic matter in the unmulched soil from 4.7 percent at the beginning of the experiment (Table 5) to 4.6 percent two years later (Table 12) constitutes a decrease of from 94,000 to 92,000 pounds or a net loss of 2000 pounds of organic matter per acre half-foot (actually about 6 2/3 inches) of soil.

Similarily, for woodshavings there was no apparent change in organic matter but for woodchips the change was from 4.7 to 5.1 percent, a gain of 8000 pounds of organic matter per acre half-foot of soil. This would be a gain of about 25 pounds of soil organic matter per plot, or about 10 percent of the 270 pounds per plot of woodchips originally applied.

The fact that the woodchips-mulched soil had the highest organic matter content suggests that the woodchips had undergone extensive decomposition within the two-year period. This was apparent by visual examination, too. Another characteristic of the woodchips-mulched soil was that it was much less easily broken apart than the unmulched soil. This must have been the result of cementing action of the residual organic matter that had percolated into the soil.

It appeared that the woodshavings mulch had compacted in volume considerably but had undergone far less decomposition than the woodchips mulch. None of the characteristics of the woodchips-mulched soil was observed for the woodshavings-mulched soil.

Apparently the succulent foliar portion of the woodchips mulch accounted for the faster decomposition of that mulch (17) and the inherently resistant nature of the douglas-fir woodshavings mulch (4, 11, 44) predisposed it to a slower rate of decomposition.

Nitrate nitrogen

The effects of differentials of mulch and fertilizer nitrogen on soil nitrate nitrogen were inconclusive since the analysis of variance for each of the two factors was not significant. The relatively large LSD values for the data indicate wide variation in the raw data. Such was the case with one of the data of Table 13; six values over which it is an averaged rangedbetween 4.8 and 59.2.

TABLE 13.--Effect of differentials of mulch and fertilizer nitrogen on the amount of nitrate nitrogen of a Yolo fine sandy loam soil two years after treatment application

Mulch treatment	Soil nitrate nitrogen, ppm, for indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	30.1	12.4	10.4	17.7
Woodshavings, a_2	10.4	16.1	15.5	13.9
Woodchips, a_3	16.3	21.1	19.3	18.9
Mean	19.0	16.5	15.1	

LSD for the mean values: 5%, 7.4; 1%, 7.8

Regardless of the lack of significance for any differences in the data, its important to note that after two years the concentration of nitrate nitrogen was still about the same as at the beginning of the experiment (Tables 5 and 13). In studying the immobilization (also termed demineralization) of mineralized (also termed available) nitrogen during the decomposition of oak and pine chip mulches, Salomon (60) likewise found little difference two years after application in the amount of mineralized nitrogen of the soil between either mulch or between either of the mulches and the check.

Had a nitrate nitrogen analysis been made in this experiment within the first year after mulch application, the results might also have coincided with those obtained by Salomon. He found that during the first 90-day period the demands for mineralized nitrogen were about twice as great with the oak chips as with the pine chips. During the second 90-day period, the demand for mineralized nitrogen was the same for both kinds of chips, indicating by then an accelerated decomposition of the pine chips.

Total nitrogen

Since the data of Table 14 for total nitrogen of the soil do not differ between fertilizer treatments, it is inferred that two years after application none of the fertilizer nitrogen remained in any of the mulched or unmulched soil. Its loss would have occurred from 1) leaching, 2) escape of gaseous forms into the atmosphere, 3) utilization anew in the growth of higher plants, and 4) erosion of the soil.

TABLE 14.--Effect of differentials of mulch and fertilizer nitrogen on the amount of total nitrogen of a Yolo fine sandy loam soil two years after treatment application

Mulch treatment	Total nitrogen, percentage, for indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	.084	.079	.081	.081
Woodshavings, a_2	.084	.082	.085	.084
Woodchips, a_3	.097	.098	.097	.097
Mean	.088	.086	.088	

LSD for the mean values: 5%, .005; 1%, .007

Within the two-year period there was also a loss of total nitrogen from the unmulched soil, regardless of fertilizer treatment. That is, to start with, the total nitrogen value of the soil was .096 percent (Table 5); at the end of the two years it was .081 (Table 14). Much of this loss must have followed further decomposition of that organic matter already in the soil at the start of the experiment.

The loss of total nitrogen was relatively the same in the woodshavings-mulched soil as in the unmulched soil, at least the mean values, when averaged across all three fertilizer levels, were not significantly different. These data do not reveal to what greater extent nitrogen of the woodshavings-mulched soil compared with that of the unmulched soil, was immobilized by microbial proliferation. The extent of such immobilization will be apparent in a later section on foliar nitrogen in the indicator plants.

With the woodchips treatment, the total amount of nitrogen was the same two years later as at the beginning of the study. Consequently, any nitrogen that might have been lost through the three processes described above must have been replenished through the mineralization of the organic nitrogen of the woodchips mulch and the subsequent movement of that nitrogen downward from the mulch into the upper portion of the soil profile.

The data for total nitrogen correspond with those for organic matter; in the unmulched soil organic matter was the lowest and so was total nitrogen. They were highest in the woodchips-mulched soil. The reason for the latter has already been stated but in summary it is that the decomposition processes had progressed to the stage where both organic matter and nitrogen were being released into the soil.

Available phosphorus

Comparing the data of Tables 5 and 15, it is seen that the amount of available phosphorus in the unmulched soil remained the same between the beginning of the experiment and the next sampling date more than two years later; in the woodshavings-mulched soil it became less and in the woodchips-mulched soil it became more.

TABLE 15.--Effect of differentials of mulch and fertilizer nitrogen on the amount of sodium bicarbonate extractable phosphorus of a Yolo fine sandy loam soil two years after treatment application

Mulch treatment	Extractable phosphorus, ppm, for indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	31.4	34.7	30.1	32.1
Woodshavings, a_2	27.7	27.0	25.1	26.6
Woodchips, a_3	41.2	32.3	36.5	36.7
Mean	33.4	31.3	30.6	

LSD for the mean values: 5%, 4.58; 1%, 6.06

With this nutrient, leaching is no problem which is probably an important reason for the amount in the unmulched soil remaining constant. The phosphorus pattern for the woodchips-mulched soil was consistent with that ordinarily reported (18, 26, 57, 71, 80, 82). This increase in phosphorus over the amount found in the soil at the beginning of the study would have resulted from at least two things. One, release of phosphorus from decomposition of the woodchips. Two, formation of organic acids thus causing the release of phosphorus from insoluble calcium, aluminum, and iron phosphates, citric acid being one of the most effective.

Why there was not also more available phosphorus in the woodshavings-mulched soil must have been because the decomposition of that mulch was at a stage where proportionately more soluble phosphorus was being immobilized or appropriated by the microorganisms than was being released. The amount of phosphorus in decomposition bacteria is known to exceed 4 percent by dry weight (79). On the same basis, the woodshavings contained only about 0.02 percent or 20 times less. Consequently, during initial decomposition of this material, immobilization of soluble phosphorus could have been substantial. Apparently, the decomposition pattern of the woodchips was already beyond such a stage.

To the extent that sodium-bicarbonate-extractable phosphorus is an indicator of the amount of available phosphorus, the results of these soil analyses show it to have been least available in the woodshavings-mulched soil, intermediately available in the unmulched soil, and most available in the woodchips-mulched soil. How these values relate to the amount of phosphorus in the indicator plants will be presented later.

Available potassium

In the two-year period from treatment to final soil sampling, the amount of available potassium remained unchanged in the woodchips-mulched soil and became less, of comparable magnitude, in the unmulched and the woodshavings-mulched soils (Tables 5 and 16). The reason for the almost 15 percent less available potassium in the soil of the latter two treatments is not apparent. Since the literature that was reviewed almost unanimously indicates an increase in this nutrient with mulch, even the lack of an increase *per se* in the woodchips-mulched soil suggests that available potassium was depleted in some manner. But, unlike the soil of the no-mulch and the woodshavings treatments, it appears that the available potassium of the woodchips-mulched soil was being replenished through the decomposition process.

Like nitrogen and phosphorus, a very large proportion of potassium in the soil is insoluble and unavailable to higher plants (17, p. 452). Competition by microorganisms for this element affects its availability to higher plants. Presumably, it is for that reason that the potassium content of the woodshavings-mulched soil was virtually the same as in the unmulched soil, that is the decomposition microorganisms of the woodshavings were tying up some of the potassium therein. In contrast, with the woodchips having been further decomposed, the demands of the microorganisms in that soil were ebbing. Consequently, proportionately more was being released as an available form than was being appropriated by the microorganisms.

TABLE 16.--Effect of differentials of mulch and fertilizer nitrogen on the amount of available potassium of a Yolo fine sandy loam soil two years after treatment application

Mulch treatment	Available potassium, ppm, for indicated fertilizer nitrogen rate			Mean
	0 lb., b_1	1 lb., b_2	2 lb., b_3	
No mulch, a_1	382	418	368	389
Woodshavings, a_2	438	378	379	398
Woodchips, a_3	490	458	427	458
Mean	437	418	391	

LSD for the mean values: 5%, 36; 1%, 48

Plant Properties

The objective of this part of the study was to determine how various aspects of plant composition and development would be affected under the conditions of the experiment. Further, it was aimed at assessing these effects on the two closely related herbaceous plants — the chrysanthemum clones — and on the two dissimilar woody evergreen shrubs — the *Feijoa* and *Ligustrum*. The results and the interpretation of each of several growth characteristics and nutrient elements of the indicator plants are discussed in the sections that follow.[20]

Nutrient Element Composition of the Indicator Plants

The effects of the mulch/fertilizer factorial treatments on the nutrient element composition of the two chrysanthemum clones on two sampling dates in 1960 and of the two woody shrubs on three sampling dates between October 5, 1960, and July 21, 1961, were determined for each of seven nutrient elements, namely: nitrogen, phosphorus, potassium, sodium, calcium, magnesium, and manganese. The analyses of variance mean squares for the raw data of each are shown in Appendix Tables 5 and 6. F-ratios for the four factors influencing the concentration of these nutrients are shown in Table 17 for the two chrysanthemum clones and in Table 18 for the two woody shrubs.

As for the chrysanthemum clones, the significant F-ratios of Table 17 indicate that the mulch factor had an important effect on the foliar concentration of all of the nutrient elements studied except sodium; the fertilizer factor on nitrogen, potassium, and manganese only. By far the largest and most significant effect on each of the seven nutrient elements was the date that the samples were collected throughout the year. It is of interest that the plant factor had next to the largest and significant influence on the foliar concentration of nitrogen, potassium, sodium, and manganese. Phosphorus, calcium, and

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[20] Some of the main effects data of the growth measurements and foliar nutrient composition of the indicator plants are composited in Appendix Tables 42 through 46. These give an overall view of the multi-effects of the mulch/fertilizer treatments on the different plants. Presented in Appendix Table 47 is a composite schematic analysis of the general change in the concentration of the foliar phosphorus, potassium, sodium, calcium, magnesium, and manganese as the concentration of foliar nitrogen diminished in each of the four indicator plants.

TABLE 17.--Significance of the relationship between the variation of the foliar concentration of each of several nutrient elements of the chrysanthemum plants and the mulch, fertilizer, plant, and sampling date factors.[1,2]

Factor	Factor code	F-ratio							$F_{.95}$	$F_{.99}$
		N	P	K	Na	Ca	Mg	Mn		
Cultural treatment										
Mulch	A	36.08**	31.26**	10.27**	< 1	70.90**	104.42**	3.53*	3.23	5.18
Fertilizer	B	16.13**	< 1	5.33**	1.84	< 1	< 1	5.82**	3.23	5.18
Plant	C	86.17	5.89*	300.77**	50.19**	3.25*	2.16	20.41**	4.06	7.26
Sampling date	D	444.31**	453.47**	924.33**	561.76**	752.00**	234.44**	135.83**	3.95	6.93

[1] F-ratios are calculated from the data of Appendix Table 5

[2] Symbols * and ** indicate significance at the 5 and 1 percent levels, respectively

magnesium were not or only minutely influenced by the kind of plant. For those three nutrient elements, the next to the largest and significant influence, after sampling date, was mulch.

Considering the data of Table 18 for the two woody shrubs, the mulch factor had an important influence on all nutrient elements in these two plants; manganese at the 5-percent level and the others at the 1-percent level. The fertilizer factor influenced the foliar concentration of potassium, nitrogen, phosphorus, magnesium, and calcium in the order given. It had no influence on the sodium or the manganese. As with the relationships of the nutrient elements in the chrysanthemum plants, the sampling date factor had by far the largest and usually the most significant influence on the foliar concentration of all of the nutrient elements with the exception of phosphorus. There was no significance for that element. The plant factor influenced the foliar concentration for sodium, nitrogen, and potassium at the 1-percent level; for manganese, calcium, and magnesium at the 5-percent level, but did not for phosphorus.

The mulch and fertilizer factors influenced the foliar potassium concentration far more than they did the foliar nitrogen concentration.

The effects of the various factors on the foliar concentration of each nutrient element is presented below.

Foliar nitrogen

The data means for the effects of the mulch/fertilizer treatments on foliar nitrogen are presented in Appendix Tables 7 and 9 for the chrysanthemum clones and the woody shrubs respectively.

Foliar nitrogen of the chrysanthemum clones

Compared with the no-mulch treatment, foliar nitrogen of the 'Arlora' clone was about 25 percent lower with either mulch in May. In

TABLE 18.--Significance of the relationship between the variation of the foliar concentration of each of several nutrient elements of the *Feijoa* and *Ligustrum* plants and the mulch, fertilizer, plant, and sampling date factors.[1,2]

Factor	Factor code	F-ratio							F .95	F .99
		N	P	K	Na	Ca	Mg	Mn		
Cultural treatment										
Mulch	A	91.66**	19.47**	301.76**	9.06**	11.81**	35.76**	3.45*	3.23	5.18
Fertilizer	B	20.26**	7.02**	138.66**	<1	5.23**	5.50**	<1	3.23	5.18
Plant	C	93.95**	<1	12.12**	237.42**	5.21*	5.49*	6.07*	4.06	7.26
Sampling date	D	175.96**	<1	265.72**	132.30**	234.22**	234.68**	50.24**	3.00	4.61

[1] F-ratios are calculated from the data of Appendix Table 6

[2] Symbols * and ** indicate significance at the 5 and 1 percent levels, respectively

July it was lower only with woodshavings. For the 'Chris Columbus' clone it was lower only with woodshavings and then only in May. These differentials are shown in Table 19.

Whereas foliar nitrogen was the same for all fertilizer levels for the May sampling, when sampled in July there was more of it with increased fertilizer (Table 20). The data of Table 19 also shows that the aforementioned pattern was consistent for all three levels of mulch, even though the magnitude of difference between fertilizer levels was greatest for woodshavings. Apparently, some condition of the environment other than nitrogen supply was the cause of the foliar nitrogen pattern in May, since, for the May sampling, the foliar nitrogen was generally the same regardless of fertilizer rates, whereas for the July sampling it was correspondingly more with higher rates of fertilizer.

TABLE 19.--Effect of the mulch treatments on the amount of foliar nitrogen of each of the two chrysanthemum clones on each of the two sampling dates (Data are those with an "acd" superscript of Appendix Table 7; LSD values are from Appendix Table 8)

Mulch treatment	Foliar nitrogen, percentage dry weight basis			
	'Arlora', c_1		'Chris Columbus', c_2	
	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	4.02	4.34	3.14	3.72
Woodshavings, a_2	2.65	4.02	2.67	3.68
Woodchips, a_3	3.03	4.39	3.00	3.89

LSD: 5%, 0.21; 1%, 0.28

TABLE 20.--Effect of the mulch treatments and the fertilizer treatments on the amount of foliar nitrogen of the chrysanthemum clones on each of two sampling dates (Data are those with an "abd" superscript of Appendix Table 7; LSD values are from Appendix Table 8)

Mulch treatment	Foliar nitrogen, percentage dry weight basis, for the indicated fertilizer rate					
	0 lb., b_1		1 lb., b_2		2 lb., b_3	
	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	3.55	3.86	3.54	3.97	3.67	4.27
Woodshavings, a_2	2.62	3.26	2.78	3.98	2.58	4.30
Woodchips, a_3	3.10	3.82	2.80	4.12	3.14	4.47

LSD between b levels; 5%, 0.26; 1%, 0.34
LSD between d levels: 5%, 0.30; 1%, 0.39

Foliar nitrogen of the *Feijoa* and *Ligustrum* plants

In comparison with no-mulch, the foliar nitrogen was consistently lower in both plants on all three sampling dates with woodshavings; for the woodchips-mulched plants the amount of foliar nitrogen was no different from the unmulched plants (Table 21).

The pattern for the amount of foliar nitrogen of the *Ligustrum* for the three sampling dates was as follows: lowest for the June 1961 sampling, of intermediate values for the July 1961 sampling, and highest for the October 1960 sampling. There was no consistent pattern for the *Feijoa*.

With increased levels of fertilizer there was a corresponding increase in foliar nitrogen of both shrubs on the October 1960 sampling. This pattern appeared as a trend on the other two sampling dates for the *Ligustrum* but not for the *Feijoa*.

TABLE 21.--Effect of the mulch treatments on the amount of foliar nitrogen of each of the two shrubs on each of the three sampling dates (Data are those with an "acd" superscript of Appendix Table 9; LSD values are from Appendix Table 10)

Mulch treatment	Foliar nitrogen, percentage dry weight basis					
	Feijoa, c_1			Ligustrum, c_2		
	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3
No mulch, a_1	1.98	1.86	1.91	2.00	1.32	1.69
Woodshavings, a_2	1.57	1.47	1.80	1.72	1.05	1.40
Woodchips, a_3	1.88	1.82	1.94	2.10	1.22	1.63

LSD: 5%, 0.11; 1%, 0.15

Discussion

Understandably, the amount of foliar nitrogen in the indicator plants was affected by an interrelationship of numerous factors. These included the four measured variables, namely: kind of mulch, amount of fertilizer nitrogen, kind of plant, and sampling date.

The markedly lower amount of foliar nitrogen in the woodshavings-mulched plants than in the unmulched ones must have resulted from a severe immobilization of the soil nitrogen which in turn resulted, as Bollen (11, 13) has shown, from the decomposition of an organic material of an unusually wide carbon-nitrogen ratio, in this case the woodshavings of douglas-fir lumber. Because the amount of foliar nitrogen in the woodchips-mulched plants was only nominally less than in the unmulched plants, there is considerable inference that the carbon-nitrogen ratio of the woodchips was such that utilization of the mineralized nitrogen of the soil by the microorganisms was minimal.

It is important to point out again that the total amount of nitrogen in the woodshavings and the woodchips was 0.04% and 0.52%

respectively (Table 6). Even with a slowly decomposable mulch as the woodshavings apparently was, the nitrogen supply must have been inadequate to meet microbial requirements. The above findings coincide with previous reports (35, 57) and tend to support Baldsiefen's statement, to wit: "From my observation over . . . several years, there is absolutely no nitrogen deficiency problem (with woodchips) as there is with sawdust" (7).

The basic questions that may be answered from the above foliar nitrogen data are 1) was the foliar nitrogen of any of the indicator plants less with either mulch compared with no-mulch and, if so, 2) was this effect averted with fertilizer nitrogen?

A composite schematic analysis of the answers to these questions is presented in Table 22. As for the first question, it has already been answered by the above discussion. The answer, in summary, is that in general there was less foliar nitrogen with woodshavings but about the same amount with woodchips.

As for the second question, the effect of the woodshavings mulch was not averted with fertilizer nitrogen at the time of the first foliar sampling of the season. At the time of the second sampling, however, the effect of the woodshavings mulch on the foliar nitrogen was averted with the fertilizer nitrogen treatment in three of the indicator plants but not in the Feijoa. Moreover, regardless of mulch treatment, with increased fertilizer nitrogen, foliar nitrogen was correspondingly higher in both chrysanthemum clones on the July 1961 sampling and in both woody shrubs on the October 1960 sampling. It appears that whatever amount of fertilizer nitrogen had not been absorbed into the plants had either become immobilized or else leached away from the vicinity of the plant roots by 1961.

TABLE 22.—General effect of the mulches and fertilizer nitrogen on the concentration of foliar nitrogen of each of the four indicator plants. (Comparison is with the foliar nitrogen of the unmulched plants)

Mulch treatment	Change in concentration of foliar nitrogen.[1]							
	First sampling date of season				Second sampling date of season			
	'Arlora'	'Chris Columbus'	Feijoa	Ligustrum	'Arlora'	'Chris Columbus'	Feijoa	Ligustrum
Woodshavings	-	-	-	-	-0	-0	-	-0
Woodchips	-	0	0	0	0	0	0	0

[1] Diminution of foliar nitrogen is indicated by -; no diminution by 0; diminution ameliorated with fertilizer nitrogen by -0.

Contrary to most published evidence, foliar nitrogen of all the indicator plants was higher on the second sampling of the growing season than on the first. Ordinarily, foliar nitrogen becomes less as the growing season advances (47, 65). Why it did not in this experiment was not determined.

Foliar phosphorus

The data means for the effects of the mulch/fertilizer treatments on foliar phosphorus of the chrysanthemum clones and the woody shrubs are presented in Appendix Tables 11 and 13 respectively.

Foliar phosphorus of the chrysanthemum clones

In May, foliar phosphorus of the 'Arlora' clone was lower with woodshavings and the same with woodchips compared with the no-mulch treatment. But in July it trended higher with woodshavings and actually was higher with woodchips. By the same comparison, foliar phosphorus of the 'Chris Columbus' clone was higher with the woodshavings and higher still with the woodchips on both sampling dates (Table 23).

TABLE 23.--Effect of the mulch treatments on the amount of foliar phosphorus of the two chrysanthemum clones on each of the two sampling dates (Data are those with an "acd" superscript of Appendix Table 11; LSD values are of Appendix Table 12)

Mulch treatment	Foliar phosphorus, percentage dry weight basis			
	'Arlora', c_1		'Chris Columbus', c_2	
	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	.291	.304	.225	.318
Woodshavings, a_2	.266	.318	.257	.365
Woodchips, a_3	.284	.333	.289	.389

LSD: 5%, .016; 1%, .021

As also shown in Table 23, the difference in foliar phosphorus between the two samplings was at least twice as much for the 'Chris Columbus' clone as for the 'Arlora' clone. This differential is because the foliar phosphorus was of somewhat comparable value between corresponding mulch levels in both clones for the May sampling while on the July sampling date, that of the 'Chris Columbus' clone was markedly higher than that of the 'Arlora' clone.

When averaged over all other factors, the foliar phosphorus of both clones was highest for the July sampling compared with the May sampling and, also, there was no difference between the three fertilizer levels.

Foliar phosphorus of the *Feijoa* and *Ligustrum* plants

The data of Table 24 show that foliar phosphorus of both shrubs, when not fertilized, was usually the same with the woodchips-mulch and

TABLE 24.--Effect of the mulch treatments, without fertilizer, on the amount of foliar phosphorus of each of the two woody shrubs on each of the three sampling dates (Data are those with an "acd" superscript at the b_1 level of Appendix Table 13; LSD values are from Appendix Table 14

Mulch treatment	Foliar phosphorus, percentage dry weight basis					
	Feijoa, c_1			Ligustrum, c_2		
	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3
No mulch, a_1	.167	.184	.165	.173	.176	.164
Woodshavings, a_2	.290	.242	.234	.262	.256	.337
Woodchips, a_3	.182	.167	.173	.177	.147	.174

LSD: 5%, 0.08; 1%, 0.10

the no-mulch treatments. In contrast, foliar phosphorus was about 40 percent more with the woodshavings mulch. These differentials were consistent for each of the three samplings.

As shown in Table 25, foliar phosphorus of both shrubs, when unmulched, was either unchanged or else lower for each sampling with increased rates of fertilizer nitrogen.

TABLE 25.—Effect of the fertilizer treatment, without mulch, on the amount of foliar phosphorus of each of the two woody shrubs on each of the three sampling dates (Data are those with an "abcd" superscript at the a_1 level of Appendix Table 13; LSD values are from Appendix Table 14

Fertilizer treatment	Foliar phosphorus, percentage dry weight basis					
	Feijoa, c_1			Ligustrum, c_2		
	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3
0 lb, b_1	.167	.184	.165	.173	.176	.164
1 lb., b_2	.167	.184	.170	.159	.174	.156
2 lb., b_3	.170	.152	.149	.162	.126	.126

LSD: 5%, 0.08; 1%, 0.10

Discussion

It appears that the effect of mulches on the amount of foliar phosphorus of different kinds of plants may vary considerably. As for the herbaceous chrysanthemum plants of this study, the greater amount of foliar phosphorus of the mulched plants compared with the unmulched plants is consistent with the general information in the literature (18, 26, 57, 71, 80, 82). In this case, there is strong support for the generality that there is an increase in available phosphorus of the soil in the presence of organic mulches (26, 57, 71, 80, 82), and that this may be due to the solubilizing of the phosphate compounds by the organic acids which are produced during microbial decomposition (18, 23, 82).

Were the amount of foliar phosphorus to follow the pattern found in citrus leaves (see Table 4), it should vary inversely with the supply of nitrogen. With the chrysanthemum plants that was not the case. With higher rates of fertilizer the amount of foliar phosphorus did not vary. Also, there was no inverse relationship between the foliar nitrogen and the foliar phosphorus of the chrysanthemum plants even though an inverse relationship would be expected on the basis of the data of Table 4.

The pattern for the amount of foliar phosphorus of the woody shrubs, both of which are evergreen like citrus, indicates that in these plants there was an inverse relationship between the supply of nitrogen and the foliar phosphorus concentration (Table 24). This agrees with the data of Smith (65) and Sitton et al. (64). A general decrease of foliar phosphorus with an increase in the supply of nitrogen is further substantiated by the data of Table 23 and Appendix Table 9. These data show that the foliar phosphorus of both shrubs was consistently higher and the foliar nitrogen consistently lower for all three samplings with woodshavings mulch compared with either no mulch or woodchips mulch. In this case, it appears that the amount of foliar phosphorus may be affected more by the supply of nitrogen than by the presence or absence of an organic mulch. Moreover, with the woodshavings-mulched shrubs on each of the three sampling dates there was a corresponding decrease in foliar phosphorus with each increase in fertilizer nitrogen. This could be either an antagonistic effect or a dilution effect. Determining which it is requires information about the growth pattern of these two shrubs which will be considered in a later section.

The fact that the foliar phosphorus of the woodshavings-mulched shrubs was correspondingly less with increased rates of fertilizer nitrogen for the June and July 1961 samplings suggests that there was still an effect from the fertilizer nitrogen even though, as was previously noted, foliar nitrogen was no greater on those dates with increased rates of fertilizer nitrogen.

The unusually large amount of foliar phosphorus of the woodshavings-mulched plants may account for the correspondingly smallest amount of phosphate phosphorus in the woodshavings-mulched soil (see discussion of page 51).

Foliar potassium

The data means for the effects of the mulch/fertilizer treatments on foliar potassium of the chrysanthemum clones and the woody shrubs are presented in Appendix Tables 15 and 17 respectively.

Foliar potassium of the chrysanthemum clones

Compared with the no-mulch treatment, the amount of foliar potassium was the same in both clones for the May and July 1960 samplings with the woodchips-mulch treatment; with the woodshavings, foliar potassium was less in the 'Arlora' clone only in July 1960 and in the 'Chris Columbus' clone in both May and July 1960 (Table 26).

With increased rates of fertilizer, the foliar potassium was no different for the May sampling but was correspondingly greater for the July sampling (Table 27). This effect was consistent for both clones.

Based on the main effect differences only, two other features of foliar potassium are of interest, too. For one thing, there was about 20 percent more foliar potassium in the 'Arlora' clone than in

TABLE 26.--Effect of the mulch treatments on the amount of foliar potassium of each of the two chrysanthemum clones on each of the two sampling dates (Data are those with an "acd" superscript of Appendix Table 15; LSD values are from Appendix Table 16)

Mulch treatment	Foliar potassium, percentage dry weight basis			
	'Arlora'c c_1		'Chris Columbus', c_2	
	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	3.76	5.03	2.58	4.50
Woodshavings, a_2	3.77	4.68	2.07	4.29
Woodchips, a_3	3.71	5.01	2.39	4.65

LSD: 5%, 0.27; 1%, 0.35

TABLE 27.--Effect of the fertilizer treatments on the amount of foliar potassium of the two chrysanthemum clones on each of the two sampling dates (Data are those with a "bd" superscript of Appendix Table 15; LSD values are from Appendix Table 16

Fertilizer treatment	Foliar potassium, percentage dry weight basis	
	5/2/60, d_1	7/2/60, d_2
0 lb., b_1	3.09	4.49
1 lb., b_2	2.94	4.73
2 lb., b_3	3.11	4.86

LSD: 5%, 0.12; 1%, 0.26

the 'Chris Columbus' clone (4.33 versus 3.41). Also, the amount of foliar potassium of the chrysanthemum plants was about 35 percent less for the May than for the July sampling (3.05 versus 4.69). More specifically, it was about 24 percent less for the 'Arlora' clone and 47 percent less for the 'Chris Columbus' clone (Table 28).

TABLE 28.--Amount of foliar potassium of each of the two chrysanthemum clones on each of the two sampling dates (Data are those with a "cd" superscript of Appendix Table 15; LSD values are from Appendix Table 16

Kind of plant	Foliar potassium, percentage dry weight basis	
	5/2/60, d_1	7/2/60, d_2
'Arlora', c_1	3.75	4.91
'Chris Columbus', c_2	2.35	4.48

LSD: 5%, 0.45; 1%, 0.60

Foliar potassium of the *Feijoa* and *Ligustrum* plants

The greatest amount of foliar potassium was found in the unfertilized woodshavings-mulched shrubs (Table 29). This pattern was consistent with each shrub and with each sampling date (Appendix Table 17). Otherwise, there was no definite pattern in the foliar potassium concentration with fertilizer nitrogen variables nor with mulch variables.

TABLE 29.--Effect of mulch treatments and fertilizer treatments on the amount of foliar potassium of the two woody shrubs (Data are those with an "ab" superscript of Appendix Table 17; LSD values are from Appendix Table 18)

Mulch treatment	Foliar potassium, percentage dry weight basis, for the indicated fertilizer rate		
	0 lb., b_1	1 lb., b_2	2 lb., b_3
No mulch, a_1	1.01	1.03	0.88
Woodshavings, a_2	1.23	1.06	1.07
Woodchips, a_3	1.05	1.04	1.04

LSD: 5%, 0.06; 1%, 0.09

On the basis of time of year (sampling date), foliar potassium was highest in June 1961 of intermediate rank in July 1961 and lowest in October 1960. The respective values were 1.21, 1.10, and 0.83. Even though the foregoing data means are averaged over both plants, the effect was consistent for each kind of plant.

Discussion

The literature generally indicates that more foliar potassium is found in the leaves of mulched plants than in those of unmulched ones. On the contrary, in this study it was generally less in the woodshavings-mulched chrysanthemums, the same in the woodchips-mulched chrysanthemums, and either more, particularly with woodshavings, or else the same in the mulched woody shrubs; each of the above differences being compared with the unmulched plants. These differences were erratic, particularly in light of the fact that the data of Table 6 indicate that there was about four times more potassium in the woodchips mulch than in the woodshavings mulch.

Henley (29) stated that while most researchers have reported a gradual decline in the amount of foliar potassium as the growing season advances, he and a few others have found that this decline is preceeded by an increase early in the growing season. Apparently, that pattern of an initial rise in the amount of foliar potassium in plants, followed by a general decline, prevailed for the two chrysanthemum clones in this study since the amount of foliar potassium was higher for the July sampling than for the May sampling. The reason such a pattern for the two woody shrubs was not found may have been due to their having been sampled too late in the growing season to detect a rise prior to the usual decline.

Foliar sodium

The data means for the effects of the mulch/fertilizer treatments on foliar sodium of the chrysanthemum clones and the woody shrubs are presented in Appendix Tables 19 and 21 respectively.

Foliar sodium of the chrysanthemum clones

For the May 1960 sampling, no difference was found in the foliar sodium of either clone for different mulch levels or with increased rates of fertilizer. On the July 1960 sampling date, however, the foliar sodium of the unmulched and woodshavings-mulched plants was lower or trended lower with increased rates of fertilizer; that of the woodchips-mulched plants was highest with the highest rate of fertilizer (Table 30).

TABLE 30.--Effect of the mulch treatments and fertilizer treatments on the amount of foliar sodium of the chrysanthemum plants on each of the two sampling dates (Data are those with an "abd" superscript of Appendix Table 19; LSD values are from Appendix Table 20)

Mulch treatment	Foliar sodium, percentage dry weight basis, for indicated fertilizer rate					
	0 lb., b_1		1 lb., b_2		2 lb., b_3	
	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	.010	.052	.010	.039	.010	.041
Woodshavings, a_2	.012	.051	.010	.048	.013	.033
Woodchips, a_3	.012	.037	.011	.036	.012	.047

LSD: 5%, .009; 1%, .011

Foliar sodium of the *Feijoa* and *Ligustrum* plants

Foliar sodium was the same for all three mulch treatments for the two samplings of 1961 (June and July), while for the October 1960 sampling it was less for the plants mulched with either the woodshavings or the woodchips compared with the no-mulch treatment (Table 31). However, for the two 1961 samplings, foliar nitrogen trended in a direction typical of the pattern found for the 1960 sampling.

TABLE 31.--Effect of the mulch treatments on the amount of foliar sodium of the woody shrubs on each of three sampling dates (Data are those with an "ad" superscript of Appendix Table 21; LSD values are from Appendix Table 22)

Mulch treatment	Foliar sodium, percentage dry weight basis		
	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3
No mulch, a_1	.095	.032	.059
Woodshavings, a_2	.072	.029	.029
Woodchips, a_3	.067	.030	.030

LSD: 5%, .014; 1%, .019

As for the amount of foliar sodium on the different sampling dates, it was highest in October 1960, of intermediate rank in July 1961, and lowest in June 1961 when averaged over all mulch levels. However, an examination of the data for each of the two shrubs showed that this seasonal variation was applicable to the <u>Ligustrum</u> only (.122, .073, and .027, respectively); not the <u>Feijoa</u> (.034, .037, and .033, respectively).

In summary, foliar sodium was slightly less in the mulched plants compared with the unmulched ones. Little or no effect was found for the fertilizer treatment differentials.

Discussion

In this study, mulching with either the woodshavings or the woodchips had relatively little or no effect on foliar sodium in any of the indicator plants. Nor was this element effected by any changes in the amount of available potassium in the soil, an effect which might have been expected because of the synergistic relationship of these two elements.

There was, however, in the chrysanthemum clones in July, an inverse relationship between the amounts of foliar potassium and sodium with increasing rates of fertilizer nitrogen, but only with the woodshavings-mulched plants. The higher the fertilizer nitrogen rate, the higher the amount of foliar potassium and the lower the amount of foliar sodium. In the unmulched and the woodchips-mulched plants, foliar potassium was greater with increased rates of fertilizer nitrogen but, unlike that in the woodshavings-mulched plants, foliar sodium usually was not correspondingly lower.

Foliar calcium

The data means for the effects of the mulch/fertilizer treatments on foliar calcium of the chrysanthemum clones and the woody shrubs are presented in Appendix Tables 23 and 25 respectively.

Foliar calcium of the chrysanthemum clones

In comparison with the unmulched plants, for the May 1960 sampling, the amount of foliar calcium was lower for the woodchips-mulched plants and it trended lower for the woodshavings-mulched ones (Table 32). For the July sampling it was lower in both the woodshavings-and the woodchips-mulched planted compared with the unmulched ones.

Fertilizer treatments had no effect on foliar calcium, nor was there a difference in the amount of foliar calcium between clones. But between sampling dates, the foliar calcium was highest for the July over the June sampling, as would be expected.

TABLE 32.--Effect of the mulch treatments on the amount of foliar calcium of the chrysanthemum plants on each of two sampling dates (Data are those with an "ad" superscript of Appendix Table 23; LSD values are from Appendix Table 24)

Mulch treatment	Foliar calcium, percentage dry weight basis	
	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	.312	.516
Woodshavings, a_2	.294	.390
Woodchips, a_3	.274	.390

LSD: 5%, .025; 1%, .032

Foliar calcium of the *Feijoa* and *Ligustrum* plants

The highest amount of foliar calcium was found in the unmulched plants, an intermediate amount in the woodchips-mulched plants, and the least amount in the woodshavings-mulched ones. The respective values, when averaged over the other three factors were 0.92, 0.87, and 0.81 (Appendix Table 25).

A corresponding increase in foliar calcium was found with an increase in fertilizer rate. The values were 0.83, 0.87, and 0.90 for 0, 1, and 2 pounds of fertilizer respectively. Consistent with the results of other workers, there was an apparent increase in foliar calcium as the growing season advanced. The lowest amount was found for the June 1961 sampling, an intermediate amount for the July 1961 sampling, and the most for the October 1960 sampling. The respective values were 0.67, 0.88, and 1.05.

Discussion

The small amount of literature pertaining to the effect of mulching on foliar calcium indicates that little or no change may be expected

(64). The usually smaller amount of foliar calcium of the mulched plants of this study disagrees with those findings and indicates that the effects of mulching on foliar calcium may vary with one or more conditions of the environment not yet identified. One possibility is that the available calcium in the soil was being immobilized by the decomposing microorganisms. The greater amount of foliar calcium with higher rates of calcium nitrate fertilizer further substantiates this possibility.

Since available soil calcium is readily lost by leaching (16, p. 534; 70, p. 274), its concentration must have been greater with increased soil depth. This, and the fact that roots of the mulched plants must have been concentrated near the soil surface (in the calcium-poor portion of the soil profile), would seem to also account for the substantially smaller amount of foliar calcium in the woodshavings- and the woodchips-mulched plants than in the unmulched plants.

Foliar magnesium

The data means for the effects of the mulch/fertilizer treatments on foliar magnesium of the chrysanthemum clones and the woody shrubs are presented in Appendix Tables 27 and 29 respectively.

Foliar magnesium of the chrysanthemum clones

Foliar magnesium of either the woodshavings-mulched or the woodchips-mulched chrysanthemum plants was about one-third less than that of the unmulched plants (Table 33).

There was no difference in foliar magnesium due to fertilizer treatments. The amount of foliar magnesium was greater for the July than for the June sampling.

TABLE 33.--Effect of the mulch treatments on the amount of foliar magnesium of each of the two chrysanthemum clones on each of two sampling dates (Data are those with an "acd" superscript of Appendix Table 27; LSD values are from Appendix Table 28)

Mulch treatment	Foliar magnesium, percentage dry weight basis			
	'Arlora', c_1		'Chris Columbus', c_2	
	5/2/60, d_1	7/2/60, d_2	5/2/60, d_1	7/2/60, d_2
No mulch, a_1	.272	.328	.221	.343
Woodshavings, a_2	.163	.214	.172	.247
Woodchips, a_3	.152	.230	.191	.163

LSD: 5%, .025; 1%, .032

Foliar magnesium of the <u>Feijoa</u> and
<u>Ligustrum</u> plants

The magnitude of difference between the foliar magnesium of the unmulched plants and those treated with either of the mulches was not the same for the two shrubs (Table 34).

TABLE 34.--Effect of the mulch treatments on the amount of foliar magnesium of each of the two woody shrubs on each of three sampling dates (Data are those with an "acd" superscript of Appendix Table 29; LSD values are from Appendix Table 30)

Mulch treatment	Foliar magnesium, percentage dry weight basis, for indicated sampling date					
	Feijoa, c_1			Ligustrum, c_2		
	10/5/60,	5/1/61,	7/21/61,	10/5/60,	6/1/61,	7/21/61
No mulch, a_1	.36	.24	.29	.31	.23	.33
Woodshavings, a_2	.29	.19	.24	.30	.16	.29
Woodchips, a_3	.28	.17	.23	.31	.20	.31

LSD: 5%, 0.03; 1%, 0.04

In the <u>Feijoa</u> the foliar magnesium was the highest with the no-mulch over either of the mulches for all three sampling dates. In the

<u>Ligustrum</u>,it was highest for the no-mulch over the woodshavings mulch on the June and July sampling dates; otherwise in this plant there was no difference between any mulch treatment on the October sampling date nor between no-mulch and woodchips-mulch treatments for the other two samplings.

The foliar magnesium in the <u>Ligustrum</u> plants increased with increased rates of fertilizer nitrogen with no-mulch and woodchips-mulch treatments; not with woodshavings mulch. This pattern existed for all three samplings. No such effect was found for the fertilizer nitrogen treatment on the <u>Feijoa</u> plants.

Discussion

Ordinarily, a greater amount of available magnesium has been reported in soil mulched with a decomposable material than in unmulched soil (37, 68, 80). This condition has been attributed to the solvent action of carbonic and nitric acid originating in the decomposition of the decomposable mulch (8, pp. 250, 284). In contrast, less foliar magnesium usually has been reported in mulched than in unmulched plants (26, 58, 80), as was found in this study. Although Robinson and Chenery (58) attributed this to an antagonistic effect with potassium, the present data do not always support such a viewpoint. For, while available potassium of the soil and foliar potassium of the plants was usually somewhat higher with the woodchips and not with the woodshavings compared with the unmulched treatment, foliar magnesium was correspondingly lower in both the woodchips-and the woodshavings-mulched plants. Consequently, it appears that the antagnostic effect between potassium and magnesium may not have been the principal reason why the foliar magnesium was so much lower in the mulched than in the unmulched plants.

Thus, another reason requires consideration. As was also indicated for available calcium, the amount of available magnesium should have been greater with increased soil depth (16, p. 534; 70, p. 274). Conversely, the roots of the mulched plants must have been concentrated near the soil surface in that part of the soil profile lowest in available magnesium, whereas proportionately more roots of the unmulched plants must have been deeper in the soil where available magnesium was more abundant. It seems reasonable, then, that there would have been substantially less uptake of magnesium in the mulched than in the unmulched plants.

Microbiological tieup of available magnesium must also have been a contributing factor in foliar magnesium being lower in the mulched than in the unmulched plants.

Foliar manganese

The data means for the effects of the mulch/fertilizer treatments on foliar manganese of the chrysanthemum clones and the woody shrubs are presented in Appendix Tables 31 and 33 respectively.

Foliar manganese of the chrysanthemum clones

Compared with the unmulched plants, foliar manganese trended lower in the plants mulched with either the woodshavings or the woodchips, especially the ones mulched with the latter.

With increased levels of the fertilizer, there was a corresponding increase in foliar manganese in the July 1960 sampling, however, no such difference was found for the May 1960 sampling. In general the foliar manganese was higher in the 'Chris Columbus' clone than in 'Arlora' and higher for the July sampling than for the May sampling.

Foliar manganese of the *Feijoa* and *Ligustrum* plants

For the October 1960 sampling but not for the June or July 1961 samplings, the foliar manganese was markedly less in the woodchips-mulched *Ligustrum* plants compared with the same kind that were not mulched (Table 35). Otherwise there was no difference in foliar manganese between any of the mulch levels.

Foliar manganese was lower in the *Feijoa* plants than in the *Ligustrum* plants, the respective means being 27.3 and 72.0. It was also lower for the June and July 1961 samplings than for the October 1960 sampling. The respective values for these three samplings was 44.6, 47.1, and 102.2.

TABLE 35.--Effect of the mulch treatments on the amount of foliar manganese of each of the two woody shrubs on each of the three sampling dates (Data are those with an "acd" superscript of Appendix Table 33; LSD values are from Appendix Table 34)

Mulch treatment	Foliar manganese, ppm dry weight basis					
	Feijoa, c_1			Ligustrum, c_2		
	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3	10/5/60, d_1	6/1/61, d_2	7/21/61, d_3
No mulch, a_1	73	54	47	145	33	51
Woodshavings, a_2	80	44	46	186	30	48
Woodchips, a_3	53	76	43	76	31	47

LSD: 5%, 33; 1%, 44

No difference was found in foliar manganese between sampling dates for *Feijoa* but there was a difference for *Ligustrum*: at least three to four times more foliar manganese for the October 1960 sampling than for the June or July 1961 samplings.

Discussion

In the chrysanthemums the amount of foliar manganese appears to be related to the amount of foliar nitrogen. That is, with higher rates of fertilizer nitrogen, there were correspondingly higher amounts of foliar nitrogen and also of foliar manganese. In contrast, Smith (65) noted that in citrus the amount of foliar manganese is usually less with applied nitrogen. No such a pattern was found between the foliar nitrogen and foliar manganese as affected by the mulches, even though the literature generally indicates a pronounced relationship (22, 47, 51).

As for the woody shrubs, the amount of foliar manganese follows such an erratic pattern as to preclude the drawing of even generalities about the effect of the mulch/fertilizer treatments on this element in either the *Feijoa* or the *Ligustrum* plants.

Growth Characteristics of the Indicator Plants

Determinations were made of the effects of the mulch/fertilizer treatments on the size, weight, and number of stems per plant of the two chrysanthemum clones, of the root growth of the *Feijoa* and *Ligustrum* shrubs, and of the linear shoot growth of the *Feijoa*.

The analyses of variance mean squares of the size and weight of the two chrysanthemum clones and of the linear shoot growth of the Feijoa are shown in Appendix Table 35.[21] F-ratios for the four factors influencing the size and weight of the two chrysanthemum clones and the two factors influencing the *Feijoa* linear shoot growth are shown in Table 36.

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[21] Statistical analyses were not made of the data for the number of stems per plant of the two chrysanthemum clones nor those for the root growth of the *Feijoa* and *Ligustrum* plants.

TABLE 36.--Significance of the variation in size and weight of the two chrysanthemum clones and linear shoot growth of the Feijoa in relation to the mulch, fertilizer, kind of plant, and sampling date factors (F-ratios are calculated from the data of Appendix Table 35)[1]

Factor	Factor code	F-ratio		
		Chrysanthemum clones		Feijoa linear shoot growth
		Size	Weight	
Cultural treatment				
Mulch	A	117.37**	93.87**	13.34**
Fertilizer	B	1	3.00	6.61**
Plant	C	32.72**	1	
Sampling date	D	1	557.41**	

[1] Symbols * and ** indicate significance at the 5- and 1-percent levels of probability, respectively

The significant F-ratios indicate that the mulch factor had an important influence on the size and weight of the chrysanthemum clones and on the linear shoot growth of the Feijoa plants. No effect was found for the fertilizer factor on either size or weight of the chrysanthemum clones but apparently linear shoot growth of the Feijoa plants was affected by the fertilizer factor. The size of the chrysanthemum clones was strongly influenced by the kind of plant, yet, surprisingly, the weight was not.

Chrysanthemum plants

The data means for the affects of the mulch/fertilizer treatments on growth characteristics of the chrysanthemum clones are presented in Table 37 for the number of stems and Appendix Tables 36, 38, and 40 for the size, weight, and weight-size ratio, respectively.

Number of stems

Shown in Table 37 are the results of the count that was made on April 28, 1960, of the number of stems of major size that had grown from the root crown of each chrysanthemum plant since the November, 1959, harvest of the tops. Even though these data have not been analyzed statistically, there appears to be some definite differences. For one thing, there were far more stems in the unmulched plants than in the mulched plants. Between the mulched plants, there were slightly, but consistently more stems in the woodchips-mulched plants than in the woodshavings-mulched ones.

Another important difference is that there were about twice as many stems in the 'Arlora' clone for each mulch level as in the 'Chris Columbus' clone. On the basis of this, on the basis of the 'Chris Columbus' plants being about 20 percent bigger than the 'Arlora' plants (Appendix Table 36), and on the basis that the weight of each clone was

TABLE 37.--Effect of the mulch treatments and the fertilizer treatments on the number of stems per plant of each of the two chrysanthemum clones on April 28, 1960[1]

Mulch treatment	Number of stems per chrysanthemum plant for the indicated fertilizer rate					
	'Arlora', c_1			'Chris Columbus', c_2		
	0 lb., b_1	1 lb., b_2	2 lb., b_3	0 lb., b_1	1 lb., b_2	2 lb., b_3
No mulch, a_1	22.71	22.39	19.49	12.08	13.95	11.29
Woodshavings, a_2	12.66	11.57	11.68	6.34	6.34	6.43
Woodchips, a_3	16.28	14.94	15.85	7.52	6.80	7.85

[1] Replications averaged--no statistical analysis made.

the same (Appendix Table 38), it is apparent that the size and weight per stem were much greater for the 'Chris Columbus' clone than for the 'Arlora'.

Size (volume)

When measured on April 27, 1960, the size of both of the chrysanthemum clones was about four times larger for the unmulched plants than for the mulched ones (Table 38). On June 30, 1960, the size of the regrowth (the tops of the plants were harvested on May 3, 1960) of the 'Arlora' plants was the same for all mulch treatments, that is, the unmulched ones were smaller and the mulched ones slightly larger than they had been when measured in April. In contrast, the size pattern of the second crop of the 'Chris Columbus' plants was somewhat like that of the first crop--the unmulched plants were the largest and the mulched ones the smallest. However, even with that size differential, the mulched 'Chris Columbus' plants were much larger than in April.

TABLE 38.--Effect of the mulch treatments on the size of each of the two chrysanthemum clones on each of two measuring dates (Data are those with an "acd" superscript of Appendix Table 36; LSD values are from Appendix Table 37)

Mulch treatment	Size, cubic inches per chrysanthemum plant			
	'Arlora', c_1		'Chris Columbus', c_2	
	4/27/60, d_1	6/30/60, d_2	4/27/60, d_1	6/30/60, d_2
No mulch, a_1	174	57	171	133
Woodshavings, a_2	30	62	38	95
Woodchips, a_3	52	63	40	88

LSD: 5%, 18; 1%, 25

Considering the two clones, there was comparable growth for each when measured in April. For the June measuring, however, the 'Chris Columbus' clone was distinctly larger.

No size differences were found for the fertilizer treatments although there was a trend for the unmulched and the woodchips-mulched plants treated with the 1-pound rate of fertilizer to be of comparable size and larger than those treated with the 0- and 2-pound fertilizer levels. Since this pattern was not present with the wood-shavings-mulched plants, for which nitrogen immobilization apparently was severe, it may be inferred that the 2-pound rate of fertilizer was an excess amount for the no-mulch and woodchips treatments.

There was also a trend for the woodshavings-mulched plants to be larger with each increase in fertilizer nitrogen when measured on June 30, 1960.

Weight

When harvested on November 3, 1959, the chrysanthemum plants weighed the same for all mulch levels. In contrast, compared with the unmulched plants, the mulched ones were at least three times lighter when harvested in May. This same differential, but of lesser magnitude, was also found for the July harvest (Table 39).

There were no weight differences for the fertilizer treatments for the November 1959 nor for the May 1960 harvests. With the July 1960 harvest, both clones treated with either no-mulch or woodchips and fertilized with the 1-pound rate of fertilizer were the heaviest, compared with the other treatments (Table 40). the lack of a similar increase for the unmulched and the woodchips-mulched plants treated with the 2-pound rate of fertilizer suggests that that much fertilizer

TABLE 39.--Effect of the mulch treatments on the weight of each of the two chrysanthemum clones on each of three harvest dates (Data are those with an "acd" superscript of Appendix Table 38; LSD values are from Appendix Table 39)

Mulch treatment	Weight, pounds per chrysanthemum plant					
	'Arlora', c_1			'Chris Columbus', C_2		
	11/30/59, d_1	5/3/60, d_2	7/8/60, d_3	11/30/59, d_1	5/3/60, d_2	7/8/60, d_3
No mulch, a_1	.30	2.98	1.82	.23	2.33	2.78
Woodshavings, a_2	.17	.52	.72	.12	.55	2.26
Woodchips, a_3	.25	.94	1.09	.13	.58	1.96

LSD (applicable only for the different a's): 5%, 0.31; 1%, 0.41

TABLE 40.--Effect of the mulch treatments and the fertilizer treatments on the weight of each of the two chrysanthemum clones on the July 8, 1960 harvest date (Data are those with an "abcd" superscript at the d_3 level of Appendix Table 38; LSD values are from Appendix Table 39)

Mulch treatment	Weight, pounds per chrysanthemum plant, for the indicated fertilizer rate					
	'Arlora', c_1			'Chris Columbus', c_2		
	0 lb., b_1	1 lb., b_2	2 lb., b_3	0 lb., b_1	1 lb., b_2	2 lb., b_3
No mulch, a_1	1.76	2.15	1.53	2.48	3.25	2.60
Woodshavings, a_2	1.23	1.42	1.76	1.72	2.32	2.73
Woodchips, a_3	1.88	2.92	1.43	1.56	2.28	2.03

LSD: 5%, 0.53; 1%, 0.71

was detrimental to maximum plant growth. It should be noted, however, that the smaller weight of the woodchips-mulched plants treated with the 2-pound compared with the 1-pound rate of fertilizer was a trend difference rather than a significant difference.

In contrast with the results described in the previous paragraph, with each increase in fertilizer nitrogen there was a corresponding increase in the weight of the July 1960 harvest of both of the chrysanthemum clones mulched with woodshavings. This appears to indicate that the increased amount of foliar nitrogen with corresponding increases in fertilizer nitrogen with these treatments (Appendix Table 7) was beneficial to plant growth. It also indicates that the application of fertilizer nitrogen was beneficial in correcting a nitrogen deficiency in both plants mulched with woodshavings.

Weight-size ratio

Ratios of the weight of the chrysanthemum plants to their size, as affected by the factorial treatments, are shown in Appendix Table 40. In general the plants harvested in May 1960 were about two-thirds as heavy per unit size as those harvested in July 1960 (Table 41). These data are reasonably comparable for both clones for any mulch or fertilizer treatment for the May harvest and also for the July harvest for the 'Chris Columbus' clone. On the other hand, when averaged over all three fertilizer levels, the July or second harvest of 'Arlora' plants mulched with woodshavings was appreciably lighter than the unmulched

TABLE 41.--Effect of the mulch treatments on the weight-size ratio of each of the two chrysanthemum clones on each of two measuring dates (Data are those with an "acd" superscript of the Appendix Table 40)

Mulch treatment	Weight-size ratio per chrysanthemum plant			
	'Arlora', c_1		'Chris Columbus', c_2	
	5/60, d_1	7/60, d_2	5/60, d_1	7/60, d_2
No mulch, a_1	1.71	3.21	1.37	2.09
Woodshavings, a_2	1.69	2.36	1.46	2.37
Woodchips, a_3	1.78	3.27	1.46	2.23

ones; the woodchips-mulched ones weighed virtually the same as the unmulched ones.

The reason the plants of the first harvest were lighter per unit volume than those of the second harvest is apparently because of a greater dry matter content of the latter. The longer days and warmer soil temperatures that prevailed during the growth period of the plants of the second harvest should have resulted in a greater photosynthetic production of carbohydrates and consequently a greater amount of dry matter.

Feijoa and Ligustrum plants

The data means for the effect of the mulch/fertilizer nitrogen treatments on growth characteristics of the two woody shrubs are presented in Appendix Table 41 for root weight of each of the shrubs and in Table 43 for linear shoot growth of the *Feijoa* plants.

Root weight

The overall differences in the root weight samples of each of the two woody shrubs are shown in Table 42. These data have not had the usual statistical analysis and so the following narrative concerning them is conservative in identifying any differences.

Between mulch treatments it appears that in the top 1- to 3-inch part of the soil profile the amount of roots of each shrub was greatest with mulching compared with no mulching; also that between the two mulches the root weight was greatest with woodchips. With the *Ligustrum*, a similar pattern but of greater magnitude was found in the 3- to 6-inch part of the soil profile while in the 6- to 9-inch part, root weight was greater with woodchips mulch but not with woodshavings. With the *Feijoa*, the amount of roots at the 3- to 6-inch depth was similar with all three mulch treatments; at the 6- to 9-inch depth, root weight in the unmulched and the woodchips-mulched plants was similar and greater than in woodshavings-mulched plants.

Between the different levels of the soil profile, with no mulch root weight of each of the shrubs was about one-half as much at the 1- to 3-inch depth as at either the 3- to 6-inch and the 6- to 9-inch depths. Root weight of the woodshavings- and woodchips-mulched Feijoa plants was less with increased soil depth. Root weight of the woodshavings and the wood-chips mulched Ligustrum was greatest at the 3- to 6-inch depth and similar at the 1- to 3-inch and 6- to 9-inch parts of the soil profile.

TABLE 42.--Effect of the mulch treatments on the root weight of each of the two woody shrubs at each of three sampling depths (Data are those with an "acd" superscript of Appendix Table 41)[1]

Mulch treatment	Root weight, grams per plant sample, for the indicated sampling depth					
	Feijoa, c_1			Ligustrum, c_2		
	1-3", d_1	3-6", d_2	6-9", d_3	1-3", d_1	3-6", d_2	6-9", d_3
No mulch, a_1	.35	.64	.63	.38	.64	.86
Woodshavings, a_2	.53	.53	.32	.75	1.75	.72
Woodchips, a_3	.74	.55	.57	1.01	1.62	1.56

[1] Replications averaged--no statistical analysis made.

Between the two plants the root weight of the Feijoa was considerably less than that of the Ligustrum, especially at the 3- to 6-inch soil depth.

Linear shoot growth of the *Feijoa* plants

There was about 40 percent more linear shoot growth for the plants mulched with either woodshavings or woodchips than for the unmulched plants (Table 43). Visual observations indicated that the greater linear shoot growth under the foregoing conditions was a result of longer internodes rather than more of them. With mulching the plants were less compact, which, from an aesthetic standpoint, made them less effective as shrub material in the usual landscape situation.

TABLE 43.—Effect of the mulch treatments and the fertilizer treatments on the linear shoot growth of the *Feijoa* plants 18 months after growing under the treatment differentials

Mulch treatment	Linear shoot growth, inches per plant, for the indicated fertilizer rate			
	0 lb., b_1	1 lb., b_2	2 lb., b_3	Mean
No mulch, a_1	477	475	595	516
Woodshavings, a_2	592	880	996	824
Woodchips, a_3	700	914	967	860
Mean	590	756	853	

LSD: 5%, 156; 1%, 206

Such "openness of growth" as a result of the mulches was not visually apparent for the *Ligustrum* plants.

With increased fertilizer rates there was a corresponding increase in the linear shoot growth of the *Feijoa* plants mulched with either woodshavings or woodchips but not for the unmulched plants.

Discussion

Comparable effects of the mulch/fertilizer treatments were generally found for each of the growth characteristics studied. In some cases, the effects were the same with all four of the indicator plants, in other cases they were diametrically different between the herbaceous chrysanthemum plants and the woody shrubs. The more pronounced of these relationships will be discussed below.

There was conclusive evidence that growth was less for the mulched chrysanthemum plants and more for the mulched woody shrubs, compared with that for the unmulched ones. With the chrysanthemum plants, the number of stems, the size, and the weight of each plant was less with either of the mulches compared with the no-mulch treatment. The magnitude of difference was usually greatest, however, with the wood-shavings mulch. In contrast, the root weight of both of the woody shrubs and the linear shoot growth of the Feijoa was more with either of the mulches.

As was pointed out in the review of literature, several workers have reported smaller yields for herbaceous plants such as corn (35, 44, 50, 54, 61, 76) and other crops (44, 54), with the application of fresh plant residue mulches. Conversely, a few workers have reported the enhancement of either the yield or vegetative growth with mulches (37, 44, 47, 85). Lunt (44) concluded in principle that the growth of plants the first and sometimes the second year after applications of a wood-chips mulch was less because of a tieup of nitrogen during the initial period of organic matter decomposition and that succeeding years thereafter, with no additional woodchips, the long-term effect of the mulching was an enhancement of plant growth. This is because after a short period of initial decomposition of the mulch, more nitrogen is released than is utilized by the decomposing microorganisms. In this study, the less growth of the mulched chrysanthemum plants the first year after application of the mulches and the greater growth of the mulched shrubs in succeeding years, in comparison with the unmulched plants, supports a portion of Lunt's aforementioned conclusion. In essence the benefits of mulching are primarily manifested in those plants that can be grown under a mulch regime for periods longer than the first year after mulch application, i.e. perennial woody plants.

But the results of this study do not support Lunt's conclusion and that of other workers (46, 57), too, that the effects of mulches on plant growth are primarily nitrogen-related. For, while growth of the mulched shrubs was greater than the unmulched shrubs, foliar nitrogen was consistently and substantially lower in the woodshavings-mulched shrubs than in the unmulched shrubs. In the woodchips-mulched shrubs it was virtually the same as in the unmulched ones. Yet, those shrubs mulched with either of the mulches had comparable and more growth than the unmulched ones.

With the chrysanthemum plants, there was less foliar nitrogen and also less growth on the May sampling date with either mulch than without mulch. However, this cannot be attributed to a shortage of nitrogen since in both clones an increase in fertilizer nitrogen had no effect on the amount of foliar nitrogen nor on any of the growth characteristics. The differential amount of foliar nitrogen and growth characteristics, therefore, must have been due to some physical aspect of the environment. As shown in the review of literature, corn yields were found to be much smaller under decomposable mulch tillage than under a cultural practice where the organic material had been incorporated into the soil. The workers attributed this to lower soil temperatures under the mulch (see page 4). In the present study, the temperature differentials between the mulched and the unmulched soil do not seem to have been great enough to entirely account for such a large growth differential as occurred in the chrysanthemum plants (Table 8) for the May sampling. An accompanying cause may have been a lower oxygen supply corresponding to the greater amount of moisture in the mulched soil. If oxygen had been limiting, respiration would have been checked in which case cell membranes would have been less permeable (48, p. 244). As a consequence there would have been less absorption of water and less accumulation of electrolytes in the root cells (48, p. 637). The net results should have been less growth of the chrysanthemum plants.

It seems probable that the 2-pound rate of fertilizer had deleterious effects in some cases. The stem number, the size, and the weight of both chrysanthemum clones and the root weight of both shrubs was usually less while foliar nitrogen was usually highest in the unmulched plants fertilized with the 2-pound compared with the 1-pound rate of fertilizer and occasionally in the woodchips-mulched plants that were fertilized likewise. Ordinarily, two pounds of fertilizer nitrogen should not be too much to apply with the quantity of mulches used in this study. However, it is well to remember that at the beginning of the study and for several months thereafter, there was an unusually large amount of nitrate nitrogen in the soil. With the addition of the 2-pound rate of fertilizer nitrogen, it is reasonable that the amount accumulating within the plants was a deterent to maximum plant growth. If so, the 4.54 and 4.00 percent foliar nitrogen in the unmulched July-sampled 'Arlora' and 'Chris Columbus' chrysanthemum plants respectively that had been treated with the 2-pound rate of fertilizer would be in the excess concentration range. Henley (28) reported no adverse effects on chrysanthemum plants in which the foliar nitrogen was as high as 5.05 percent. However, these were 4-week-old plants. He found that the foliar nitrogen concentration of similarly grown 14-week-old plants was 3.94 percent.

The latter plants were of comparable age to those sampled in the present study.

As noted in the discussion on foliar phosphorus, the amount of that element in the woodchips-mulched and the unmulched plants was virtually the same, especially with no fertilizer, whereas with the woodshavings-mulched plants there was usually less foliar phosphorus with increased rates of the fertilizer. If the lesser amount of foliar phosphorus in the plants supplied with the higher rates of fertilizer were due to a dilution effect then the growth of the plants should have been correspondingly more with the more nitrogen/less foliar phosphorus relationship. As such, the growth of the plants should have been comparable and more with the no-mulch and the woodchips treatments than with the woodshavings mulch treatment. However, that was not the case. Instead, the greatest amount of shoot growth was found in the woodchips- and the woodshavings-mulched plants; the least in the unmulched plants. These comparisons are shown in Table 44. It seems reasonable to conclude, therefore, that the pattern of the foliar phosphorus being highest when the foliar nitrogen was lowest was not a dilution effect but rather an antagonistic effect.

TABLE 44.--Effects of the mulch treatments on foliar nitrogen, foliar phosphorus, and linear shoot growth of the Feijoa plants (data are from Appendix Tables 9 and 13 and Table 43, respectively)

Mulch treatment	Foliar nitrogen	Foliar phosphorus	Shoot growth
	percent	percent	centimeters
No mulch	1.79	.163	515
Woodshavings	1.50	.217	824
Woodchips	1.77	.174	860

In the discussion concerning foliar calcium and magnesium, it was suggested that the reason the concentration of these two nutrient elements was lower in the mulched than in the unmulched plants may have been due in part to the root distribution pattern in the soil profile. This premise was based on the consideration that while the roots of the unmulched plants were probably distributed more or less evenly throughout the soil profile to a reasonable depth, those of the mulched plants must have been concentrated near the soil surface in that part of the soil profile having the least amounts of available calcium and magnesium. Such a root distribution pattern was, in fact, found with each of the woody shrubs. It is surprising that this concept has received so little attention in the literature, since it reconciles the findings that mulching enhances the availability of calcium and magnesium (37, 47, 58, 80) with the findings of lower concentrations of these two nutrients in mulched than in unmulched plants (26, 58, 80).

General Discussion

This portion of the dissertation is supplementary to the discussion presented in each of the various subparts. It concerns results within those subparts that are most meaningful when related to one another and which, consequently, were not presented in previous discussion.

No consistent relationship was found between the amount of the various nutrients in the soil and their concentration in the indicator plants. While total nitrogen of the soil was highest for the woodchips treatment over that for the no-mulch and the woodshavings treatments, foliar nitrogen of the indicator plants was highest in the unmulched and the woodchips-mulched plants and lowest in the woodshavings-mulched ones. In the two woody shrubs, the amount of foliar phosphorus was about 40 percent more for the woodshavings treatment over that in either the no-mulch or the woodchips treatments while the amount of soil phosphorus was much the less for the woodshavings treatment compared with the other treatments. The pattern of these data suggests that the soil phosphorus might have been lowest for the woodshavings treatment due to more phosphorus being absorbed into the woodshavings-mulched plants. The same line of reasoning cannot be followed for potassium, however, since the amount of that nutrient element in both the soil and the foliage of the indicator plants was usually correspondingly lowest for the woodshavings treatment. It is apparent from these data that it would be unwise to speculate about the adequacy of the aforementioned nutrients on the basis of their amount in the soil.

Noteworthy about the foliar nutrient concentrations was the constancy of difference between the herbaceous and the woody plants. Typical of this was the gross average foliar nitrogen of 3.55 percent for the chrysanthemum clones opposed to 1.69 percent for the woody shrubs. Actually, variation in the concentration of a foliar nutrient between different kinds of plants is well known even between clones of the same plant species (20, 29, 30, 55, 62, 84). Of the two chrysanthemum clones used in this study, the foliar concentration of nitrogen, potassium, and sodium was highest in the 'Arlora' clone for both samplings; that for phosphorus, magnesium, and manganese was highest in the 'Arlora' clone for the May sampling only and in the 'Chris Columbus' clone for the July sampling. Parenthetically, even though plant clones are ordinarily selected because of some unique morphological characteristic, it is apparent from these results that clones of a single plant species may have physiological differences, too. For this reason, the results of a physiological study of one clone of a plant species may not be applicable to other clones of that species as Howlett (30) found with certain vegetable crops.

Despite any clonal differences in foliar nutrient concentration, wherever a treatment caused a lower concentration of foliar nitrogen in the chrysanthemum plants, any change in the amount of the various other foliar nutrients was comparable for both clones as denoted schematically in Appendix Table 47.

Another point of interest, shown in Appendix Table 47, is that with a diminution in the concentration of foliar nitrogen, the change in the amount of foliar phosphorus and foliar potassium was usually downward for the chrysanthemum clones and upward for the woody shrubs. For the other nutrients studied, the direction of change was comparable in all of the indicator plants.

SUMMARY AND CONCLUSIONS

Field investigations were conducted to elucidate the effects of two wood fragment mulches and fertilizer nitrogen on the concentration of plant nutrients and the amount of vegetative growth of four kinds of indicator plants. Woodshavings of douglas-fir wood and woodchips of prunings of primarily Eucalyptus camaldulensis were employed as the mulches. The fertilizer nitrogen was calcium nitrate. The indicator plants were two clones of Chrysanthemum morifolium and two woody shrubs, namely Feijoa sellowiana and Ligustrum japonicum. Quantitative data were obtained by chemical analyses of the soil and plant properties and by physical measurements of the plants. The principal findings from the investigations are enumerated below. Unless otherwise indicated, the results described are those obtained about two years after treatment application. Also, any reference to the woodshavings mulch treatment or the woodchips mulch treatment or to a certain fertilizer nitrogen treatment implies a comparison with the no-mulch or the no-fertilizer nitrogen treatment, whichever the case may be.

1. Either mulch resulted in sufficient insulation to maintain the soil considerably cooler in the summer and to greatly reduce moisture loss by evaporation.

2. Mulching appeared to have had little acidifying effect on soil reaction. The principal change in the soil pH was to a more alkaline condition of the unmulched soil only. This is attributed to more cation accumulation in that soil than in the mulched soils.

3. Mulching also affected other soil properties in much the same manner as previous studies have shown. Soil organic matter was slightly higher in the woodchips-mulched soil after two years but not in either the woodshavings-mulched soil or the unmulched soil. This differential between the two mulched soils apparently was because the woodchips mulch underwent decomposition so much faster than did the woodshavings mulch. Total nitrogen of the soil was unchanged with woodchips; substantially less with the woodshavings and no-mulch treatments. Soil phosphorus was more with woodchips, less with woodshavings, and unchanged with no mulch. Available potassium was unchanged with woodchips and lower with the other two treatments.

4. Foliar nitrogen was often lower with mulching especially with the woodshavings mulch and sometimes, though not always, this condition was averted with fertilizer nitrogen. On one sampling date, that in July 1960, the amount of foliar nitrogen in either chrysanthemum clone varied directly with the fertilizer nitrogen rate. However, the magnitude of increase with increased fertilizer nitrogen was greatest with the woodshavings treatment. On an earlier sampling date in 1960, that in May, the amount of foliar nitrogen did not vary between fertilizer nitrogen levels. In both of the woody shrubs, foliar nitrogen was consistently lower on all three sampling dates when mulched with woodshavings; in the woodchips-mulched ones it was the same as in the unmulched ones. With increased levels of fertilizer nitrogen, there was correspondingly more foliar nitrogen in each of the woody shrubs in October, 1960. This pattern ebbed in the Ligustrum in June and July, 1961, while in the Feijoa it was totally absent.

5. Foliar phosphorus was affected differently in the two chrysanthemum clones. For the May 1960 sampling of the 'Arlora' clone, it

was lower with woodshavings mulch and unchanged with woodchips. Similarily, in July, foliar phosphorus trended higher with woodshavings and was, indeed, higher with woodchips. In the 'Chris Columbus' clone it was higher with woodshavings and higher still with the woodchips in both May and July 1960. With increased fertilizer nitrogen rates, the amount of foliar phosphorus of the chrysanthemum plants was unchanged. In October 1960 and June and July 1961 the amount of foliar phosphorus of each woody shrub was virtually the same with the no-mulch and the woodchips. In comparison with these, it was markedly more with woodshavings. With increased rates of fertilizer nitrogen, foliar phosphorus in the Feijoa and Ligustrum shrubs was correspondingly less. In the woody shrubs it was practically the same on all three sampling dates. Virtually the same amount was found in each of the two woody shrubs.

6. The amount of foliar potassium was generally less with mulching but this pattern was sometimes lacking with the application of fertilizer nitrogen. Foliar potassium of the unmulched and the wood-chips-mulched plants was of comparable value in both clones for the May and July 1960 samplings. With the woodshavings-mulch treatment, it was less in the 'Arlora' clone only for the July sampling and in the 'Chris Columbus' clone for both the May and July samplings. With increased rates of fertilizer nitrogen, the amount of foliar potassium was unchanged for the May 1960 sampling but was correspondingly greater two months later in July. With the woody shrubs, the greatest amount of foliar potassium was found in the unfertilized woodshavings-mulched plants. This pattern prevailed in both shrubs and in both the May and July samplings. Otherwise there was no definite pattern in the amount of foliar potassium in relation to the mulch/fertilizer nitrogen treatments for the woody shrubs.

7. Little difference was found for the foliar sodium between the mulch and fertilizer treatments. In the chrysanthemum clones it was only slightly if at all different between the mulch treatments; with increased rates of fertilizer nitrogen it trended lower. With the two woody shrubs, the amount of foliar sodium was constant between mulch treatments for the samplings in June and July 1961, while for the October 1960 sampling it was less for the mulched plants than for the unmulched ones.

8. Foliar calcium was lower in all four indicator plants when mulched with either the woodshavings or the woodchips. With the woody shrubs, however, the magnitude of difference was greatest between the woodshavings-mulched plants and the unmulched ones. With increased rates of fertilizer nitrogen there was a corresponding increase in foliar calcium of the two woody shrubs.

9. As with foliar calcium, foliar magnesium was markedly lower in all four indicator plants with mulching. Only in the woodshavings-mulched *Ligustrum* was it lower than in the unmulched plants and this only for the June and July 1961 samplings. Increased rates of fertilizer nitrogen had no effect on the amount of foliar magnesium.

10. Foliar manganese trended lower in the mulched chrysanthemum plants. With increased fertilizer nitrogen, there was a corresponding increase of it in the chrysanthemum clones for the July but not for the May sampling. The principal difference in this nutrient element in the two woody shrubs was the substantially lower amount in the woodchips-mulched *Ligustrum* plants compared with that in the unmulched ones. Foliar manganese was about 3 times less in the *Feijoa* than in the *Ligustrum* plants.

11. A description of the general pattern of the change of various nutrient elements in the foliage of the indicator plants with a diminutive change in foliar nitrogen follows.

a. Phosphorus. In both chrysanthemum clones, phosphorus was either lower or it trended lower with the mulch treatments; was unchanged with the fertilizer treatments. In the *Feijoa* and *Ligustrum* the phosphorus was either higher or of a higher trend with the mulch treatments and generally unchanged with the fertilizer treatments.

b. Potassium. The foliar potassium followed a pattern similar to that of phosphorus but by a greater magnitude of difference. With the chrysanthemum clones it was generally lower with both mulch and fertilizer nitrogen treatment factors on the July 1960 sampling date, but unchanged on the May 1960 sampling. With *Feijoa* and *Ligustrum* there was a definite increase in foliar potassium with a diminutive change in foliar nitrogen.

c. Sodium. With only two exceptions, foliar sodium was unchanged with any diminutive change in foliar nitrogen.

d. Calcium. In about half of the cases where foliar nitrogen was lower so also was foliar calcium. Otherwise foliar calcium was unchanged regardless of a diminutive change in foliar nitrogen.

e. Magnesium. Foliar magnesium was usually lower anytime the foliar nitrogen was lower.

f. Manganese. Occasionally foliar manganese was lower but usually it was unchanged whenever the foliar nitrogen was lower.

12. Linear shoot growth of the chrysanthemum plants was adversely affected by mulching; that of the woody shrubs was apparently enhanced. There was far fewer stems per plant in the mulched chrysanthemum plants. By April 1960 spring regrowth of the unmulched ones was practically

maximal whereas the mulched ones were about four times smaller. The stem weight of the woodshavings-mulched ones, when harvested in May and again in July 1960, was as much as three times lighter than the unmulched ones. Those harvested in July 1960 were heaviest where they were either unmulched or else mulched with woodchips and fertilized with one pound of nitrogen. The lack of similar weight increase for the unmulched and the woodchips-mulched plants fertilized with two pounds of nitrogen is attributed to incipient toxicity resulting from excess nitrogen.

13. The growth of the roots of the woody shrubs, particularly their distribution in the soil profile, was apparently affected by the mulch treatments. Roots of the mulched shrubs were concentrated in the top 1- to 3-inch portion of the soil profile; those of the unmulched shrubs were more evenly distributed throughout the soil profile to a more conventional depth. Gross weight of the <u>Feijoa</u> roots was unaffected by the mulch treatments; that of the <u>Ligustrum</u> roots was substantially heavier with mulching.

14. In conclusion, under the conditions of this study, the overall results indicate that the kind of decomposable organic material used for mulching has a pronounced effect on the concentration of at least some of the nutrient elements in plants. For instance, on many of the sampling dates, foliar nitrogen was considerably less with the woodshavings than with the no-mulch treatment. On the other hand, with woodchips, which contained much more nitrogen than did the woodshavings, foliar nitrogen was often comparable to that found in the unmulched plants. The status of foliar nitrogen of the indicator plants was sometimes improved with the application of fertilizer

nitrogen. But in final analysis, in terms of maximum growth, mulching had an adverse effect on the chrysanthemum plants and a beneficial effect on the woody shrubs. Also, the benefit of using fertilizer nitrogen with either of the mulches was not demonstrated.

APPENDIX

APPENDIX TABLE 1

A representative split-split-plot analysis of variance table, this for the amount of nitrogen, percentage dry weight basis, in the foliage of two plant taxa, C (Chrysanthemum 'Arlora' and Chrysanthemum 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960) due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 pounds of elemental nitrogen, derived from calcium nitrate, per 1000 square feet).

Sources	df	Mean square	F	$F_{.95}$	$F_{.99}$
(whole-unit analysis)					
Replicates, R	5	.051	<1	2.45	3.51
Cultural treatm'ts,(CT)	(8)	---	---	---	---
Mulches, A	2	5.628	36.08**	3.23	5.18
Fertilizers, B	2	2.516	16.13**	3.23	5.18
AB	4	.317	2.38	2.61	3.85
Error (a)	40	.156	---	---	---
Whole-unit total	53	---	---	---	---
(sub-unit analysis)					
Plants, C	1	8.272	86.17**	4.06	7.26
(CT)C	(8)	---	---	---	---
AC	2	1.761	18.34**	3.21	5.13
BC	2	0.023	<1	3.21	5.13
ABC	4	0.077	<1	2.59	3.80
Error (b)	45	0.096	---	---	---
Sub-unit total	54	---	---	---	---
(sub-sub-unit analysis)					
Sampling dates, D	1	45.770	444.31**	3.95	6.93
(CT)D	(8)	---	---	---	---
AD	2	3.062	29.73**	3.10	4.87
BD	2	2.036	19.77**	3.10	4.87
ABD	4	.302	2.93*	2.48	3.56
CD	1	.471	4.57*	3.95	6.83
(CT)CD	8	---	---	---	---
ACD	2	.678	6.58**	3.10	4.87
BCD	2	.040	<1	3.10	4.87
ABCD	4	.066	<1	2.48	3.56
Error (c)	90	.103	---	---	---
Sub-sub-unit total	108	---	---	---	---
Grand total	215	---	---	---	---

* and ** indicate significance at the 5 and 1 percent levels respectively.

APPENDIX TABLE 2

Analyses of variance mean squares for the effect of the mulch and fertilizer factorial treatments on soil properties[1]

Source of Variation	Degrees of Freedom	Mean square							
		Temperature[2]	Moisture	pH	Organic matter	Nitrate nitrogen	Total nitrogen	Phosphate phosphorus	Exchangeable potassium
Replicates	5	11.47**	5.71	.09	.65	40203	.01	60.95	2251
Treatments									
Mulch (A)	2	181.15**	400.63**	.76**	1.18*	186696	.13**	454.13**	25481**
Fertilizer (B)	2	0.08	15.16	.10	.02	149163	.00	39.93	9395*
A x B	4	1.12	9.06	.07	.13	53127	.01	37.71	2386
Error (a)	40	1.52	9.74	.05	.30	76070	.01	41.68	2619
Measuring date (C)	2	9762.79**							
A x C	4	165.92**							
B x C	4	.65							
A x B x C	8	1.05							
Error (b)	90	1.31							

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[1] Symbols * and ** indicate significance at 5 and 1 percent levels, respectively. Significance of each was determined by calculating the F-value (the treatment datum divided by the appropriate error datum) and comparing it with the tabular F-value. The F-values needed for significance are shown below:

Probability of a larger F-value	Numerator (treatment) df/Denominator (error) df				
	2/40	4/40	2/90	4/90	8/90
.05	3.23	2.61	3.11	2.49	2.06
.01	5.18	3.85	4.88	3.56	2.73

[2] Factor C and all interactions containing it were analyzed as a sub-unit.

APPENDIX TABLE 3

Soil temperature at a depth of 20 centimeters on three dates, C (August 16, 1960, March 21, 1961, and May 27, 1961) due to factorial treatments of three levels of mulch, A(none, woodshavings, and woodchips) and three levels of fertilizer, B(0, 1, and 2 lb. of elemental nitrogen from calcium nitrate per 1000 square feet).[1,2]

Cultural treatment A + B		Soil temperature, degrees F, for the indicated recording date C			
Mulch, A	Fertilizer, B	2/16/60 c_1	3/21/61 c_2	5/27/61 c_3	$(c_1+c_2+c_3)/3$
None, a_1	0# $CaNo_3$, b_1	83.27^{abc}	49.78^{abc}	65.72^{abc}	66.26^{ab}
	1# $CaNO_3$, b_2	83.11^{abc}	49.66^{abc}	66.67^{abc}	66.48^{ab}
	2# $CaNO_3$, b_3	83.50^{abc}	49.44^{abc}	65.83^{abc}	66.26^{ab}
	$(b_1+b_2+b_3)/3$	83.29^{ac}	49.63^{ac}	66.07^{ac}	66.33^{a}
Wood-shavings, a_2	0# $CaNO_3$, b_1	74.28^{abc}	50.88^{abc}	64.61^{abc}	63.25^{ab}
	1# $CaNO_3$, b_2	74.27^{abc}	50.88^{abc}	64.17^{abc}	63.11^{ab}
	2# $CaNO_3$, b_3	73.33^{abc}	50.83^{abc}	64.38^{abc}	62.85^{ab}
	$(b_1+b_2+b_3)/3$	73.96^{ac}	50.87^{ac}	64.38^{ac}	63.07^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	75.11^{abc}	50.83^{abc}	63.89^{abc}	63.28^{ab}
	1# $CaNO_3$, b_2	73.88^{abc}	50.88^{abc}	64.16^{abc}	62.98^{ab}
	2# $CaNO_3$, b_3	75.08^{abc}	50.83^{abc}	64.61^{abc}	63.50^{ab}
	$(b_1+b_2+b_3)/3$	74.69^{ac}	50.85^{ac}	64.22^{ac}	63.25^{a}
$(a_1+a_2+a_3)/3$	0# $CaNO_3$, b_1	77.75^{bc}	50.50^{bc}	64.74^{bc}	64.26^{b}
	1# $CaNO_3$, b_2	77.09^{bc}	50.47^{bc}	65.00^{bc}	64.19^{b}
	2# $CaNO_3$, b_3	77.30^{bc}	50.37^{bc}	64.94^{bc}	64.20^{b}
	$(b_1+b_2+b_3)/3$	77.31^{c}	50.45^{c}	64.89^{c}	64.22

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e.g. a value with a superscript of "ac" is a mean of 18 observation (6 replications x 3 levels of factor B).

APPENDIX TABLE 4

Standard error of difference ($S_{\bar{d}}$) and least significant difference (LSD) for the data of Appendix Table 3

Item[1]	Difference between	Measured as		$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
						.05	.01
a	Different a	a_1	$-a_0$	$\sqrt{2E_a/r\beta b}$	.237	.50	.64
b	Different b	b_1	$-b_0$	$\sqrt{2E_a/r\beta a}$	.237	.50	.64
c	Different c	c_1	$-c_0$	$\sqrt{2E_b/r\alpha}$	.221	.45	.60
ab	Same a, different b	$a_1\ b_1$	$-a_1\ b_0$				
ab	Different a, same b	$a_1\ b_1$	$-a_0\ b_1$				
ab	Different a, different b	$a_1\ b_1$	$-a_0\ b_0$	$\sqrt{2E_a/r\beta}$	.411	.86	1.11
ac	Same a, different c	$a_1\ c_1$	$-a_1\ c_0$	$\sqrt{2E_b/r\ b}$	.382	.78	1.03
ac	Different a, different c	$a_1\ c_1$	$-a_0\ c_0$				
ac	Different a, same c	$a_1\ c_1$	$-a_0\ c_1$	$\sqrt{2\left[(\beta-1)E_b + E_a\right]/r\beta b}$	.391	.82	1.06
bc	Same b, different c	$b_1\ c_1$	$-b_1\ c_0$	$\sqrt{2E_b/r\ a}$	.382	.78	1.03
bc	Different b, same c	$b_1\ c_1$	$-b_0\ c_1$				
bc	Different b, different c	$b_1\ c_1$	$-b_0\ c_0$	$\sqrt{2\left[(\beta-1)E_b+E_a\right]/r\beta a}$	.391	.82	1.06

APPENDIX TABLE 4 (Continued)

Standard error of difference ($S_{\bar{d}}$) and least significant difference (LSD) for the data of Appendix Table 3

Item[1]	Difference between	Measured as	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$		.661	1.36	1.78
	Same a, different b, same c	$a_1 b_1 c_1 - a_0 b_1 c_1$				
	Different a, same b, same c	$a_1 b_1 c_1 - a_0 b_1 c_1$				
	Diff a, diff b, same c	$a_1 b_1 c_1 - a_0 b_0 c_1$				
	Same a, diff b, diff c	$a_1 b_1 c_1 - a_1 b_0 c_0$				
	Diff a, same b, diff c	$a_1 b_1 c_1 - a_0 b_1 c_0$				
	Diff a, diff b, diff c	$a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2\left[(\beta-1)E_b + E_a\right]/r\beta}$	.678	1.42	1.83

[1] Factors averaged at single levels; the others over all levels.

[2] E_a and E_b = 1.52 and 1.31, resp. = error (residual) in whole-unit and sub-unit analyses, resp.; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B;   = 9 = levels of factor A x levels of factor B;   = 3 = levels of factor C.

APPENDIX TABLE 5

Analyses of variance (on a sub-sub-unit basis) mean squares for the effect of mulch and fertilizer factorial treatments on different nutrients in the two chrysanthemum clones on two sampling dates.[1]

Source of variation	df	Mean square for indicated nutrient						
		N	P[2]	K	Na[2]	Ca[2]	Mg[2]	Mn
Replicates	5	.05	2.80	.14	.39*	12.7*	1.34	137.99
Treatments:								
Mulches (A)	2	5.63**	27.83**	1.52**	.07	141.8**	202.58**	572.22**
Fertilizers (B)	2	2.52**	.65	.79**	.23	1.6	1.09	988.54**
A x B	4	.32	.12	.12	.39*	2.9	2.25	53.99
Error (a)	40	.16	.89	.15	.13	2.0	1.94	168.91
Plants (C)	1	8.27**	3.36**	45.05**	3.21**	3.9	2.14	1,530.67**
A x C	2	1.76**	15.58**	.23	.09	2.4	8.13	35.19
B x C	2	.02	.33	.04	.08	2.9	.67	150.81
A x B x C	4	.08	.32	.10	.06	2.2	.34	19.39
Error (b)	45	.10	.57	.15	.06	1.2	.99	75.02
Sampling dates (D)	1	45.77**	258.44**	146.11**	53.93**	1052.8**	328.22**	12,225.11**
A x D	2	3.06**	3.70**	.24	.18	58.2**	3.28	183.80

APPENDIX TABLE 5 (continued)

Analyses of variance (on a sub-sub-unit basis) mean squares for the effect of mulch and fertilizer factorial treatments on different nutrients in the two chrysanthemum clones on two sampling dates.[1]

Source of variation	df	Mean square for indicated nutrient						
		N	P[2]	K	Na[2]	Ca[2]	Mg[2]	Mn
B x D	2	2.04**	.20	.81	.23	2.9	3.30	816.78**
A x B x D	4	.30*	.33	.07	.43	3.2	2.58	94.73
C x D	1	.47*	52.52**	12.79**	1.97**	1.8	15.00**	3,227.89**
A x C x D	2	.68**	1.04	.51*	.01	1.9	3.88	8.80
B x C x D	2	.04	.05	.05	.10	1.1	.74	23.81
A x B x C x D	4	.07	.35	.15	.10	0.7	1.07	64.53
Error (c)	90	.10	.57	.16	.10	1.4	1.40	90.58
TOTAL	215	.51	2.56	1.12	.39	2.6	5.05	197.40

[1] Each datum is a mean square from the appropriate analysis of variance table. Symbols * and ** indicate significance at the 5 and 1 percent levels, respectively. Significance of each was determined by calculating the F-ratio (treatment datum divided by appropriate error datum) and comparing it with the tabular F-value. F-ratios needed for significance are shown below.

Probability of a larger F-value	Numerator df (treatment)/denominator df (error)							
	2/40	4/40	1/45	2/45	4/45	1/90	2/90	4/90
.05	3.23	2.61	4.06	3.21	2.59	3.95	3.10	2.48
.01	5.18	3.85	7.26	5.13	3.80	6.93	4.87	3.56

[2] Actual value is the datum multiplied by 10^{-3}.

APPENDIX TABLE 6

Analyses of variance (on a sub-sub-unit basis) mean squares for the effect of mulch and fertilizer factorial treatments on the amount of different nutrients in the two woody shrubs on three sampling dates.[1]

Source of variation	df	Mean square for indicated nutrient						
		N	P[2]	K	Na[2]	Ca[2]	Mg[2]	Mn
Replicates	5	.06	15.46	.12**	1.34*	73.6*	6.98	6773*
Treatments:								
Mulches (A)	2	2.78**	88.78**	.56**	4.87**	346.1**	77.78**	9411*
Fertilizers (B)	2	.61**	32.03**	.27**	.09	153.5**	11.97**	886
A x B	4	.08	33.65**	.15**	.26	31.8	5.33	6137
Error (a)	40	.03	4.56	.02	.54	29.8	2.18	2724
Plants (C)	1	4.33**	.08	.21**	128.92**	145.3*	21.84*	17,556**
A x C	2	.00	3.13	.07*	1.03	43.1	20.47**	9473
B x C	2	.28**	5.41	.11**	.26	45.8	15.90**	5930
A x B x C	4	.04	5.24	.00	2.36**	44.7	1.29	1718
Error (b)	45	.05	4.88	.02	.54	27.9	3.98	2893
Sampling dates (D)	2	4.86**	.80	4.15**	61.12**	4052.0**	346.86**	114,550**
A x D	4	.09*	19.95**	.16**	1.80**	21.8	1.04	18,241**
B x D	4	.43**	3.30	.02	.25	7.5	2.11	5310
A x B x D	8	.07	6.14	.03*	.67	23.2	1.27	3021
C x D	2	2.96**	.65	.72**	60.40**	1055.8**	33.82**	61,609**
A x C x D	4	.13**	6.92	.04*	1.22*	22.2	3.94*	4,144
B x C x D	4	.02	5.09	.01	.35	10.2	3.21	2373
A x B x C x D	8	.07**	2.31	.02	.50	26.8	2.21	3604

APPENDIX TABLE 6 (continued)

Analyses of variance (on a sub-sub-unit basis) mean squares for the effect of mulch and fertilizer factorial treatments on the amount of different nutrients in the two woody shrubs on three sampling dates.[1]

Source of Variation	df	Mean square for indicated nutrient						
		N	P[2]	K	Na[2]	Ca[2]	Mg[2]	Mn
Error (c)	180	.03	4.21	.02	.46	17.3	1.48	2280
TOTAL	323							

[1] The symbols * and ** indicate significance at the 5 and 1 percent levels respectively. The significance of each was determined by calculating the F-ratio (the treatment datum divided by the appropriate error datum) and comparing it with the tabular F-value. F-ratios needed for significance are shown below.

Probability of a larger F value	Numerator (treatment) df/ Denominator (error) df							
	2/40	4/40	1/45	2/45	4/45	2/180	4/180	8/180
.05	3.23	2.61	4.06	3.21	2.59	3.00	2.37	1.94
.01	5.18	3.85	7.26	5.13	3.80	4.61	3.32	2.51

[2] Actual value is the datum x 10^{-3}.

APPENDIX TABLE 7

Nitrogen, percentage dry weight basis, in the foliage of two plant taxa, C (*Chrysanthemum* 'Arlora' and *Chrysanthemum* 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrite per 1000 sq. ft.)[1,2]

Cultural treatment, A ≠ B		Plant taxa, C						$(c_1 \neq c_2)/2$		$(d_1 \neq d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
Mulch, A	Fertilizer, B	Sampling date, D			Sampling date, D					
		5-2-60, d_1	7-2-60, d_2	$(d_1 \neq d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 \neq d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	3.99^{abcd}	4.17^{abcd}	4.08^{abc}	3.10^{abcd}	3.54^{abcd}	3.32^{abc}	3.55^{abd}	3.86^{abd}	3.70^{ab}
	1# $CaNO_3$, b_2	3.98^{abcd}	4.31^{abcd}	4.14^{abc}	3.10^{abcd}	3.62^{abcd}	3.36^{abc}	3.54^{abd}	3.97^{abd}	3.75^{ab}
	2# $CaNO_3$, b_3	4.11^{abcd}	4.54^{abcd}	4.33^{abc}	3.24^{abcd}	4.00^{abcd}	3.62^{abc}	3.67^{abd}	4.27^{abd}	3.97^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	4.02^{acd}	4.34^{acd}	4.18^{ac}	3.14^{acd}	3.72^{acd}	3.44^{ac}	3.59^{ad}	4.03^{ad}	3.81^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	2.63^{abcd}	3.42^{abcd}	3.02^{abc}	2.60^{abcd}	3.10^{abcd}	2.85^{abc}	2.62^{abd}	3.26^{abd}	2.94^{ab}
	1# $CaNO_3$, b_2	2.83^{abcd}	4.17^{abcd}	3.50^{abc}	2.74^{abcd}	3.79^{abcd}	3.27^{abc}	2.78^{abd}	3.98^{abd}	3.38^{ab}
	2# $CaNO_3$, b_3	2.50^{abcd}	4.46^{abcd}	3.48^{abc}	2.66^{abcd}	4.15^{abcd}	3.40^{abc}	2.58^{abd}	4.30^{abd}	3.44^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	2.65^{acd}	4.01^{acd}	3.33^{ac}	2.67^{acd}	3.68^{acd}	3.17^{ac}	2.66^{ad}	3.85^{ad}	3.25^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	3.02^{abcd}	4.04^{abcd}	3.53^{abc}	3.18^{abcd}	3.61^{abcd}	3.40^{abc}	3.10^{abd}	3.82^{abd}	3.46^{ab}
	1# $CaNO_3$, b_2	2.76^{abcd}	4.43^{abcd}	3.59^{abc}	2.85^{abcd}	3.82^{abcd}	3.34^{abc}	2.80^{abd}	4.12^{abd}	3.46^{ab}
	2# $CaNO_3$, b_3	3.32^{abcd}	4.71^{abcd}	4.02^{abc}	2.95^{abcd}	4.24^{abcd}	3.59^{abc}	3.14^{abd}	4.47^{abd}	3.80^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	3.03^{acd}	4.39^{acd}	3.71^{ac}	3.00^{acd}	3.89^{acd}	3.44^{ac}	3.01^{ad}	4.14^{ad}	3.58^{a}
$(a_1 \neq a_2 \neq a_3)/3$	0# $CaNO_3$, b_1	3.21^{bcd}	3.87^{bcd}	3.54^{bc}	2.96^{bcd}	3.41^{bcd}	3.19^{bc}	3.09^{bd}	3.64^{bd}	3.37^{b}
	1# $CaNO_3$, b_2	3.19^{bcd}	4.30^{bcd}	3.74^{bc}	2.90^{bcd}	3.75^{bcd}	3.32^{bc}	3.04^{bd}	4.02^{bd}	3.53^{b}
	2# $CaNO_3$, b_3	3.31^{bcd}	4.57^{bcd}	3.94^{bc}	2.95^{bcd}	4.13^{bcd}	3.54^{bc}	3.13^{bd}	4.35^{bd}	3.74^{b}
	$(b_1 \neq b_2 \neq b_3)/3$	3.23^{cd}	4.25^{cd}	3.74^{c}	2.94^{cd}	3.76^{cd}	3.35^{c}	3.08^{d}	4.01^{d}	3.55

[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 8
Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 7.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	LSD .05	LSD .01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0658	.13	.18
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0658	.13	.18
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0422	.08	.11
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0437	.09	.12
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.1140	.23	.31
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.0730	.15	.20
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta b}$	.075	.15	.20
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.1070	.21	.28
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma b}$	.085	.16	.22
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.0730	.15	.20
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta a}$	.075	.15	.20
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.1070	.21	.28
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma a}$	.085	.16	.22
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.1853	.36	.48
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\alpha\gamma}$	.061	.12	.16
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.1265	.25	.34
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta}$	.130	.26	.35
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.1310	.26	.34
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma}$	.147	.30	.39
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.1070	.21	.28
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	.105	.21	.28
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma b}$	.1128	.20	.26
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.1070	.21	.28
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	.105	.21	.28
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma a}$	.1128	.20	.26
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.1853	.36	.48
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma}$	.182	.36	.48
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma}$	.1954	.39	.46

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .156 , .096 , and .103 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; $r = 6$ = replications; $a = 3$ = levels of factor A; $b = 3$ = levels of factor B; $\alpha = 9$ = levels of factor A x levels of factor B; $\beta = 2$ = levels of factor C; $\gamma = 2$ = levels of factor D.

APPENDIX TABLE 9

Nitrogen, percentage dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1, 2]

Cultural treatment A + B		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Feijoa sellowiana, c_1				Ligustrum japonicum, c_2							
		Sampling date, D				Sampling date, D							
Mulch, A	Fertilizer, B	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	
None, a_1	0# $CaNO_3$, b_1	1.85^{abcd}	1.94^{abcd}	1.92^{abcd}	1.90^{abc}	1.92^{abcd}	1.24^{abcd}	1.57^{abcd}	1.58^{abc}	1.88^{abd}	1.59^{abd}	1.74^{abd}	1.74^{ab}
	1# $CaNO_3$, b_2	1.92^{abcd}	1.76^{abcd}	1.85^{abcd}	1.84^{abc}	2.00^{abcd}	1.24^{abcd}	1.66^{abcd}	1.63^{abc}	1.96^{abd}	1.50^{abd}	1.76^{abd}	1.74^{ab}
	2# $CaNO_3$, b_3	2.16^{abcd}	1.87^{abcd}	1.95^{abcd}	1.99^{abc}	2.07^{abcd}	1.47^{abcd}	1.84^{abcd}	1.80^{abc}	2.12^{abd}	1.67^{abd}	1.90^{abd}	1.90^{ab}
	$(b_1 + b_2 + b_3)/3$	1.98^{acd}	1.86^{acd}	1.91^{acd}	1.91^{ac}	2.00^{acd}	1.32^{acd}	1.69^{acd}	1.68^{ac}	1.99^{ad}	1.59^{ad}	1.80^{ad}	1.79^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	1.45^{abcd}	1.52^{abcd}	1.84^{abcd}	1.60^{abc}	1.25^{abcd}	1.08^{abcd}	1.45^{abcd}	1.26^{abc}	1.35^{abd}	1.30^{abd}	1.64^{abd}	1.43^{ab}
	1# $CaNO_3$, b_2	1.57^{abcd}	1.44^{abcd}	1.81^{abcd}	1.61^{abc}	1.95^{abcd}	1.05^{abcd}	1.40^{abcd}	1.47^{abc}	1.76^{abd}	1.24^{abd}	1.60^{abd}	1.54^{ab}
	2# $CaNO_3$, b_3	1.68^{abcd}	1.44^{abcd}	1.76^{abcd}	1.63^{abc}	1.96^{abcd}	1.04^{abcd}	1.35^{abcd}	1.45^{abc}	1.82^{abd}	1.24^{abd}	1.55^{abd}	1.54^{ab}
	$(b_1 + b_2 + b_3)/3$	1.57^{acd}	1.47^{acd}	1.80^{acd}	1.61^{ac}	1.72^{acd}	1.05^{acd}	1.40^{acd}	1.39^{ac}	1.64^{ad}	1.26^{ad}	1.60^{ad}	1.50^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	1.70^{abcd}	1.91^{abcd}	2.06^{abcd}	1.89^{abc}	1.88^{abcd}	1.11^{abcd}	1.58^{abcd}	1.52^{abc}	1.79^{abd}	1.51^{abd}	1.82^{abd}	1.71^{ab}
	1# $CaNO_3$, b_2	1.84^{abcd}	1.74^{abcd}	1.94^{abcd}	1.84^{abc}	2.03^{abcd}	1.17^{abcd}	1.58^{abcd}	1.59^{abc}	1.94^{abd}	1.45^{abd}	1.76^{abd}	1.72^{ab}
	2# $CaNO_3$, b_3	2.10^{abcd}	1.82^{abcd}	1.81^{abcd}	1.91^{abc}	2.40^{abcd}	1.38^{abcd}	1.75^{abcd}	1.84^{abc}	2.25^{abd}	1.60^{abd}	1.78^{abd}	1.88^{ab}
	$(b_1 + b_2 + b_3)/3$	1.88^{acd}	1.82^{acd}	1.94^{acd}	1.88^{ac}	2.10^{acd}	1.22^{acd}	1.63^{acd}	1.65^{ac}	1.99^{ad}	1.52^{ad}	1.78^{ad}	1.77^{a}
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	1.67^{bcd}	1.79^{bcd}	1.94^{bcd}	1.80^{bc}	1.68^{bcd}	1.14^{bcd}	1.53^{bcd}	1.45^{bc}	1.68^{bd}	1.47^{bd}	1.73^{bd}	1.62^{b}
	1# $CaNO_3$, b_2	1.78^{bcd}	1.64^{bcd}	1.86^{bcd}	1.76^{bc}	1.99^{bcd}	1.15^{bcd}	1.55^{bcd}	1.56^{bc}	1.89^{bd}	1.40^{bd}	1.71^{bd}	1.66^{b}
	2# $CaNO_3$, b_3	1.98^{bcd}	1.71^{bcd}	1.84^{bcd}	1.84^{bc}	2.14^{bcd}	1.30^{bcd}	1.65^{bcd}	1.70^{bc}	2.06^{bd}	1.50^{bd}	1.74^{bd}	1.77^{b}
	$(b_1 + b_2 + b_3)/3$	1.81^{cd}	1.72^{cd}	1.88^{cd}	1.80^{c}	1.94^{cd}	1.20^{cd}	1.57^{cd}	1.57^{c}	1.87^{d}	1.46^{d}	1.73^{d}	1.69

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 10
Standard Error of Differences ($S_{\bar d}$) and Least Significant Differences (LSD) for the data of Appendix Table 9.

Item[1]	Difference between:	Measured as:	$S_{\bar d}$ Model[2]	$S_{\bar d}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.024	.05	.06
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.024	.05	.06
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.024	.05	.06
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.023	.05	.06
ab " "	Same a, different b Different a, same b Different a, different b	$a_1b_1 - a_1b_0$ $a_1b_1 - a_0b_1$ $a_1b_1 - a_0b_0$	$\sqrt{2E_a/r\beta\gamma}$	.041	.08	.11
ac	Same a, different c	$a_1c_1 - a_1c_0$	$\sqrt{2E_b/r\gamma b}$	.041	.08	.11
" "	Different a, same c Different a, different c	$a_1c_1 - a_0c_1$ $a_1c_1 - a_0c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.038	.08	.10
ad	Same a, different d	$a_1d_1 - a_1d_0$	$\sqrt{2E_c/rb}$	.055	.11	.14
" "	Different a, same d Different a, different d	$a_1d_1 - a_0d_1$ $a_1d_1 - a_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.040	.08	.11
bc	Same b, different c	$b_1c_1 - b_1c_0$	$\sqrt{2E_b/r\gamma a}$	.041	.08	.11
" "	Different b, same c Different b, different c	$b_1c_1 - b_0c_1$ $b_1c_1 - b_0c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.038	.08	.10
bd	Same b, different d	$b_1d_1 - b_1d_0$	$\sqrt{2E_c/ra}$	.055	.11	.14
" "	Different b, same d Different b, different d	$b_1d_1 - b_0d_1$ $b_1d_1 - b_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.040	.08	.11
cd	Same c, different d	$c_1d_1 - c_1d_0$	$\sqrt{2E_c/r}$	.096	.18	.25
" "	Different c, same d Different c, different d	$c_1d_1 - c_0d_1$ $c_1d_1 - c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.035	.07	.09
abc	Same a, same b, different c	$a_1b_1c_1 - a_1b_1c_0$	$\sqrt{2E_b/r\gamma}$	.072	.15	.19
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1b_1c_1 - a_1b_0c_1$ $a_1b_1c_1 - a_0b_1c_1$ $a_1b_1c_1 - a_0b_0c_1$ $a_1b_1c_1 - a_1b_0c_0$ $a_1b_1c_1 - a_0b_1c_0$ $a_1b_1c_1 - a_0b_0c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.065	.13	.18
abd	Same a, same b, different d	$a_1b_1d_1 - a_1b_1d_0$	$\sqrt{2E_c/r\beta}$	.068	.13	.19
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1b_1d_1 - a_1b_0d_1$ $a_1b_1d_1 - a_0b_1d_1$ $a_1b_1d_1 - a_0b_0d_1$ $a_1b_1d_1 - a_1b_0d_0$ $a_1b_1d_1 - a_0b_1d_0$ $a_1b_1d_1 - a_0b_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.069	.14	.18
acd	Same a, same c, different d	$a_1c_1d_1 - a_1c_1d_0$	$\sqrt{2E_c/rb}$	.055	.11	.14
" "	Same a, different c, same d Same a, diff c, different d	$a_1c_1d_1 - a_1c_0d_1$ $a_1c_1d_1 - a_1c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.061	.12	.16
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1c_1d_1 - a_0c_1d_1$ $a_1c_1d_1 - a_0c_1d_0$ $a_1c_1d_1 - a_0c_1d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.058	.11	.15
bcd	Same b, same c, different d	$b_1c_1d_1 - b_1c_1d_0$	$\sqrt{2E_c/ra}$	.055	.11	.14
" "	Same b, different c, same d Same b, diff c, different d	$b_1c_1d_1 - b_1c_0d_1$ $b_1c_1d_1 - b_1c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.061	.12	.16
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1c_1d_1 - b_0c_1d_1$ $b_1c_1d_1 - b_0c_1d_0$ $b_1c_1d_1 - b_0c_0d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.058	.11	.15
abcd	Same a, same b, same c, diff d	$a_1b_1c_1d_1 - a_1b_1c_1d_0$	$\sqrt{2E_c/r}$	.096	.19	.26
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1b_1c_1d_1 - a_1b_1c_0d_1$ $a_1b_1c_1d_1 - a_1b_1c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.106	.21	.28
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1b_1c_1d_1 - a_1b_0c_1d_1$ $a_1b_1c_1d_1 - a_0b_1c_1d_1$ $a_1b_1c_1d_1 - a_0b_0c_1d_1$ $a_1b_1c_1d_1 - a_1b_0c_0d_1$ $a_1b_1c_1d_1 - a_0b_1c_0d_1$ $a_1b_1c_1d_1 - a_0b_0c_0d_1$ $a_1b_1c_1d_1 - a_1b_0c_1d_0$ $a_1b_1c_1d_1 - a_0b_1c_1d_0$ $a_1b_1c_1d_1 - a_0b_0c_1d_0$ $a_1b_1c_1d_1 - a_1b_0c_0d_0$ $a_1b_1c_1d_1 - a_0b_1c_0d_0$ $a_1b_1c_1d_1 - a_0b_0c_0d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.102	.20	.27

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .0303, .0463, and .0276 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; $r = 6$ = replications; $a = 3$ = levels of factor A; $b = 3$ = levels of factor B; $\alpha = 9$ = levels of factor A x levels of factor B; $\beta = 2$ = levels of factor C; $\gamma = 3$ = levels of factor D.

APPENDIX TABLE 11

Phosphorus, percentage dry weight basis, in the foliage of two plant taxa, C (*Chrysanthemum* 'Arlora' and *Chrysanthemum* 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1,2]

Cultural treatment, A + B		Plant taxa, C						$(c_1 + c_2)/2$		$(d_1 + d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
		Sampling date, D			Sampling date, D					
Mulch, A	Fertilizer, B	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	.292^{abcd}	.308^{abcd}	.300^{abc}	.227^{abcd}	.331^{abcd}	.279^{abc}	.260^{abd}	.319^{abd}	.289^{ab}
	1# $CaNO_3$, b_2	.286^{abcd}	.306^{abcd}	.296^{abc}	.223^{abcd}	.320^{abcd}	.271^{abc}	.254^{abd}	.313^{abd}	.283^{ab}
	2# $CaNO_3$, b_3	.293^{abcd}	.298^{abcd}	.295^{abc}	.226^{abcd}	.303^{abcd}	.264^{abc}	.260^{abd}	.300^{abd}	.280^{ab}
	$(b_1 + b_2 + b_3)/3$	.291^{acd}	.304^{acd}	.297^{ac}	.225^{acd}	.318^{acd}	.272^{ac}	.258^{ad}	.311^{ad}	.284^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	.272^{abcd}	.329^{abcd}	.301^{abc}	.252^{abcd}	.364^{abcd}	.308^{abc}	.262^{abd}	.347^{abd}	.304^{ab}
	1# $CaNO_3$, b_2	.263^{abcd}	.311^{abcd}	.287^{abc}	.260^{abcd}	.369^{abcd}	.315^{abc}	.262^{abd}	.340^{abd}	.301^{ab}
	2# $CaNO_3$, b_3	.262^{abcd}	.315^{abcd}	.289^{abc}	.259^{abcd}	.362^{abcd}	.310^{abc}	.261^{abd}	.338^{abd}	.300^{ab}
	$(b_1 + b_2 + b_3)/3$	.266^{acd}	.318^{acd}	.292^{ac}	.257^{acd}	.365^{acd}	.311^{ac}	.262^{ad}	.342^{ad}	.302^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	.284^{abcd}	.338^{abcd}	.311^{abc}	.298^{abcd}	.383^{abcd}	.341^{abc}	.291^{abd}	.361^{abd}	.326^{ab}
	1# $CaNO_3$, b_2	.278^{abcd}	.328^{abcd}	.303^{abc}	.286^{abcd}	.390^{abcd}	.338^{abc}	.282^{abd}	.359^{abd}	.321^{ab}
	2# $CaNO_3$, b_3	.290^{abcd}	.332^{abcd}	.311^{abc}	.281^{abcd}	.393^{abcd}	.337^{abc}	.285^{abd}	.363^{abd}	.324^{ab}
	$(b_1 + b_2 + b_3)/3$	.284^{acd}	.333^{acd}	.308^{ac}	.289^{acd}	.389^{acd}	.339^{ac}	.286^{ad}	.361^{ad}	.324^{a}
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	.283^{bcd}	.325^{bcd}	.304^{bc}	.259^{bcd}	.360^{bcd}	.309^{bc}	.271^{bd}	.342^{bd}	.306^{b}
	1# $CaNO_3$, b_2	.276^{bcd}	.315^{bcd}	.295^{bc}	.257^{bcd}	.360^{bcd}	.308^{bc}	.266^{bd}	.337^{bd}	.302^{b}
	2# $CaNO_3$, b_3	.282^{bcd}	.315^{bcd}	.298^{bc}	.255^{bcd}	.353^{bcd}	.304^{bc}	.268^{bd}	.334^{bd}	.301^{b}
	$(b_1 + b_2 + b_3)/3$	.280^{cd}	.318^{cd}	.299^{c}	.257^{cd}	.357^{cd}	.307^{c}	.269^{d}	.338^{d}	.303

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[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "bc" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 12

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 11.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	LSD .05	LSD .01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.00497	.010	.013
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.00497	.010	.013
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.00325	.007	.009
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.00325	.006	.008
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.00861	.017	.023
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.00563	.011	.015
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.00637	.013	.017
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.00796	.016	.021
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.00637	.011	.015
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.00563	.011	.015
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.00637	.013	.017
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.00796	.016	.021
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.00637	.013	.017
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.01378	.027	.036
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.004595	.09	.012
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.00975	.020	.026
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.01103	.022	.030
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.00975	.019	.025
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.01103	.022	.030
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.00796	.016	.021
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.00796	.016	.021
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.00751	.015	.020
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.00796	.016	.021
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.00796	.016	.021
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.00751	.015	.020
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.01378	.027	.036
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.01378	.027	.036
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.01301	.026	.035

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .00089, .00057, and .00057 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 2 = levels of factor D.

APPENDIX TABLE 13

Phosphorus, percentage dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1, 2]

Cultural treatment A + B		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Feijoa sellowiana, c_1				Ligustrum japonicum, c_2							
		Sampling date, D				Sampling date, D							
Mulch, A	Fertilizer, B	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	
None, a_1	0# $CaNO_3$, b_1	.167^{abcd}	.184^{abcd}	.165^{abcd}	.173^{abc}	.173^{abcd}	.176^{abcd}	.164^{abcd}	.171^{abc}	.170^{abd}	.182^{abd}	.165^{abd}	.173^{ab}
	1# $CaNO_3$, b_2	.167^{abcd}	.184^{abcd}	.170^{abcd}	.174^{abc}	.159^{abcd}	.174^{abcd}	.156^{abcd}	.163^{abc}	.163^{abd}	.179^{abd}	.163^{abd}	.168^{ab}
	2# $CaNO_3$, b_3	.170^{abcd}	.152^{abcd}	.149^{abcd}	.157^{abc}	.162^{abcd}	.126^{abcd}	.126^{abcd}	.138^{abc}	.166^{abd}	.139^{abd}	.138^{abd}	.148^{ab}
	$(b_1 + b_2 + b_3)/3$	.168^{acd}	.174^{acd}	.161^{acd}	.168^{ac}	.164^{acd}	.159^{acd}	.149^{acd}	.157^{ac}	.166^{ad}	.167^{ad}	.155^{ad}	.163^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	.290^{abcd}	.242^{abcd}	.234^{abcd}	.255^{abc}	.262^{abcd}	.256^{abcd}	.337^{abcd}	.285^{abc}	.276^{abd}	.249^{abd}	.285^{abd}	.270^{ab}
	1# $CaNO_3$, b_2	.162^{abcd}	.210^{abcd}	.228^{abcd}	.200^{abc}	.163^{abcd}	.175^{abcd}	.238^{abcd}	.192^{abc}	.163^{abd}	.193^{abd}	.233^{abd}	.196^{ab}
	2# $CaNO_3$, b_3	.154^{abcd}	.170^{abcd}	.214^{abcd}	.179^{abc}	.172^{abcd}	.160^{abcd}	.235^{abcd}	.189^{abc}	.163^{abd}	.165^{abd}	.224^{abd}	.184^{ab}
	$(b_1 + b_2 + b_3)/3$	.202^{acd}	.208^{acd}	.225^{acd}	.212^{ac}	.199^{acd}	.197^{acd}	.270^{acd}	.222^{ac}	.201^{ad}	.202^{ad}	.248^{ad}	.217^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	.182^{abcd}	.167^{abcd}	.173^{abcd}	.174^{abc}	.177^{abcd}	.147^{abcd}	.174^{abcd}	.166^{abc}	.180^{abd}	.157^{abd}	.174^{abd}	.170^{ab}
	1# $CaNO_3$, b_2	.167^{abcd}	.166^{abcd}	.172^{abcd}	.168^{abc}	.173^{abcd}	.127^{abcd}	.126^{abcd}	.142^{abc}	.170^{abd}	.147^{abd}	.149^{abd}	.155^{ab}
	2# $CaNO_3$, b_3	.194^{abcd}	.170^{abcd}	.155^{abcd}	.173^{abc}	.261^{abcd}	.270^{abcd}	.120^{abcd}	.217^{abc}	.228^{abd}	.220^{abd}	.138^{abd}	.195^{ab}
	$(b_1 + b_2 + b_3)/3$	.181^{acd}	.168^{acd}	.167^{acd}	.172^{ac}	.204^{acd}	.182^{acd}	.140^{acd}	.185^{ac}	.192^{ad}	.175^{ad}	.153^{ad}	.174^{a}
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	.213^{bcd}	.199^{bcd}	.191^{bcd}	.201^{bc}	.204^{bcd}	.193^{bcd}	.225^{bcd}	.207^{bc}	.208^{bd}	.196^{bd}	.208^{bd}	.204^{b}
	1# $CaNO_3$, b_2	.165^{bcd}	.187^{bcd}	.190^{bcd}	.181^{bc}	.165^{bcd}	.159^{bcd}	.173^{bcd}	.166^{bc}	.165^{bd}	.173^{bd}	.182^{bd}	.173^{b}
	2# $CaNO_3$, b_3	.173^{bcd}	.164^{bcd}	.173^{bcd}	.170^{bc}	.198^{bcd}	.186^{bcd}	.160^{bcd}	.181^{bc}	.186^{bd}	.175^{bd}	.166^{bd}	.176^{b}
	$(b_1 + b_2 + b_3)/3$	.184^{cd}	.183^{cd}	.184^{cd}	.184^{c}	.189^{cd}	.179^{cd}	.186^{cd}	.184^{c}	.186^{d}	.181^{d}	.185^{d}	.184

[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 14

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 13.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0092	.019	.025
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0092	.019	.025
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0078	.016	.021
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0088	.017	.023
ab " "	Same a, different b Different a, same b Different a, different b	$a_1b_1 - a_1b_0$ $a_1b_1 - a_0b_1$ $a_1b_1 - a_0b_0$	$\sqrt{2E_a/r\beta\gamma}$	.0159	.032	.043
ac	Same a, different c	$a_1c_1 - a_1c_0$	$\sqrt{2E_b/r\gamma b}$	.0134	.027	.036
" "	Different a, same c Different a, different c	$a_1c_1 - a_0c_1$ $a_1c_1 - a_0c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.0132	.027	.036
ad	Same a, different d	$a_1d_1 - a_1d_0$	$\sqrt{2E_c/rb}$	.0216	.043	.056
" "	Different a, same d Different a, different d	$a_1d_1 - a_0d_1$ $a_1d_1 - a_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.0155	.031	.041
bc	Same b, different c	$b_1c_1 - b_1c_0$	$\sqrt{2E_b/r\gamma a}$	.0134	.027	.036
" "	Different b, same c Different b, different c	$b_1c_1 - b_0c_1$ $b_1c_1 - b_0c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.0132	.027	.036
bd	Same b, different d	$b_1d_1 - b_1d_0$	$\sqrt{2E_c/ra}$	.0216	.043	.056
" "	Different b, same d Different b, different d	$b_1d_1 - b_0d_1$ $b_1d_1 - b_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.0155	.031	.041
cd	Same c, different d	$c_1d_1 - c_1d_0$	$\sqrt{2E_c/r}$	.0375	.074	.098
" "	Different c, same d Different c, different d	$c_1d_1 - c_0d_1$ $c_1d_1 - c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.0128	.025	.034
abc	Same a, same b, different c	$a_1b_1c_1 - a_1b_1c_0$	$\sqrt{2E_b/r\gamma}$	.0233	.047	.063
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1b_1c_1 - a_1b_0c_1$ $a_1b_1c_1 - a_0b_1c_1$ $a_1b_1c_1 - a_0b_0c_1$ $a_1b_1c_1 - a_1b_0c_0$ $a_1b_1c_1 - a_0b_1c_0$ $a_1b_1c_1 - a_0b_0c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.0229	.046	.062
abd	Same a, same b, different d	$a_1b_1d_1 - a_1b_1d_0$	$\sqrt{2E_c/r\beta}$	.0265	.052	.069
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1b_1d_1 - a_1b_0d_1$ $a_1b_1d_1 - a_0b_1d_1$ $a_1b_1d_1 - a_0b_0d_1$ $a_1b_1d_1 - a_1b_0d_0$ $a_1b_1d_1 - a_0b_1d_0$ $a_1b_1d_1 - a_0b_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.0269	.054	.072
acd	Same a, same c, different d	$a_1c_1d_1 - a_1c_1d_0$	$\sqrt{2E_c/rb}$	.0216	.043	.056
" "	Same a, different c, same d Same a, diff c, different d	$a_1c_1d_1 - a_1c_0d_1$ $a_1c_1d_1 - a_1c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.0222	.044	.059
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1c_1d_1 - a_0c_1d_1$ $a_1c_1d_1 - a_0c_1d_0$ $a_1c_1d_1 - a_0c_1d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.0221	.044	.059
bcd	Same b, same c, different d	$b_1c_1d_1 - b_1c_1d_0$	$\sqrt{2E_c/ra}$	.0216	.043	.056
" "	Same b, different c, same d Same b, diff c, different d	$b_1c_1d_1 - b_1c_0d_1$ $b_1c_1d_1 - b_1c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.0222	.044	.059
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1c_1d_1 - b_0c_1d_1$ $b_1c_1d_1 - b_0c_1d_0$ $b_1c_1d_1 - b_0c_0d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.0221	.044	.059
abcd	Same a, same b, same c, diff d	$a_1b_1c_1d_1 - a_1b_1c_1d_0$	$\sqrt{2E_c/r}$	.0375	.074	.098
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1b_1c_1d_1 - a_1b_1c_0d_1$ $a_1b_1c_1d_1 - a_1b_1c_0d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.0384	.076	.102
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1b_1c_1d_1 - a_1b_0c_1d_1$ $a_1b_1c_1d_1 - a_0b_1c_1d_1$ $a_1b_1c_1d_1 - a_0b_0c_1d_1$ $a_1b_1c_1d_1 - a_1b_0c_0d_1$ $a_1b_1c_1d_1 - a_0b_1c_0d_1$ $a_1b_1c_1d_1 - a_0b_0c_0d_1$ $a_1b_1c_1d_1 - a_1b_0c_1d_0$ $a_1b_1c_1d_1 - a_0b_1c_1d_0$ $a_1b_1c_1d_1 - a_0b_0c_1d_0$ $a_1b_1c_1d_1 - a_1b_0c_0d_0$ $a_1b_1c_1d_1 - a_0b_1c_0d_0$ $a_1b_1c_1d_1 - a_0b_0c_0d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.0382	.076	.102

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .00456 , .00468 , and .00421 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 3 = levels of factor D.

APPENDIX TABLE 15

Potassium, percentage dry weight basis, in the foliage of two plant taxa, C (*Chrysanthemum* 'Arlora' and *Chrysanthemum* 'Chris Columbus'), on two dates, D (May 2 and and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1,2]

Cultural treatment, A ≠ B		Plant taxa, C						$(c_1 ≠ c_2)/2$		$(d_1 ≠ d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
		Sampling date, D			Sampling date, D					
Mulch, A	Fertilizer, B	5-2-60, d_1	7-2-60, d_2	$(d_1 ≠ d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 ≠ d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	3.84^{abcd}	4.85^{abcd}	4.34^{abc}	2.54^{abcd}	4.50^{abcd}	3.52^{abc}	3.19^{abd}	4.68^{abd}	3.93^{ab}
	1# $CaNO_3$, b_2	3.76^{abcd}	5.12^{abcd}	4.44^{abc}	2.42^{abcd}	4.46^{abcd}	3.44^{abc}	3.09^{abd}	4.79^{abd}	3.94^{ab}
	2# $CaNO_3$, b_3	3.68^{abcd}	5.13^{abcd}	4.41^{abc}	2.77^{abcd}	4.53^{abcd}	3.65^{abc}	3.23^{abd}	4.83^{abd}	4.03^{ab}
	$(b_1 ≠ b_2 ≠ b_3)/3$	3.76^{acd}	5.03^{acd}	4.40^{ac}	2.58^{acd}	4.50^{acd}	3.54^{ac}	3.17^{ad}	4.77^{ad}	3.97^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	3.88^{abcd}	4.41^{abcd}	4.14^{abc}	1.97^{abcd}	3.90^{abcd}	2.93^{abc}	2.92^{abd}	4.15^{abd}	3.54^{ab}
	1# $CaNO_3$, b_2	3.64^{abcd}	4.77^{abcd}	4.20^{abc}	2.05^{abcd}	4.41^{abcd}	3.23^{abc}	2.84^{abd}	4.59^{abd}	3.72^{ab}
	2# $CaNO_3$, b_3	3.81^{abcd}	4.84^{abcd}	4.33^{abc}	2.20^{abcd}	4.56^{abcd}	3.38^{abc}	3.00^{abd}	4.70^{abd}	3.85^{ab}
	$(b_1 ≠ b_2 ≠ b_3)/3$	3.77^{acd}	4.68^{acd}	4.22^{ac}	2.07^{acd}	4.29^{acd}	3.18^{ac}	2.92^{ad}	4.48^{ad}	3.70^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	3.78^{abcd}	4.84^{abcd}	4.31^{abc}	2.51^{abcd}	4.41^{abcd}	3.46^{abc}	3.15^{abd}	4.63^{abd}	3.89^{ab}
	1# $CaNO_3$, b_2	3.45^{abcd}	5.02^{abcd}	4.24^{abc}	2.34^{abcd}	4.60^{abcd}	3.47^{abc}	2.90^{abd}	4.81^{abd}	3.85^{ab}
	2# $CaNO_3$, b_3	3.90^{abcd}	5.16^{abcd}	4.53^{abc}	2.32^{abcd}	4.93^{abcd}	3.62^{abc}	3.11^{abd}	5.04^{abd}	4.08^{ab}
	$(b_1 ≠ b_2 ≠ b_3)/3$	3.71^{acd}	5.01^{acd}	4.36^{ac}	2.39^{acd}	4.65^{acd}	3.52^{ac}	3.05^{ad}	4.83^{ad}	3.94^{a}
$(a_1 ≠ a_2 ≠ a_3)/3$	0# $CaNO_3$, b_1	3.83^{bcd}	4.70^{bcd}	4.27^{bc}	2.34^{bcd}	4.27^{bcd}	3.30^{bc}	3.09^{bd}	4.49^{bd}	3.79^{b}
	1# $CaNO_3$, b_2	3.61^{bcd}	4.97^{bcd}	4.29^{bc}	2.27^{bcd}	4.49^{bcd}	3.38^{bc}	2.94^{bd}	4.73^{bd}	3.84^{b}
	2# $CaNO_3$, b_3	3.80^{bcd}	5.04^{bcd}	4.42^{bc}	2.43^{bcd}	4.68^{bcd}	3.55^{bc}	3.11^{bd}	4.86^{bd}	3.99^{b}
	$(b_1 ≠ b_2 ≠ b_3)/3$	3.75^{cd}	4.91^{cd}	4.33^{c}	2.35^{cd}	4.48^{cd}	3.41^{c}	3.05^{d}	4.69^{d}	3.87

[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 16

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 15.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	LSD .05	LSD .01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0641	.13	.17
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0641	.13	.17
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0527	.11	.14
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0541	.11	.14
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.1111	.22	.30
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.0913	.18	.25
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.0910	.18	.25
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.1325	.26	.34
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.092	.18	.24
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.0913	.18	.25
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.0910	.18	.25
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.1325	.26	.34
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.092	.18	.24
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.2295	.45	.60
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.0755	.15	.20
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.1581	.32	.43
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.1576	.32	.43
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.1623	.32	.42
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.1597	.32	.42
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.1325	.26	.34
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.1308	.27	.35
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.1306	.26	.35
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.1325	.26	.34
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.1308	.27	.35
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.1306	.26	.35
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.2295	.45	.60
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.2266	.45	.60
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.2262	.45	.60

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .148 , .150 , and .158 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; $r = 6$ = replications; $a = 3$ = levels of factor A; $b = 3$ = levels of factor B; $\alpha = 9$ = levels of factor A x levels of factor B; $\beta = 2$ = levels of factor C; $\gamma = 2$ = levels of factor D.

APPENDIX TABLE 17

Potassium, percentage dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1, 2]

Cultural treatment $A \neq B$		Plant taxa, C								$(c_1 \neq c_2)/2$			$(d_1 \neq d_2 \neq d_3)/3$
		Feijoa sellowiana, c_1				*Ligustrum japonicum*, c_2							
Mulch, A	Fertilizer, B	Sampling date, D				Sampling date, D							
		10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 \neq d_2 \neq d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 \neq d_2 \neq d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	
None, a_1	0# $CaNO_3$, b_1	$.65^{abcd}$	1.14^{abcd}	$.99^{abcd}$	$.93^{abc}$	1.03^{abcd}	1.26^{abcd}	$.99^{abcd}$	1.10^{abc}	$.84^{abd}$	1.20^{abd}	$.99^{abd}$	1.01^{ab}
	1# $CaNO_3$, b_2	$.68^{abcd}$	1.28^{abcd}	$.98^{abcd}$	$.98^{abc}$	$.93^{abcd}$	1.25^{abcd}	1.06^{abcd}	1.08^{abc}	$.81^{abd}$	1.26^{abd}	1.02^{abd}	1.03^{ab}
	2# $CaNO_3$, b_3	$.59^{abcd}$	1.04^{abcd}	$.95^{abcd}$	$.86^{abc}$	$.79^{abcd}$	1.01^{abcd}	$.94^{abcd}$	$.91^{abc}$	$.69^{abd}$	1.02^{abd}	$.94^{abd}$	$.88^{ab}$
	$(b_1 \neq b_2 \neq b_3)/3$	$.64^{acd}$	1.15^{acd}	$.98^{acd}$	$.92^{ac}$	$.92^{acd}$	1.17^{acd}	1.00^{acd}	1.03^{ac}	$.78^{ad}$	1.16^{ad}	$.99^{ad}$	$.98^{a}$
Woodshavings, a_2	0# $CaNO_3$, b_1	$.85^{abcd}$	1.44^{abcd}	1.24^{abcd}	1.18^{abc}	1.03^{abcd}	1.52^{abcd}	1.29^{abcd}	1.28^{abc}	$.94^{abd}$	1.48^{abd}	1.26^{abd}	1.23^{ab}
	1# $CaNO_3$, b_2	$.66^{abcd}$	1.33^{abcd}	1.15^{abcd}	1.04^{abc}	$.87^{abcd}$	1.26^{abcd}	1.09^{abcd}	1.07^{abc}	$.76^{abd}$	1.29^{abd}	1.12^{abd}	1.06^{ab}
	2# $CaNO_3$, b_3	$.76^{abcd}$	1.22^{abcd}	1.24^{abcd}	1.07^{abc}	$.93^{abcd}$	1.24^{abcd}	1.05^{abcd}	1.07^{abc}	$.84^{abd}$	1.23^{abd}	1.15^{abd}	1.07^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	$.76^{acd}$	1.33^{acd}	1.21^{acd}	1.10^{ac}	$.94^{acd}$	1.34^{acd}	1.14^{acd}	1.14^{ac}	$.85^{ad}$	1.33^{ad}	1.18^{ad}	1.12^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	$.67^{abcd}$	1.01^{abcd}	1.33^{abcd}	1.00^{abc}	1.03^{abcd}	1.17^{abcd}	1.09^{abcd}	1.10^{abc}	$.85^{abd}$	1.09^{abd}	1.21^{abd}	1.05^{ab}
	1# $CaNO_3$, b_2	$.78^{abcd}$	1.16^{abcd}	1.25^{abcd}	1.07^{abc}	$.97^{abcd}$	1.10^{abcd}	$.98^{abcd}$	1.02^{abc}	$.88^{abd}$	1.13^{abd}	1.11^{abd}	1.04^{ab}
	2# $CaNO_3$, b_3	$.78^{abcd}$	1.20^{abcd}	1.21^{abcd}	1.06^{abc}	$.91^{abcd}$	1.13^{abcd}	1.04^{abcd}	1.02^{abc}	$.84^{abd}$	1.16^{abd}	1.12^{abd}	1.04^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	$.75^{acd}$	1.12^{acd}	1.26^{acd}	1.04^{ac}	$.97^{acd}$	1.14^{acd}	1.03^{acd}	1.05^{ac}	$.86^{ad}$	1.13^{ad}	1.15^{ad}	1.05^{a}
$(a_1 \neq a_2 \neq a_3)/3$	0# $CaNO_3$, b_1	$.72^{bcd}$	1.20^{bcd}	1.19^{bcd}	1.04^{bc}	1.03^{bcd}	1.32^{bcd}	1.12^{bcd}	1.16^{bc}	$.88^{bd}$	1.26^{bd}	1.16^{bd}	1.10^{b}
	1# $CaNO_3$, b_2	$.71^{bcd}$	1.26^{bcd}	1.13^{bcd}	1.03^{bc}	$.92^{bcd}$	1.20^{bcd}	1.04^{bcd}	1.06^{bc}	$.82^{bd}$	1.23^{bd}	1.08^{bd}	1.04^{b}
	2# $CaNO_3$, b_3	$.71^{bcd}$	1.15^{bcd}	1.13^{bcd}	1.00^{bc}	$.87^{bcd}$	1.13^{bcd}	1.01^{bcd}	1.00^{bc}	$.79^{bd}$	1.14^{bd}	1.07^{bd}	1.00^{b}
	$(b_1 \neq b_2 \neq b_3)/3$	$.71^{cd}$	1.20^{cd}	1.15^{cd}	1.02^{c}	$.94^{cd}$	1.22^{cd}	1.06^{cd}	1.07^{c}	$.83^{d}$	1.21^{d}	1.10^{d}	1.05

[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 18
Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 17.

Item[1]	Difference between:	Measured as:	$s_{\bar{d}}$ Model[2]	$s_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0186	.04	.05
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0186	.04	.05
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0146	.03	.04
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0170	.03	.04
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.0322	.06	.09
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.0252	.05	.07
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.0258	.05	.07
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.0416	.08	.11
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.0304	.06	.08
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.0252	.05	.07
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.0258	.05	.07
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.0416	.082	.108
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.0304	.061	.080
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.0721	.142	.187
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.0245	.049	.065
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.0437	.088	.118
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.0447	.090	.121
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.0510	.100	.133
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.0527	.105	.139
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.0416	.082	.108
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.0423	.084	.112
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.0427	.084	.112
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.0416	.082	.108
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.0423	.084	.112
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.0427	.084	.112
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.0721	.142	.187
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.0733	.146	.194
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.0739	.147	.195

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .0187 , .0172 , and .0156 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 3 = levels of factor D.

APPENDIX TABLE 19

Sodium, percentage dry weight basis, in the foliage of two plant taxa, C (*Chrysanthemum* 'Arlora' and *Chrysanthemum* 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1,2]

Cultural treatment, A + B		Plant taxa, C						$(c_1 + c_2)/2$		$(d_1 + d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
Mulch, A	Fertilizer, B	Sampling date, D			Sampling date, D					
		5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	.010^{abcd}	.053^{abcd}	.032^{abc}	.010^{abcd}	.052^{abcd}	.031^{abc}	.010^{abd}	.052^{abd}	.031^{ab}
	1# $CaNO_3$, b_2	.010^{abcd}	.044^{abcd}	.027^{abc}	.010^{abcd}	.035^{abcd}	.022^{abc}	.010^{abd}	.039^{abd}	.025^{ab}
	2# $CaNO_3$, b_3	.010^{abcd}	.052^{abcd}	.031^{abc}	.010^{abcd}	.030^{abcd}	.020^{abc}	.010^{abd}	.041^{abd}	.025^{ab}
	$(b_1 + b_2 + b_3)/3$	.010^{acd}	.050^{acd}	.030^{ac}	.010^{acd}	.039^{acd}	.024^{ac}	.010^{ad}	.044^{ad}	.027^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	.013^{abcd}	.057^{abcd}	.035^{abc}	.010^{abcd}	.045^{abcd}	.028^{abc}	.012^{abd}	.051^{abc}	.031^{ab}
	1# $CaNO_3$, b_2	.010^{abcd}	.060^{abcd}	.035^{abc}	.010^{abcd}	.035^{abcd}	.022^{abc}	.010^{abd}	.048^{abd}	.029^{ab}
	2# $CaNO_3$, b_3	.015^{abcd}	.040^{abcd}	.028^{abc}	.010^{abcd}	.027^{abcd}	.018^{abc}	.013^{abd}	.033^{abd}	.023^{ab}
	$(b_1 + b_2 + b_3)/3$	.013^{acd}	.052^{acd}	.032^{ac}	.010^{acd}	.036^{acd}	.023^{ac}	.011^{ad}	.044^{ad}	.028^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	.013^{abcd}	.043^{abcd}	.028^{abc}	.010^{abcd}	.030^{abcd}	.020^{abc}	.012^{abd}	.037^{abd}	.024^{ab}
	1# $CaNO_3$, b_2	.017^{abcd}	.042^{abcd}	.027^{abc}	.010^{abcd}	.030^{abcd}	.020^{abc}	.011^{abd}	.036^{abd}	.023^{ab}
	2# $CaNO_3$, b_3	.013^{abcd}	.055^{abcd}	.034^{abc}	.017^{abcd}	.038^{abcd}	.025^{abc}	.012^{abd}	.047^{abd}	.030^{ab}
	$(b_1 + b_2 + b_3)/3$	.013^{acd}	.047^{acd}	.030^{ac}	.011^{acd}	.033^{acd}	.022^{ac}	.012^{ad}	.040^{ad}	.026^{a}
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	.012^{bcd}	.051^{bcd}	.032^{bc}	.010^{bcd}	.042^{bcd}	.026^{bc}	.011^{bd}	.047^{bd}	.029^{b}
	1# $CaNO_3$, b_2	.010^{bcd}	.048^{bcd}	.030^{bc}	.010^{bcd}	.033^{bcd}	.022^{bc}	.010^{bd}	.041^{bd}	.026^{b}
	2# $CaNO_3$, b_3	.013^{bcd}	.049^{bcd}	.031^{bc}	.011^{bcd}	.032^{bcd}	.021^{bc}	.012^{bd}	.040^{bd}	.026^{b}
	$(b_1 + b_2 + b_3)/3$	.012^{cd}	.050^{cd}	.031^{c}	.010^{cd}	.036^{cd}	.023^{c}	.011^{d}	.043^{d}	.027

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[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 20

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 19.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.00188	.004	.005
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.00188	.004	.005
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.00109	.002	.003
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.00133	.003	.004
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.00325	.007	.009
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.00188	.004	.005
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta b}$	.00230	.005	.006
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.00326	.006	.008
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma b}$	.00249	.005	.007
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.00188	.004	.005
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta a}$	.00230	.005	.006
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.00326	.006	.008
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma a}$	.00249	.005	.007
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.00566	.011	.015
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\alpha\gamma}$	.00178	.004	.005
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.00326	.007	.009
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta}$	.00399	.008	.011
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.00400	.008	.010
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma}$	.00431	.009	.011
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.00326	.006	.008
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	.00298	.006	.008
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma b}$	.00326	.006	.008
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.00326	.006	.008
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	.00298	.006	.008
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma a}$	.00326	.006	.008
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.00566	.011	.015
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma}$	.00516	.010	.014
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma}$	.00565	.011	.015

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .000127, .000064, and .000096 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 2 = levels of factor D.

APPENDIX TABLE 21

Sodium, percentage dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips; and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1, 2]

Cultural treatment A + B		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Feijoa sellowiana, c_1				Ligustrum japonicum, c_2							
Mulch, A	Fertilizer, B	Sampling date, D				Sampling date, D							
		10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	
None, a_1	0# CaNO$_3$, b_1	.048^{abcd}	.042^{abcd}	.052^{abcd}	.047^{abc}	.120^{abcd}	.028^{abcd}	.072^{abcd}	.073^{abc}	.084^{abd}	.035^{abd}	.061^{abd}	.060^{ab}
	1# CaNO$_3$, b_2	.035^{abcd}	.033^{abcd}	.045^{abcd}	.038^{abc}	.153^{abcd}	.032^{abcd}	.080^{abcd}	.088^{abc}	.094^{abd}	.032^{abd}	.062^{abd}	.063^{ab}
	2# CaNO$_3$, b_3	.035^{abcd}	.030^{abcd}	.032^{abcd}	.032^{abc}	.177^{abcd}	.030^{abcd}	.077^{abcd}	.094^{abc}	.106^{abd}	.030^{abd}	.054^{abd}	.063^{ab}
	$(b_1 + b_2 + b_3)/3$	.039^{acd}	.035^{acd}	.043^{acd}	.039^{ac}	.150^{acd}	.030^{acd}	.076^{acd}	.085^{ac}	.095^{ad}	.032^{ad}	.059^{ad}	.062^{a}
Woodshavings, a_2	0# CaNO$_3$, b_1	.017^{abcd}	.025^{abcd}	.030^{abcd}	.024^{abc}	.127^{abcd}	.032^{abcd}	.080^{abcd}	.079^{abc}	.072^{abd}	.028^{abd}	.055^{abd}	.052^{ab}
	1# CaNO$_3$, b_2	.015^{abcd}	.028^{abcd}	.033^{abcd}	.037^{abc}	.110^{abcd}	.023^{abcd}	.068^{abcd}	.067^{abc}	.080^{abd}	.026^{abd}	.051^{abd}	.052^{ab}
	2# CaNO$_3$, b_3	.027^{abcd}	.037^{abcd}	.038^{abcd}	.034^{abc}	.103^{abcd}	.027^{abcd}	.070^{abcd}	.067^{abc}	.065^{abd}	.032^{abd}	.054^{abd}	.050^{ab}
	$(b_1 + b_2 + b_3)/3$	.031^{acd}	.030^{acd}	.034^{acd}	.032^{ac}	.113^{acd}	.027^{acd}	.073^{acd}	.071^{ac}	.072^{ad}	.029^{ad}	.053^{ad}	.051^{a}
Woodchips, a_3	0# CaNO$_3$, b_1	.028^{abcd}	.040^{abcd}	.027^{abcd}	.032^{abc}	.110^{abcd}	.027^{abcd}	.073^{abcd}	.070^{abc}	.069^{abd}	.033^{abd}	.050^{abd}	.051^{ab}
	1# CaNO$_3$, b_2	.027^{abcd}	.032^{abcd}	.035^{abcd}	.031^{abc}	.087^{abcd}	.024^{abcd}	.072^{abcd}	.061^{abc}	.057^{abd}	.028^{abd}	.053^{abd}	.046^{ab}
	2# CaNO$_3$, b_3	.035^{abcd}	.032^{abcd}	.041^{abcd}	.036^{abc}	.115^{abcd}	.027^{abcd}	.068^{abcd}	.070^{abc}	.075^{abd}	.029^{abd}	.055^{abd}	.053^{ab}
	$(b_1 + b_2 + b_3)/3$	.030^{acd}	.034^{acd}	.034^{acd}	.033^{ac}	.104^{acd}	.026^{acd}	.071^{acd}	.067^{ac}	.067^{ad}	.030^{ad}	.053^{ad}	.050^{a}
$(a_1 + a_2 + a_3)/3$	0# CaNO$_3$, b_1	.031^{bcd}	.036^{bcd}	.036^{bcd}	.034^{bc}	.119^{bcd}	.029^{bcd}	.075^{bcd}	.074^{bc}	.075^{bd}	.032^{bd}	.056^{bd}	.054^{b}
	1# CaNO$_3$, b_2	.037^{bcd}	.031^{bcd}	.038^{bcd}	.035^{bc}	.117^{bcd}	.026^{bcd}	.073^{bcd}	.072^{bc}	.077^{bd}	.029^{bd}	.056^{bd}	.054^{b}
	2# CaNO$_3$, b_3	.032^{bcd}	.032^{bcd}	.037^{bcd}	.034^{bc}	.131^{bcd}	.028^{bcd}	.072^{bcd}	.077^{bc}	.082^{bd}	.030^{bd}	.054^{bd}	.056^{b}
	$(b_1 + b_2 + b_3)/3$	.034^{cd}	.033^{cd}	.037^{cd}	.035^{c}	.122^{cd}	.027^{cd}	.073^{cd}	.074^{c}	.080^{d}	.030^{d}	.055^{d}	.055

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 22
Standard Error of Differences ($S_{\bar d}$) and Least Significant Differences (LSD) for the data of Appendix Table 21.

Item[1]	Difference between:	Measured as:	$S_{\bar d}$ Model[2]	$S_{\bar d}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.00315	.006	.009
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.00315	.006	.009
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.00259	.005	.007
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.00292	.006	.008
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.00546	.011	.015
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.00448	.010	.012
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.00447	.010	.012
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.00716	.014	.019
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.00520	.010	.011
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.00448	.010	.012
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.00448	.010	.012
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.00716	.014	.019
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.00520	.010	.011
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.01241	.024	.032
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.00426	.008	.011
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.00777	.016	.021
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.00775	.016	.021
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.00877	.017	.023
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.00901	.018	.024
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.00716	.014	.019
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.00737	.015	.020
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.00736	.015	.020
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.00716	.014	.019
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.00737	.015	.020
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.00736	.015	.020
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.01241	.024	.032
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.01277	.025	.034
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.01276	.025	.034

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .000537, .000543, and .000462 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 3 = levels of factor D.

APPENDIX TABLE 23

Calcium, percentage dry weight basis, in the foliage of two plant taxa, C (Chrysanthemum 'Arlora' and Chrysanthemum 'Chris Columbus'), on two dates, D (May 2 and and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrite per 1000 sq. ft.)[1,2]

Cultural treatment, A + B		Plant taxa, C						$(c_1 + c_2)/2$		$(d_1 + d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
		Sampling date, D			Sampling date, D					
Mulch, A	Fertilizer, B	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	.325^{abcd}	.563^{abcd}	.444^{abc}	.300^{abcd}	.533^{abcd}	.417^{abc}	.312^{abd}	.548^{abd}	.430^{ab}
	1# $CaNO_3$, b_2	.340^{abcd}	.528^{abcd}	.434^{abc}	.305^{abcd}	.492^{abcd}	.398^{abc}	.322^{abd}	.510^{abd}	.416^{ab}
	2# $CaNO_3$, b_3	.310^{abcd}	.482^{abcd}	.396^{abc}	.295^{abcd}	.500^{abcd}	.398^{abc}	.302^{abd}	.491^{abd}	.397^{ab}
	$(b_1 + b_2 + b_3)/3$	.325^{acd}	.524^{acd}	.425^{ac}	.300^{acd}	.508^{acd}	.404^{ac}	.312^{ad}	.516^{ad}	.414^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	.285^{abcd}	.365^{abcd}	.325^{abc}	.305^{abcd}	.405^{abcd}	.355^{abc}	.295^{abd}	.385^{abd}	.340^{ab}
	1# $CaNO_3$, b_2	.290^{abcd}	.400^{abcd}	.345^{abc}	.300^{abcd}	3.75^{abcd}	.338^{abc}	.295^{abd}	.388^{abd}	.341^{ab}
	2# $CaNO_3$, b_3	.295^{abcd}	.410^{abcd}	.352^{abc}	.290^{abcd}	.385^{abcd}	.338^{abc}	.292^{abd}	.398^{abd}	.345^{ab}
	$(b_1 + b_2 + b_3)/3$	.290^{acd}	.392^{acd}	.341^{ac}	.298^{acd}	.388^{acd}	.343^{ac}	.294^{ad}	.390^{ad}	.342^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	.270^{abcd}	.390^{abcd}	.330^{abc}	.285^{abcd}	.395^{abcd}	.340^{abc}	2.78^{abd}	.392^{abd}	.335^{ab}
	1# $CaNO_3$, b_2	.280^{abcd}	.400^{abcd}	.340^{abc}	.285^{abcd}	.355^{abcd}	.320^{abc}	.282^{abd}	.378^{abd}	.330^{ab}
	2# $CaNO_3$, b_3	.260^{abcd}	.425^{abcd}	.342^{abc}	.265^{abcd}	.395^{abcd}	.330^{abc}	.262^{abd}	.410^{abd}	.336^{ab}
	$(b_1 + b_2 + b_3)/3$	.270^{acd}	.405^{acd}	.338^{ac}	.278^{acd}	.382^{acd}	.330^{ac}	.274^{ad}	.390^{ad}	.334^{a}
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	.293^{bcd}	.439^{bcd}	.366^{bc}	.297^{bcd}	.444^{bcd}	.371^{bc}	.295^{bd}	.442^{bd}	.368^{b}
	1# $CaNO_3$, b_2	.303^{bcd}	.443^{bcd}	.373^{bc}	.297^{bcd}	.407^{bcd}	.352^{bc}	.300^{bd}	.425^{bd}	.362^{b}
	2# $CaNO_3$, b_3	.288^{bcd}	.439^{bcd}	.364^{bc}	.283^{bcd}	.427^{bcd}	.355^{bc}	.286^{bd}	.433^{bd}	.359^{b}
	$(b_1 + b_2 + b_3)/3$	.295^{cd}	.440^{cd}	.368^{c}	.292^{cd}	.426^{cd}	.359^{c}	.294^{d}	.433^{d}	.363

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[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 24

Standard Error of Differences ($S_{\bar d}$) and Least Significant Differences (LSD) for the data of Appendix Table 23.

Item[1]	Difference between:	Measured as:	$S_{\bar d}$ Model[2]	$S_{\bar d}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.00745	.015	.020
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.00745	.015	.020
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.00471	.009	.013
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.00509	.010	.013
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.01291	.026	.035
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.00816	.016	.022
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.00943	.019	.025
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.01247	.025	.032
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.00972	.023	.030
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.00816	.016	.022
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.00943	.019	.025
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.01247	.025	.032
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.0972		
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.02160	.043	.056
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.00861	.017	.023
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.01414	.028	.038
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.01633	.033	.044
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.01527	.030	.040
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.01683		
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.01247	.025	.032
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.01491	.030	.040
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.01291	.026	.034
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.01247	.025	.032
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.01491	.030	.040
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.01291	.026	.034
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.02160	.043	.056
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.02582	.051	.068
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.02236	.045	.059

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[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .0020, .0012, and .0014 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 2 = levels of factor D.

APPENDIX TABLE 25

Calcium, percentage dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1, 2]

Cultural treatment A + B		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Feijoa sellowiana, c_1				Ligustrum japonicum, c_2							
Mulch, A	Fertilizer, B	Sampling date, D				Sampling date, D							
		10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	
None, a_1	0# CaNO$_3$, b_1	$.98^{abcd}$	$.75^{abcd}$	$.90^{abcd}$	$.88^{abc}$	1.18^{abcd}	$.56^{abcd}$	1.02^{abcd}	$.92^{abc}$	1.08^{abd}	$.66^{abd}$	$.96^{abd}$	$.90^{ab}$
	1# CaNO$_3$, b_2	1.05^{abcd}	$.85^{abcd}$	$.96^{abcd}$	$.95^{abc}$	1.05^{abcd}	$.55^{abcd}$	$.87^{abcd}$	$.82^{abc}$	1.05^{abd}	$.70^{abd}$	$.91^{abd}$	$.89^{ab}$
	2# CaNO$_3$, b_3	1.20^{abcd}	$.87^{abcd}$	$.90^{abcd}$	$.99^{abc}$	1.21^{abcd}	$.66^{abcd}$	1.02^{abcd}	$.96^{abc}$	1.21^{abd}	$.76^{abd}$	$.96^{abd}$	$.98^{ab}$
	$(b_1 + b_2 + b_3)/3$	1.08^{acd}	$.82^{acd}$	$.92^{acd}$	$.94^{ac}$	1.15^{acd}	$.59^{acd}$	$.97^{acd}$	$.90^{ac}$	1.11^{ad}	$.71^{ad}$	$.94^{ad}$	$.92^{a}$
Woodshavings, a_2	0# CaNO$_3$, b_1	$.92^{abcd}$	$.66^{abcd}$	$.75^{abcd}$	$.78^{abc}$	$.98^{abcd}$	$.46^{abcd}$	$.72^{abcd}$	$.72^{abc}$	$.95^{abd}$	$.56^{abd}$	$.73^{abd}$	$.75^{ab}$
	1# CaNO$_3$, b_2	1.02^{abcd}	$.81^{abcd}$	$.87^{abcd}$	$.90^{abc}$	1.10^{abcd}	$.47^{abcd}$	$.78^{abcd}$	$.78^{abc}$	1.06^{abd}	$.64^{abd}$	$.83^{abd}$	$.84^{ab}$
	2# CaNO$_3$, b_3	$.90^{abcd}$	$.89^{abcd}$	$.83^{abcd}$	$.87^{abc}$	1.13^{abcd}	$.48^{abcd}$	$.77^{abcd}$	$.79^{abc}$	1.02^{abd}	$.68^{abd}$	$.80^{abd}$	$.83^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.94^{acd}$	$.79^{acd}$	$.82^{acd}$	$.85^{ac}$	1.07^{acd}	$.47^{acd}$	$.76^{acd}$	$.76^{ac}$	1.01^{ad}	$.63^{ad}$	$.79^{ad}$	$.81^{a}$
Woodchips, a_3	0# CaNO$_3$, b_1	1.04^{abcd}	$.81^{abcd}$	$.78^{abcd}$	$.88^{abc}$	1.04^{abcd}	$.49^{abcd}$	$.86^{abcd}$	$.80^{abc}$	1.04^{abd}	$.65^{abd}$	$.82^{abd}$	$.84^{ab}$
	1# CaNO$_3$, b_2	$.96^{abcd}$	$.84^{abcd}$	$.85^{abcd}$	$.88^{abc}$	1.05^{abcd}	$.56^{abcd}$	$.97^{abcd}$	$.86^{abc}$	1.00^{abd}	$.70^{abd}$	$.91^{abd}$	$.87^{ab}$
	2# CaNO$_3$, b_3	$.93^{abcd}$	$.72^{abcd}$	$.93^{abcd}$	$.86^{abc}$	1.26^{abcd}	$.59^{abcd}$	$.98^{abcd}$	$.94^{abc}$	1.09^{abd}	$.65^{abd}$	$.96^{abd}$	$.90^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.98^{acd}$	$.79^{acd}$	$.85^{acd}$	$.87^{ac}$	1.11^{acd}	$.54^{acd}$	$.94^{acd}$	$.87^{ac}$	1.04^{ad}	$.67^{ad}$	$.90^{ad}$	$.87^{a}$
$(a_1 + a_2 + a_3)/3$	0# CaNO$_3$, b_1	$.97^{bcd}$	$.74^{bcd}$	$.81^{bcd}$	$.84^{bc}$	1.06^{bcd}	$.51^{bcd}$	$.87^{bcd}$	$.81^{bc}$	1.02^{bd}	$.62^{bd}$	$.84^{bd}$	$.83^{b}$
	1# CaNO$_3$, b_2	1.01^{bcd}	$.83^{bcd}$	$.89^{bcd}$	$.91^{bc}$	1.07^{bcd}	$.52^{bcd}$	$.88^{bcd}$	$.82^{bc}$	1.04^{bd}	$.68^{bd}$	$.88^{bd}$	$.87^{b}$
	2# CaNO$_3$, b_3	1.01^{bcd}	$.82^{bcd}$	$.89^{bcd}$	$.91^{bc}$	1.20^{bcd}	$.57^{bcd}$	$.92^{bcd}$	$.90^{bc}$	1.10^{bd}	$.70^{bd}$	$.91^{bd}$	$.90^{b}$
	$(b_1 + b_2 + b_3)/3$	1.00^{cd}	$.80^{cd}$	$.86^{cd}$	$.89^{c}$	1.11^{cd}	$.53^{cd}$	$.89^{cd}$	$.84^{c}$	1.05^{d}	$.67^{d}$	$.88^{d}$	$.87$

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 26

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 25.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0235	.047	.064
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0235	.047	.064
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0186	.037	.050
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0179	.035	.047
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.0407	.082	.110
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.0321	.065	.086
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.0327	.067	.088
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.0438	.086	.114
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.0345	.069	.091
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.0321	.065	.086
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.0327	.065	.086
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.0438	.086	.114
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.0345	.069	.091
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.0759	.150	.197
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.0278	.055	.074
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.0557	.112	.150
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.0566	.115	.153
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.0537	.106	.140
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.0598	.119	.158
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.0438	.086	.114
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.0481	.096	.127
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.0485	.096	.127
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.0438	.086	.114
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.0481	.096	.127
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.0485	.096	.127
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.0759	.150	.197
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.0833	.166	.221
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.0840	.167	.222

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .0298 , .0279 , and .0173 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; $r = 6$ = replications; $a = 3$ = levels of factor A; $b = 3$ = levels of factor B; $\alpha = 9$ = levels of factor A x levels of factor B; $\beta = 2$ = levels of factor C; $\gamma = 3$ = levels of factor D.

APPENDIX TABLE 27

Magnesium, percentage dry weight basis, in the foliage of two plant taxa, C (*Chrysanthemum* 'Arlora' and *Chrysanthemum* 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrite per 1000-sq. ft.)[1,2]

Cultural treatment, A + B		Plant taxa, C						$(c_1 + c_2)/2$		$(d_1 + d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
		Sampling date, D			Sampling date, D					
Mulch, A	Fertilizer, B	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 + d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	$.263^{abcd}$	$.328^{abcd}$	$.296^{abc}$	$.208^{abcd}$	$.350^{abcd}$	$.279^{abc}$	$.236^{abd}$	$.339^{abd}$	$.288^{ab}$
	1# $CaNO_3$, b_2	$.292^{abcd}$	$.328^{abcd}$	$.310^{abc}$	$.232^{abcd}$	$.337^{abcd}$	$.284^{abc}$	$.262^{abd}$	$.332^{abd}$	$.297^{ab}$
	2# $CaNO_3$, b_3	$.262^{abcd}$	$.327^{abcd}$	$.294^{abc}$	$.223^{abcd}$	$.342^{abcd}$	$.282^{abc}$	$.242^{abd}$	$.334^{abd}$	$.288^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.272^{acd}$	$.328^{acd}$	$.300^{ac}$	$.221^{acd}$	$.343^{acd}$	$.282^{ac}$	$.247^{ad}$	$.335^{ad}$	$.291^{a}$
Woodshavings, a_2	0# $CaNO_3$, b_1	$.183^{abcd}$	$.183^{abcd}$	$.183^{abc}$	$.175^{abcd}$	$.237^{abcd}$	$.206^{abc}$	$.179^{abd}$	$.210^{abd}$	$.195^{ab}$
	1# $CaNO_3$, b_2	$.162^{abcd}$	$.233^{abcd}$	$.198^{abc}$	$.180^{abcd}$	$.253^{abcd}$	$.217^{abc}$	$.171^{abd}$	$.243^{abd}$	$.207^{ab}$
	2# $CaNO_3$, b_3	$.145^{abcd}$	$.225^{abcd}$	$.185^{abc}$	$.162^{abcd}$	$.252^{abcd}$	$.207^{abc}$	$.153^{abd}$	$.238^{abd}$	$.196^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.163^{acd}$	$.214^{acd}$	$.189^{ac}$	$.172^{acd}$	$.247^{acd}$	$.210^{ac}$	$.168^{ad}$	$.231^{ad}$	$.199^{a}$
Woodchips, a_3	0# $CaNO_3$, b_1	$.143^{abcd}$	$.213^{abcd}$	$.178^{abc}$	$.175^{abcd}$	$.243^{abcd}$	$.209^{abc}$	$.159^{abd}$	$.228^{abd}$	$.194^{ab}$
	1# $CaNO_3$, b_2	$.147^{abcd}$	$.227^{abcd}$	$.187^{abc}$	$.158^{abcd}$	$.228^{abcd}$	$.193^{abc}$	$.152^{abd}$	$.228^{abd}$	$.190^{ab}$
	2# $CaNO_3$, b_3	$.167^{abcd}$	$.250^{abcd}$	$.208^{abc}$	$.157^{abcd}$	$.280^{abcd}$	$.218^{abc}$	$.162^{abd}$	$.265^{abd}$	$.213^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.152^{acd}$	$.230^{acd}$	$.191^{ac}$	$.163^{acd}$	$.251^{acd}$	$.207^{ac}$	$.158^{ad}$	$.240^{ad}$	$.199^{a}$
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	$.196^{bcd}$	$.241^{bcd}$	$.219^{bc}$	$.186^{bcd}$	$.276^{bcd}$	$.231^{bc}$	$.191^{bd}$	$.259^{bd}$	$.225^{b}$
	1# $CaNO_3$, b_2	$.200^{bcd}$	$.263^{bcd}$	$.231^{bc}$	$.190^{bcd}$	$.273^{bcd}$	$.229^{bc}$	$.195^{bd}$	$.268^{bd}$	$.231^{b}$
	2# $CaNO_3$, b_3	$.191^{bcd}$	$.267^{bcd}$	$.229^{bc}$	$.181^{bcd}$	$.291^{bcd}$	$.236^{bc}$	$.186^{bd}$	$.279^{bd}$	$.232^{b}$
	$(b_1 + b_2 + b_3)/3$	$.196^{cd}$	$.257^{cd}$	$.227^{c}$	$.185^{cd}$	$.280^{cd}$	$.233^{c}$	$.191^{d}$	$.269^{d}$	.230

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[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 28

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 27.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.00734	.015	.020
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.00734	.015	.020
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.00428	.009	.012
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.00509	.010	.013
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.01272	.026	.034
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.00742	.015	.020
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.00902	.018	.024
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.01247	.025	.032
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.00963	.020	.025
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.00742	.015	.020
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.00902	.018	.024
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.01247	.025	.032
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.00963	.020	.025
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.02160	.043	.056
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.00665	.014	.018
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.01285	.026	.035
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.01563	.032	.042
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.01527	.030	.040
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.01668	.033	.044
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.01247	.025	.032
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.01152	.023	.030
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.01262	.025	.032
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.01247	.025	.032
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - c_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.01152	.023	.030
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.01262	.025	.032
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.02160	.043	.056
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.01996	.041	.053
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.02185	.044	.057

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .00194 , .00099 , and .00140 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; $r = 6$ = replications; $a = 3$ = levels of factor A; $b = 3$ = levels of factor B; $\alpha = 9$ = levels of factor A x levels of factor B; $\beta = 2$ = levels of factor C; $\gamma = 2$ = levels of factor D.

APPENDIX TABLE 29

Magnesium, percentage dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1,2]

Cultural treatment A + B		Plant taxa, C								(c$_1$ + c$_2$)/2			(d$_1$ + d$_2$ + d$_3$)/3
		Feijoa sellowiana, c$_1$				*Ligustrum japonicum*, c$_2$							
Mulch, A	Fertilizer, B	Sampling date, D				Sampling date, D							
		10-5-60, d$_1$	6-1-61, d$_2$	7-21-61, d$_3$	(d$_1$ + d$_2$ + d$_3$)/3	10-5-60, d$_1$	6-1-61, d$_2$	7-21-61, d$_3$	(d$_1$ + d$_2$ + d$_3$)/3	10-5-60, d$_1$	6-1-61, d$_2$	7-21-61, d$_3$	
None, a$_1$	0# CaNO$_3$, b$_1$	.36^{abcd}	.24^{abcd}	.29^{abcd}	.30^{abc}	.29^{abcd}	.20^{abcd}	.32^{abcd}	.27^{abc}	.33^{abd}	.22^{abd}	.31^{abd}	.28^{ab}
	1# CaNO$_3$, b$_2$	.32^{abcd}	.24^{abcd}	.29^{abcd}	.28^{abc}	.29^{abcd}	.22^{abcd}	.30^{abcd}	.27^{abc}	.31^{abd}	.23^{abd}	.30^{abd}	.28^{ab}
	2# CaNO$_3$, b$_3$	.39^{abcd}	.25^{abcd}	.29^{abcd}	.31^{abc}	.33^{abcd}	.26^{abcd}	.38^{abcd}	.32^{abc}	.36^{abd}	.26^{abd}	.33^{abd}	.32^{ab}
	(b$_1$ + b$_2$ + b$_3$)/3	.36^{acd}	.24^{acd}	.29^{acd}	.30^{ac}	.31^{acd}	.23^{acd}	.33^{acd}	.29^{ac}	.33^{ad}	.23^{ad}	.31^{ad}	.29^{a}
Woodshavings, a$_2$	0# CaNO$_3$, b$_1$	.31^{abcd}	.18^{abcd}	.24^{abcd}	.24^{abc}	.28^{abcd}	.16^{abcd}	.28^{abcd}	.24^{abc}	.30^{abd}	.17^{abd}	.26^{abd}	.24^{ab}
	1# CaNO$_3$, b$_2$	.29^{abcd}	.20^{abcd}	.24^{abcd}	.24^{abc}	.31^{abcd}	.16^{abcd}	.29^{abcd}	.26^{abc}	.30^{abd}	.18^{abd}	.27^{abd}	.25^{ab}
	2# CaNO$_3$, b$_3$	.26^{abcd}	.19^{abcd}	.24^{abcd}	.23^{abc}	.31^{abcd}	.17^{abcd}	.29^{abcd}	.26^{abc}	.28^{abd}	.18^{abd}	.26^{abd}	.24^{ab}
	(b$_1$ + b$_2$ + b$_3$)/3	.29^{acd}	.19^{acd}	.24^{acd}	.24^{ac}	.30^{acd}	.16^{acd}	.29^{acd}	.25^{ac}	.29^{ad}	.18^{ad}	.26^{ad}	.24^{a}
Woodchips, a$_3$	0# CaNO$_3$, b$_1$	.32^{abcd}	.17^{abcd}	.21^{abcd}	.24^{abc}	.27^{abcd}	.17^{abcd}	.29^{abcd}	.24^{abc}	.30^{abd}	.17^{abd}	.25^{abd}	.24^{ab}
	1# CaNO$_3$, b$_2$	.24^{abcd}	.18^{abcd}	.24^{abcd}	.22^{abc}	.29^{abcd}	.19^{abcd}	.31^{abcd}	.26^{abc}	.27^{abd}	.19^{abd}	.28^{abd}	.24^{ab}
	2# CaNO$_3$, b$_3$	.26^{abcd}	.16^{abcd}	.23^{abcd}	.22^{abc}	.36^{abcd}	.23^{abcd}	.33^{abcd}	.31^{abc}	.31^{abd}	.20^{abd}	.28^{abd}	.26^{ab}
	(b$_1$ + b$_2$ + b$_3$)/3	.28^{acd}	.17^{acd}	.23^{acd}	.23^{ac}	.31^{acd}	.20^{acd}	.31^{acd}	.27^{ac}	.29^{ad}	.18^{ad}	.27^{ad}	.25^{a}
(a$_1$ + a$_2$ + a$_3$)/3	0# CaNO$_3$, b$_1$	.33^{bcd}	.19^{bcd}	.25^{bcd}	.26^{bc}	.28^{bcd}	.18^{bcd}	.30^{bcd}	.25^{bc}	.31^{bd}	.18^{bd}	.27^{bd}	.25^{b}
	1# CaNO$_3$, b$_2$	.29^{bcd}	.21^{bcd}	.26^{bcd}	.25^{bc}	.30^{bcd}	.19^{bcd}	.30^{bcd}	.26^{bc}	.29^{bd}	.20^{bd}	.28^{bd}	.26^{b}
	2# CaNO$_3$, b$_3$	.30^{bcd}	.20^{bcd}	.25^{bcd}	.25^{bc}	.34^{bcd}	.22^{bcd}	.33^{bcd}	.30^{bc}	.32^{bd}	.21^{bd}	.29^{bd}	.27^{b}
	(b$_1$ + b$_2$ + b$_3$)/3	.31^{cd}	.20^{cd}	.25^{cd}	.25^{c}	.31^{cd}	.20^{cd}	.31^{cd}	.27^{c}	.31^{d}	.20^{d}	.28^{d}	.26

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 30
Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 29.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0062	.01	.02
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0062	.01	.02
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0070	.01	.02
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0052	.01	.01
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.0107	.02	.03
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.0121	.02	.03
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta b}$	.0106	.02	.03
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.0128	.03	.03
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma b}$	.0097	.02	.03
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.0121	.02	.03
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta a}$	.0106	.02	.03
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.0128	.03	.03
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma a}$	.0097	.02	.03
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.0222	.04	.06
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\alpha\gamma}$	.0093	.02	.03
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.0210	.04	.06
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta}$	.0183	.04	.05
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.0157	.03	.04
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma}$	.0167	.03	.04
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.0128	.03	.03
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	.0160	.03	.04
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma b}$	.0149	.03	.04
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.0128	.03	.03
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	.0160	.03	.04
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma a}$	.0149	.03	.04
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.0222	.04	.06
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma}$	.0277	.06	.07
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma}$	.0259	.06	.07

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .002175, .003977, and .001478 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 3 = levels of factor D.

APPENDIX TABLE 31

Manganese, parts per million dry weight basis, in the foliage of two plant taxa, C (*Chrysanthemum* 'Arlora' and *Chrysanthemum* 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrite per 1000 sq. ft.)[1,2]

Cultural treatment, A ≠ B		Plant taxa, C						$(c_1 \neq c_2)/2$		$(d_1 \neq d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
		Sampling date, D			Sampling date, D					
Mulch, A	Fertilizer, B	5-2-60, d_1	7-2-60, d_2	$(d_1 \neq d_2)/2$	5-2-60, d_1	7-2-60, d_2	$(d_1 \neq d_2)/2$	5-2-60, d_1	7-2-60, d_2	
None, a_1	0# $CaNO_3$, b_1	49.17^{abcd}	49.17^{abcd}	49.17^{abc}	45.83^{abcd}	65.00^{abcd}	55.42^{abc}	47.50^{abd}	57.08^{abd}	52.29^{ab}
	1# $CaNO_3$, b_2	50.83^{abcd}	50.83^{abcd}	50.83^{abc}	45.00^{abcd}	62.50^{abcd}	53.75^{abc}	47.92^{abd}	56.67^{abd}	52.29^{ab}
	2# $CaNO_3$, b_3	45.83^{abcd}	58.33^{abcd}	52.08^{abc}	52.50^{abcd}	74.17^{abcd}	63.33^{abc}	49.17^{abd}	66.25^{abd}	57.71^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	48.61^{acd}	52.78^{acd}	50.69^{ac}	47.78^{acd}	67.22^{acd}	57.50^{ac}	48.19^{ad}	60.00^{ad}	54.10^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	45.00^{abcd}	45.00^{abcd}	45.00^{abc}	40.83^{abcd}	55.00^{abcd}	47.92^{abc}	42.92^{abd}	50.00^{abd}	46.46^{ab}
	1# $CaNO_3$, b_2	42.50^{abcd}	55.83^{abcd}	49.17^{abc}	40.00^{abcd}	66.67^{abcd}	53.33^{abc}	41.25^{abd}	61.25^{abd}	51.25^{ab}
	2# $CaNO_3$, b_3	41.67^{abcd}	57.50^{abcd}	49.58^{abc}	38.33^{abcd}	77.50^{abcd}	57.92^{abc}	40.00^{abd}	67.50^{abd}	53.75^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	43.06^{acd}	52.78^{acd}	47.92^{ac}	39.72^{acd}	66.39^{acd}	53.06^{ac}	41.39^{ad}	59.58^{ad}	50.49^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	40.83^{abcd}	43.33^{abcd}	42.08^{abc}	40.00^{abcd}	54.17^{abcd}	47.08^{abc}	40.42^{abd}	48.75^{abd}	44.58^{ab}
	1# $CaNO_3$, b_2	40.83^{abcd}	52.50^{abcd}	46.67^{abc}	37.50^{abcd}	58.33^{abcd}	47.92^{abc}	39.17^{abd}	55.42^{abd}	47.29^{ab}
	2# $CaNO_3$, b_3	45.83^{abcd}	55.83^{abcd}	50.83^{abc}	40.83^{abcd}	72.50^{abcd}	56.67^{abc}	43.33^{abd}	64.17^{abd}	53.75^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	42.50^{acd}	50.56^{acd}	46.53^{ac}	39.44^{acd}	61.67^{acd}	50.56^{ac}	40.97^{ad}	56.11^{ad}	48.54^{a}
$(a_1 \neq a_2 \neq a_3)/3$	0# $CaNO_3$, b_1	45.00^{bcd}	45.83^{bcd}	45.42^{bc}	42.22^{bcd}	58.06^{bcd}	50.14^{bc}	43.61^{bd}	51.94^{bd}	47.78^{b}
	1# $CaNO_3$, b_2	44.72^{bcd}	53.06^{bcd}	48.89^{bc}	40.83^{bcd}	62.50^{bcd}	51.67^{bc}	42.78^{bd}	57.78^{bd}	50.28^{b}
	2# $CaNO_3$, b_3	44.44^{bcd}	57.02^{bcd}	50.83^{bc}	43.89^{bcd}	74.72^{bcd}	59.31^{bc}	44.17^{bd}	65.97^{bd}	55.07^{b}
	$(b_1 \neq b_2 \neq b_3)/3$	44.72^{cd}	52.04^{cd}	48.38^{c}	42.31^{cd}	65.09^{cd}	53.70^{c}	43.52^{d}	58.56^{d}	51.04

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[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 32

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 31.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	LSD	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	1.81	3.70	4.89
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	1.81	3.70	4.89
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	1.179	2.33	3.18
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	1.295	6.25	8.25
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2F_a/r\beta\gamma}$	3.14	6.43	8.49
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	2.042	4.11	5.50
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta b}$	2.32	4.68	6.26
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	3.172	6.25	8.25
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma b}$	3.12	6.30	8.24
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	2.042	4.11	5.50
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta a}$	2.32	4.68	6.26
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	3.172	6.25	8.25
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma a}$	2.41	4.82	6.36
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	5.495	10.83	14.29
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\alpha\gamma}$	1.75	3.52	4.64
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	3.536	7.13	9.52
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b + E_a]/r\gamma\beta}$	4.02	8.13	10.85
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	3.886	7.66	10.10
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_a]/r\beta\gamma}$	4.17	8.34	11.00
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	3.172	6.25	8.25
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	3.22	6.46	8.53
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma b}$	3.44	6.77	8.95
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	3.172	6.25	8.25
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma a}$	3.22	6.46	8.53
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma a}$	3.44	6.77	8.95
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	5.495	10.83	14.29
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c + E_b]/r\gamma}$	5.25	10.54	13.91
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c + (\beta-1)E_b + E_a]/r\beta\gamma}$	5.95	11.88	15.49

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = 168.61 , 75.02 , and 90.58 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 2 = levels of factor D.

APPENDIX TABLE 33

Manganese, parts per million dry weight basis, in the foliage of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*), on three dates, D (October 5, 1960, and June 1 and July 21, 1961), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)[1, 2]

Cultural treatment A + B		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Feijoa sellowiana, c_1				Ligustrum japonicum, c_2							
Mulch, A	Fertilizer, B	Sampling date, D				Sampling date, D							
		10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	10-5-60, d_1	6-1-61, d_2	7-21-61, d_3	
None, a_1	0# $CaNO_3$, b_1	65.0^{abcd}	58.3^{abcd}	46.7^{abcd}	56.7^{abc}	130.8^{abcd}	30.0^{abcd}	57.5^{abcd}	72.8^{abc}	97.9^{abd}	44.2^{abd}	52.1^{abd}	64.7^{ab}
	1# $CaNO_3$, b_2	79.2^{abcd}	45.0^{abcd}	43.3^{abcd}	55.8^{abc}	113.3^{abcd}	33.3^{abcd}	48.3^{abcd}	65.0^{abc}	96.2^{abd}	39.2^{abd}	45.8^{abd}	60.4^{ab}
	2# $CaNO_3$, b_3	75.8^{abcd}	57.5^{abcd}	50.0^{abcd}	61.1^{abc}	190.8^{abcd}	35.8^{abcd}	48.3^{abcd}	91.7^{abc}	133.3^{abd}	46.7^{abd}	49.2^{abd}	76.4^{ab}
	$(b_1 + b_2 + b_3)/3$	73.3^{acd}	53.6^{acd}	46.7^{acd}	57.9^{ac}	145.0^{acd}	33.0^{acd}	51.4^{acd}	76.5^{ac}	109.2^{ad}	43.3^{ad}	49.0^{ad}	67.2^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	72.5^{abcd}	40.8^{abcd}	46.7^{abcd}	53.3^{abc}	100.8^{abcd}	28.3^{abcd}	49.2^{abcd}	59.4^{abc}	86.7^{abd}	34.6^{abd}	47.9^{abd}	56.4^{ab}
	1# $CaNO_3$, b_2	101.7^{abcd}	43.3^{abcd}	47.5^{abcd}	64.2^{abc}	245.0^{abcd}	33.3^{abcd}	47.5^{abcd}	108.6^{abc}	173.3^{abd}	38.3^{abd}	47.5^{abd}	86.4^{ab}
	2# $CaNO_3$, b_3	65.8^{abcd}	48.3^{abcd}	45.0^{abcd}	53.1^{abc}	211.7^{abcd}	28.3^{abcd}	48.3^{abcd}	96.1^{abc}	138.8^{abd}	38.3^{abd}	46.7^{abd}	74.6^{ab}
	$(b_1 + b_2 + b_3)/3$	80.0^{acd}	44.2^{acd}	46.4^{acd}	56.8^{ac}	185.8^{acd}	30.0^{acd}	48.3^{acd}	88.1^{ac}	132.9^{ad}	37.1^{ad}	47.4^{ad}	72.4^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	57.5^{abcd}	135.8^{abcd}	41.7^{abcd}	78.3^{abc}	75.8^{abcd}	27.5^{abcd}	44.2^{abcd}	49.2^{abc}	66.7^{abd}	81.7^{abd}	42.9^{abd}	63.8^{ab}
	1# $CaNO_3$, b_2	42.5^{abcd}	45.8^{abcd}	38.3^{abcd}	42.2^{abc}	79.2^{abcd}	31.7^{abcd}	51.7^{abcd}	54.2^{abc}	60.8^{abd}	38.8^{abd}	45.0^{abd}	49.2^{ab}
	2# $CaNO_3$, b_3	58.3^{abcd}	45.8^{abcd}	48.3^{abcd}	50.8^{abc}	74.2^{abcd}	33.3^{abcd}	45.8^{abcd}	51.1^{abc}	66.2^{abd}	39.6^{abd}	47.1^{abd}	51.0^{ab}
	$(b_1 + b_2 + b_3)/3$	52.8^{acd}	75.8^{acd}	42.8^{acd}	57.1^{ac}	76.4^{acd}	30.8^{acd}	47.2^{acd}	51.5^{ac}	64.6^{ad}	53.3^{ad}	45.0^{ad}	54.3^{a}
$(a_1 + a_2 + a_3)/3$	0# $CaNO_3$, b_1	65.0^{bcd}	78.3^{bcd}	45.0^{bcd}	62.8^{bc}	102.5^{bcd}	28.6^{bcd}	50.3^{bcd}	60.5^{bc}	83.8^{bd}	53.5^{bd}	47.6^{bd}	61.6^{b}
	1# $CaNO_3$, b_2	74.4^{bcd}	44.7^{bcd}	43.1^{bcd}	54.1^{bc}	145.8^{bcd}	32.8^{bcd}	49.2^{bcd}	75.9^{bc}	110.1^{bd}	38.8^{bd}	46.1^{bd}	65.0^{b}
	2# $CaNO_3$, b_3	66.7^{bcd}	50.6^{bcd}	47.8^{bcd}	55.0^{bc}	158.9^{bcd}	32.5^{bcd}	47.5^{bcd}	80.0^{bc}	112.8^{bd}	41.5^{bd}	47.6^{bd}	67.3^{b}
	$(b_1 + b_2 + b_3)/3$	68.7^{cd}	57.9^{cd}	45.3^{cd}	57.3^{c}	135.7^{cd}	31.3^{cd}	49.0^{cd}	72.0^{c}	102.2^{d}	44.6^{d}	47.1^{d}	64.6

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 34

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 33.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	LSD .05	LSD .01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	7.10	14.3	19.2
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	7.10	14.3	19.2
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	5.98	12.0	16.1
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	6.50	12.8	16.9
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	12.30	24.9	33.3
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	10.35	20.9	27.9
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	10.20	20.6	27.5
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	15.92	31.4	41.4
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	11.61	23.2	30.6
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	10.35	20.9	27.9
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	10.20	20.6	27.5
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	15.92	31.4	41.4
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	11.61	23.2	30.6
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	27.57	54.3	71.7
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	9.59	19.1	25.4
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	17.93	36.1	48.3
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	17.66	35.6	47.7
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	19.49	38.4	50.7
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	20.12	40.1	53.1
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	15.92	31.4	41.4
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	16.61	33.1	44.0
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	16.52	33.0	43.9
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	15.92	31.4	41.4
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	16.61	33.1	44.0
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	16.52	33.0	43.9
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	27.57	54.3	71.7
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	28.78	57.3	76.3
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	28.61	57.0	76.0

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = 2724., 2893., and 2280. respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 3 = levels of factor D.

APPENDIX TABLE 35

Analyses of variance mean squares for the effect of mulch and fertilizer factorial treatments on size and weight of the two chrysanthemum clones and linear shoot growth of the *Feijoa*.[1]

Source of variation	df	Mean square, sometimes rounded to nearest unit		
		Chrysanthemum clones		*Feijoa sellowiana* shoot growth
		Size[2]	Weight[2,3]	
Replicates	5	1,958	.16	56,578
Treatments:				
Mulches (A)	2	135,911**	24.63**	642,535**
Fertilizer (B)	2	1,149	.79	318,228**
A x B	4	1,278	.20	44,541
Error (a)	40	1,158	.26	48,168
Plants (C)	1	24,151**	.17	
A x C	2	4,044	1.42**	
B x C	2	413	.13	
A x B x C	4	614	.12	
Error (b)	45	738	.24	

APPENDIX TABLE 35 (continued)

Analyses of variance mean squares for the effect of mulch and fertilizer factorial treatments on size and weight of the two chrysanthemum clones and linear shoot growth of the Feijoa[1]

Source of variation	df	Mean square, sometimes rounded to nearest unit		
		Chrysanthemum clones		Feijoa sellowiana shoot growth
		Size[2]	Weight[2,3]	
Sampling dates (D)	1	88	94.76**	
A x D	2	80,294**	12.94**	
B x D	2	616	1.38**	
A x B x D	4	2,158**	.74**	
C x D	1	30,341**	5.41**	
A x C x D	2	3,673**	1.32**	
B x C x D	2	515	.41*	
A x B x C x D	4	245	.24	
Error (c)	90	584	.17	
Total	215			

[1] Symbols * and ** indicate significance at the 5 and 1 percent levels, respectively. Significance of each was determined by calculating the F-ratio (treatment datum divided by appropriate error datum) and comparing it with the tabular F-value. F-ratios needed for significance are shown below:

Probability of a larger F-value	Numerator (treatment) df / denominator (error) df										
	2/40	4/40	1/45	2/45	4/45	1/90	2/90	4/90	2/180	4/180	8/180
.05	3.23	2.61	4.06	3.21	2.59	3.95	3.10	2.48	3.00	2.37	1.94
.01	5.18	3.85	7.26	5.13	3.80	6.93	4.87	3.56	4.61	3.32	2.51

[2] Analysis of variance was on a sub-sub-unit basis, with plants (C) in the sub-unit analysis and sampling dates (D) in the sub-sub-unit.

[3] Degrees of freedom (df) for sampling dates (D) and all interactions containing that factor should be twice the values given since the weight analysis of variance consisted of three sampling dates. Accordingly, the Error (c) df should be 180; the total df 323.

APPENDIX TABLE 36

The size, (cubic inches per plant), of two plant taxa, C (C. 'Arlora' and C. 'Chris Col.'), on two dates, D (April 27 and June 30, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of nitrogen from calcium nitrate per 1000 square feet).[1,2]

Cultural treatment, $A \neq B$		Plant taxa, C						$(c_1 \neq c_2)/2$		$(d_1 \neq d_2)/2$
		Chrysanthemum 'Arlora', c_1			Chrysanthemum 'Chris Columbus, c_2					
Mulch, A	Fertilizer, B	Sampling date, D			Sampling date, D					
		4-27-60, d_1	6-30-60, d_2	$(d_1 \neq d_2)/2$	4-27-60, d_1	6-30-60, d_2	$(d_1 \neq d_2)/2$	4-27-60, d_1	6-30-60, d_2	
None, a_1	0# $CaNO_3$, b_1	170.50^{abcd}	68.00^{abcd}	119.25^{abc}	169.83^{abcd}	122.50^{abcd}	146.17^{abc}	170.17^{abd}	95.25^{abd}	132.71^{ab}
	1# $CaNO_3$, b_2	181.33^{abcd}	56.33^{abcd}	118.83^{abc}	185.50^{abcd}	153.17^{abcd}	169.33^{abc}	183.34^{abd}	104.75^{abd}	144.08^{ab}
	2# $CaNO_3$, b_3	171.33^{abcd}	45.50^{abcd}	108.25^{abc}	157.67^{abcd}	123.17^{abcd}	140.42^{abc}	164.33^{abd}	84.33^{abd}	124.33^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	174.28^{acd}	56.61^{acd}	115.44^{ac}	171.00^{acd}	132.94^{acd}	151.97^{ac}	172.64^{ad}	94.78^{ad}	133.71^{a}
Woodshavings, a_2	0# $CaNO_3$, b_1	30.00^{abcd}	49.00^{abcd}	39.50^{abc}	36.33^{abcd}	80.83^{abcd}	58.58^{abc}	33.17^{abd}	64.92^{abd}	49.04^{ab}
	1# $CaNO_3$, b_2	39.00^{abcd}	63.67^{abcd}	51.33^{abc}	39.00^{abcd}	86.83^{abcd}	62.92^{abc}	39.00^{abd}	75.25^{abd}	57.12^{ab}
	2# $CaNO_3$, b_3	21.17^{abcd}	74.50^{abcd}	47.83^{abc}	38.17^{abcd}	118.17^{abcd}	78.17^{abc}	29.67^{abd}	96.33^{abd}	63.00^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	30.06^{acd}	62.39^{acd}	46.22^{ac}	37.83^{acd}	95.28^{acd}	66.55^{ac}	33.94^{ad}	78.83^{ad}	56.39^{a}
Woodchips, a_3	0# $CaNO_3$, b_1	57.00^{abcd}	63.17^{abcd}	60.08^{abc}	44.50^{abcd}	78.33^{abcd}	61.42^{abc}	50.75^{abd}	70.75^{abd}	60.75^{ab}
	1# $CaNO_3$, b_2	41.17^{abcd}	79.50^{abcd}	60.33^{abc}	32.00^{abcd}	100.67^{abcd}	66.32^{abc}	36.58^{abd}	90.08^{abd}	63.33^{ab}
	2# $CaNO_3$, b_3	58.50^{abcd}	45.17^{abcd}	51.83^{abc}	43.67^{abcd}	84.83^{abcd}	64.25^{abc}	51.08^{abd}	65.00^{abd}	58.04^{ab}
	$(b_1 \neq b_2 \neq b_3)/3$	52.22^{acd}	62.61^{acd}	57.42^{ac}	40.06^{acd}	87.94^{acd}	64.00^{ac}	46.74^{ad}	75.28^{ad}	60.71^{a}
$(a_1 \neq a_2 \neq a_3)/3$	0# $CaNO_3$, b_1	85.83^{bcd}	60.06^{bcd}	72.94^{bc}	83.56^{bcd}	93.89^{bcd}	88.72^{bc}	84.69^{bd}	76.97^{bd}	80.83^{b}
	1# $CaNO_3$, b_2	87.17^{bcd}	60.50^{bcd}	76.83^{bc}	85.50^{bcd}	113.56^{bcd}	99.53^{bc}	86.33^{bd}	90.03^{bd}	88.18^{b}
	2# $CaNO_3$, b_3	83.56^{bcd}	50.06^{bcd}	69.31^{bc}	79.83^{bcd}	108.72^{bcd}	94.28^{bc}	81.69^{bd}	81.89^{bd}	81.79^{b}
	$(b_1 \neq b_2 \neq b_3)/3$	85.52^{cd}	60.54^{cd}	73.03^{c}	82.96^{cd}	105.39^{cd}	94.17^{c}	84.24^{d}	82.96^{d}	83.60

[1] Superscripts indicate the factors that are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 36 observations (6 replications x 3 levels of factor B x 2 levels of factor D).

APPENDIX TABLE 37
Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 36

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	5.67	11.46	15.35
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	5.67	11.46	15.35
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	3.70	7.46	9.96
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	3.29	6.48	8.55
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	9.82	19.85	26.55
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	6.40	12.90	17.24
"	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	7.43	14.99	20.06
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	8.06	15.88	20.96
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	8.04	16.04	21.23
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	6.40	12.90	17.24
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	7.43	14.99	20.06
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	8.06	15.88	20.96
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	8.04	16.04	21.23
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	13.96	27.50	36.30
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	5.94	11.82	15.74
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	11.09	22.35	29.87
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	12.86	25.95	34.72
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	9.92	19.54	25.79
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	13.92	27.77	36.75
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	8.06	15.88	20.96
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	10.29	20.48	27.27
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	9.23	18.42	24.55
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	8.06	15.88	20.96
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	10.29	20.48	27.27
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	9.23	18.42	24.55
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	13.96	27.50	36.30
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	17.82	35.46	47.22
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff A, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	15.98	31.90	42.57

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c =1,158.17 737.58 and 584.23 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 2 = levels of factor D.

APPENDIX TABLE 38

The weight, pounds per plant, of two plant taxa, C (C. 'Arlora' and C. 'Chris Columbus'), on three dates, D (Nov. 3, 1959; May 2, 1960, and July 8, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of nitrogen from calcium nitrate per 1000 square feet).[1,2]

Cultural treatment $A + B$		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Chrysanthemum 'Arlora', c_1				Chrysanthemum 'Chris Columbus, c_2							
		Sampling date, D				Sampling date, D							
Mulch, A	Fertilizer, B	11-30-59, d_1	5-2-60, d_2	7-8-60, d_3	$(d_1 + d_2 + d_3)/3$	11-30-59, d_1	5-2-60, d_2	7-8-60, d_3	$(d_1 + d_2 + d_3)/3$	11-30-59, d_1	5-2-60, d_2	7-8-60, d_3	
None, a_1	0# CaNO$_3$, b_1	$.29^{abcd}$	2.88^{abcd}	1.76^{abcd}	1.64^{abc}	$.20^{abcd}$	2.65^{abcd}	2.48^{abcd}	1.78^{abc}	$.25^{abd}$	2.77^{abd}	2.12^{abd}	1.71^{ab}
	1# CaNO$_3$, b_2	$.32^{abcd}$	2.95^{abcd}	2.15^{abcd}	1.81^{abc}	$.26^{abcd}$	2.18^{abcd}	3.25^{abcd}	1.90^{abc}	$.29^{abd}$	2.57^{abd}	2.70^{abd}	1.85^{ab}
	2# CaNO$_3$, b_3	$.28^{abcd}$	3.10^{abcd}	1.53^{abcd}	1.64^{abc}	$.22^{abcd}$	2.15^{abcd}	2.60^{abcd}	1.66^{abc}	$.25^{abd}$	2.62^{abd}	2.07^{abd}	1.65^{ab}
	$(b_1 + b_2 + b_3)/3$	$.30^{acd}$	2.98^{acd}	1.82^{acd}	1.70^{ac}	$.23^{acd}$	2.33^{acd}	2.78^{acd}	1.78^{ac}	$.26^{ad}$	2.65^{ad}	2.30^{ad}	1.74^{a}
Woodshavings, a_2	0# CaNO$_3$, b_1	$.19^{abcd}$	$.58^{abcd}$	1.23^{abcd}	$.67^{abc}$	$.13^{abcd}$	$.55^{abcd}$	1.72^{abcd}	$.80^{abc}$	$.16^{abd}$	$.57^{abd}$	1.48^{abd}	$.73^{ab}$
	1# CaNO$_3$, b_2	$.23^{abcd}$	$.65^{abcd}$	1.42^{abcd}	$.76^{abc}$	$.13^{abcd}$	$.58^{abcd}$	2.32^{abcd}	1.01^{abc}	$.18^{abd}$	$.62^{abd}$	1.87^{abd}	$.89^{ab}$
	2# CaNO$_3$, b_3	$.09^{abcd}$	$.33^{abcd}$	1.76^{abcd}	$.73^{abc}$	$.11^{abcd}$	$.52^{abcd}$	2.73^{abcd}	1.12^{abc}	$.10^{abd}$	$.42^{abd}$	2.25^{abd}	$.93^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.17^{acd}$	$.52^{acd}$	1.47^{acd}	$.72^{ac}$	$.12^{acd}$	$.55^{acd}$	2.26^{acd}	$.98^{ac}$	$.15^{ad}$	$.54^{ad}$	1.86^{ad}	$.85^{a}$
Woodchips, a_3	0# CaNO$_3$, b_1	$.24^{abcd}$	$.93^{abcd}$	1.88^{abcd}	1.02^{abc}	$.12^{abcd}$	$.62^{abcd}$	1.56^{abcd}	$.77^{abc}$	$.18^{abd}$	$.78^{abd}$	1.72^{abd}	$.89^{ab}$
	1# CaNO$_3$, b_2	$.18^{abcd}$	$.70^{abcd}$	2.92^{abcd}	1.26^{abc}	$.09^{abcd}$	$.48^{abcd}$	2.28^{abcd}	$.95^{abc}$	$.13^{abd}$	$.59^{abd}$	2.60^{abd}	1.11^{ab}
	2# CaNO$_3$, b_3	$.33^{abcd}$	1.18^{abcd}	1.43^{abcd}	$.98^{abc}$	$.16^{abcd}$	$.65^{abcd}$	2.03^{abcd}	$.95^{abc}$	$.25^{abd}$	$.92^{abd}$	1.73^{abd}	$.97^{ab}$
	$(b_1 + b_2 + b_3)/3$	$.25^{acd}$	$.94^{acd}$	2.08^{acd}	1.09^{ac}	$.13^{acd}$	$.58^{acd}$	1.96^{acd}	$.89^{ac}$	$.19^{ad}$	$.76^{ad}$	2.02^{ad}	$.99^{a}$
$(a_1 + a_2 + a_3)/3$	0# CaNO$_3$, b_1	$.24^{bcd}$	1.47^{bcd}	1.63^{bcd}	1.11^{bc}	$.15^{bcd}$	1.27^{bcd}	1.92^{bcd}	1.11^{bc}	$.20^{bd}$	1.37^{bd}	1.78^{bd}	1.11^{b}
	1# CaNO$_3$, b_2	$.24^{bcd}$	1.43^{bcd}	2.16^{bcd}	1.28^{bc}	$.16^{bcd}$	1.08^{bcd}	2.62^{bcd}	1.29^{bc}	$.20^{bd}$	1.26^{bd}	2.39^{bd}	1.28^{b}
	2# CaNO$_3$, b_3	$.24^{bcd}$	1.54^{bcd}	1.58^{bcd}	1.12^{bc}	$.16^{bcd}$	1.11^{bcd}	2.46^{bcd}	1.24^{bc}	$.20^{bd}$	1.32^{bd}	2.02^{bd}	1.18^{b}
	$(b_1 + b_2 + b_3)/3$	$.24^{cd}$	1.48^{cd}	1.79^{cd}	1.17^{c}	$.16^{cd}$	1.15^{cd}	2.33^{cd}	1.21^{c}	$.20^{d}$	1.32^{d}	2.06^{d}	1.19

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

APPENDIX TABLE 39

Standard Error of Differences ($S_{\bar{d}}$) and Least Significant Differences (LSD) for the data of Appendix Table 38.

Item[1]	Difference between:	Measured as:	$S_{\bar{d}}$ Model[2]	$S_{\bar{d}}$	L S D	
					.05	.01
a	Different a	$a_1 - a_0$	$\sqrt{2E_a/r\beta\gamma b}$	.0850	.17	.23
b	Different b	$b_1 - b_0$	$\sqrt{2E_a/r\beta\gamma a}$	.0850	.17	.23
c	Different c	$c_1 - c_0$	$\sqrt{2E_b/r\alpha\gamma}$	.0667	.13	.18
d	Different d	$d_1 - d_0$	$\sqrt{2E_c/r\alpha\beta}$	.0561	.11	.15
ab " "	Same a, different b Different a, same b Different a, different b	$a_1 b_1 - a_1 b_0$ $a_1 b_1 - a_0 b_1$ $a_1 b_1 - a_0 b_0$	$\sqrt{2E_a/r\beta\gamma}$	.1480	.30	.40
ac	Same a, different c	$a_1 c_1 - a_1 c_0$	$\sqrt{2E_b/r\gamma b}$	.1156	.23	.31
" "	Different a, same c Different a, different c	$a_1 c_1 - a_0 c_1$ $a_1 c_1 - a_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta b}$	.1182	.24	.32
ad	Same a, different d	$a_1 d_1 - a_1 d_0$	$\sqrt{2E_c/rb}$	.1374	.27	.36
" "	Different a, same d Different a, different d	$a_1 d_1 - a_0 d_1$ $a_1 d_1 - a_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma b}$	.1294	.26	.34
bc	Same b, different c	$b_1 c_1 - b_1 c_0$	$\sqrt{2E_b/r\gamma a}$	.1156	.23	.31
" "	Different b, same c Different b, different c	$b_1 c_1 - b_0 c_1$ $b_1 c_1 - b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta a}$	.1182	.24	.32
bd	Same b, different d	$b_1 d_1 - b_1 d_0$	$\sqrt{2E_c/ra}$	.1374	.27	.36
" "	Different b, same d Different b, different d	$b_1 d_1 - b_0 d_1$ $b_1 d_1 - b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma a}$	.1294	.26	.34
cd	Same c, different d	$c_1 d_1 - c_1 d_0$	$\sqrt{2E_c/r}$	.2380	.47	.62
" "	Different c, same d Different c, different d	$c_1 d_1 - c_0 d_1$ $c_1 d_1 - c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\alpha\gamma}$	.1037	.21	.28
abc	Same a, same b, different c	$a_1 b_1 c_1 - a_1 b_1 c_0$	$\sqrt{2E_b/r\gamma}$	.2063	.40	.54
" " " " " "	Same a, different b, same c Different a, same b, same c Different a, different b, same c Same a, different b, different c Different a, same b, different c Different a, diff b, different c	$a_1 b_1 c_1 - a_1 b_0 c_1$ $a_1 b_1 c_1 - a_0 b_1 c_1$ $a_1 b_1 c_1 - a_0 b_0 c_1$ $a_1 b_1 c_1 - a_1 b_0 c_0$ $a_1 b_1 c_1 - a_0 b_1 c_0$ $a_1 b_1 c_1 - a_0 b_0 c_0$	$\sqrt{2[(\beta-1)E_b+E_a]/r\gamma\beta}$	.2048	.41	.55
abd	Same a, same b, different d	$a_1 b_1 d_1 - a_1 b_1 d_0$	$\sqrt{2E_c/r\beta}$	.1683	.33	.44
" " " " " "	Same a, different b, same d Different a, same b, same d Different a, different b, same d Same a, different b, different d Different a, same b, different d Different a, diff b, different d	$a_1 b_1 d_1 - a_1 b_0 d_1$ $a_1 b_1 d_1 - a_0 b_1 d_1$ $a_1 b_1 d_1 - a_0 b_0 d_1$ $a_1 b_1 d_1 - a_1 b_0 d_0$ $a_1 b_1 d_1 - a_0 b_1 d_0$ $a_1 b_1 d_1 - a_0 b_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_a]/r\beta\gamma}$	.2241	.45	.59
acd	Same a, same c, different d	$a_1 c_1 d_1 - a_1 c_1 d_0$	$\sqrt{2E_c/rb}$	.1374	.27	.36
" "	Same a, different c, same d Same a, diff c, different d	$a_1 c_1 d_1 - a_1 c_0 d_1$ $a_1 c_1 d_1 - a_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.1796	.36	.48
" " "	Different a, same c, same d Different a, same c, different d Different a, diff c, different d	$a_1 c_1 d_1 - a_0 c_1 d_1$ $a_1 c_1 d_1 - a_0 c_1 d_0$ $a_1 c_1 d_1 - a_0 c_1 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma b}$	.1530	.31	.41
bcd	Same b, same c, different d	$b_1 c_1 d_1 - b_1 c_1 d_0$	$\sqrt{2E_c/ra}$	.1374	.27	.36
" "	Same b, different c, same d Same b, diff c, different d	$b_1 c_1 d_1 - b_1 c_0 d_1$ $b_1 c_1 d_1 - b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma a}$	.1796	.36	.48
" " "	Different b, same c, same d Different b, same c, different d Different b, diff c, different d	$b_1 c_1 d_1 - b_0 c_1 d_1$ $b_1 c_1 d_1 - b_0 c_1 d_0$ $b_1 c_1 d_1 - b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma a}$	.1530	.31	.41
abcd	Same a, same b, same c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_1 d_0$	$\sqrt{2E_c/r}$	.2380	.47	.62
" "	Same a, same b, diff c, same d Same a, same b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_1 c_0 d_0$	$\sqrt{2[(\gamma-1)E_c+E_b]/r\gamma}$	.3111	.62	.82
" " " " " " " " " " " "	Same a, diff b, same c, same d Diff a, same b, same c, same d Diff a, diff b, same c, same d Same a, diff b, diff c, same d Diff a, same b, diff c, same d Diff a, diff b, diff c, same d Same a, diff b, same c, diff d Diff a, same b, same c, diff d Diff a, diff b, same c, diff d Same a, diff b, diff c, diff d Diff a, same b, diff c, diff d Diff a, diff b, diff c, diff d	$a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_1$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_1 d_0$ $a_1 b_1 c_1 d_1 - a_1 b_0 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_1 c_0 d_0$ $a_1 b_1 c_1 d_1 - a_0 b_0 c_0 d_0$	$\sqrt{2[\beta(\gamma-1)E_c+(\beta-1)E_b+E_a]/r\beta\gamma}$	.2651	.53	.71

[1] Factors averaged at single levels; the others over all levels.

[2] E_a, E_b, and E_c = .2625 , .2406 , and .1700 respectively = error (residual) in whole-unit, sub-unit, and sub-sub-unit analyses, respectively; r = 6 = replications; a = 3 = levels of factor A; b = 3 = levels of factor B; α = 9 = levels of factor A x levels of factor B; β = 2 = levels of factor C; γ = 3 = levels of factor D.

APPENDIX TABLE 40

Weight/size ratio for two plant taxa, C (Chrysanthemum 'Arlora' and Chrysanthemum 'Chris Columbus'), on two dates, D (May 2 and July 2, 1960), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips), and three levels of fertilizer, B (0, 1, and 2 lb. of calcium nitrate per 1000 sq. ft.)

Cultural treatment, A - B		Plant taxa, C					
		Chrysanthemum 'Arlora'			Chrysanthemum 'Chris Columbus', c_1		
		Sampling date, D			Sampling date, D		
Mulch, A	Fertilizer, B	5/2/60, d_1	7/2/60, d_2	Differential %	5/2/60, d_1	7/2/60, d_2	Differential %
None, a_1	0# $CaNO_3$, b_1	1.69	2.59	53	1.56	2.02	29
	1# $CaNO_3$, b_2	1.63	3.84	136	1.18	2.12	80
	2# $CaNO_3$, b_3	1.81	3.36	86	1.36	2.11	55
	$(b_1+b_2+b_3)/3$	1.71	3.21	38	1.37	2.09	67
Wood-shavings, a_2	0# $CaNO_3$, b_1	1.93	2.51	30	1.53	2.13	39
	1# $CaNO_3$, b_2	1.66	2.22	34	1.49	2.67	79
	2# $CaNO_3$, b_3	1.57	2.36	50	1.37	2.31	69
	$(b_1+b_2+b_3)/3$	1.69	2.36	40	1.46	2.37	62
Woodchips, a_3	0# $CaNO_3$, b_1	1.63	2.98	82	1.39	1.99	43
	1# $CaNO_3$, b_2	1.70	3.67	116	1.50	2.26	51
	2# $CaNO_3$, b_3	2.02	3.17	57	1.48	2.39	61
	$(b_1+b_2+b_3)/3$	1.78	3.27	84	1.46	2.23	53
$\frac{(a_1+a_2+a_3)}{3}$	0# $CaNO_3$, b_1	1.75	2.36	35	1.52	2.04	34
	1# $CaNO_3$, b_2	1.66	3.24	95	1.26	2.31	83
	2# $CaNO_3$, b_3	1.80	2.96	64	1.39	2.26	63
	$(b_1+b_2+b_3)/3$	1.73	2.96	71	1.38	2.21	60

APPENDIX TABLE 41

Weight, grams per plant sample, of roots of two plant taxa, C (*Feijoa sellowiana* and *Ligustrum japonicum*) at three depths, D (1-3, 3-6, and 6-9 inches), due to factorial treatments of three levels of mulch, A (none, woodshavings, and woodchips) and three levels of fertilizer, B (0, 1, and 2 lb. of nitrogen from calcium nitrate per 1000 sq. ft.)[1,2,3]

Cultural treatment A + B		Plant taxa, C								$(c_1 + c_2)/2$			$(d_1 + d_2 + d_3)/3$
		Feijoa sellowiana, c_1				Ligustrum japonicum, c_2							
Mulch, A	Fertilizer, B	Sampling depth, D				Sampling depth, D							
		1-3", d_1	3-6", d_2	6-9", d_3	$(d_1 + d_2 + d_3)/3$	1-3", d_1	3-6", d_2	7-21-61, d_3	$(d_1 + d_2 + d_3)/3$	1-3", d_1	3-6", d_2	6-9", d_3	
None, a_1	0# CaNO$_3$, b_1	.30^{abcd}	.60^{abcd}	.38^{abcd}	.42^{abc}	.32^{abcd}	.94^{abcd}	1.35^{abcd}	.87^{abc}	.31^{abd}	.77^{abd}	.86^{abd}	.65^{ab}
	1# CaNO$_3$, b_2	.38^{abcd}	.68^{abcd}	.86^{abcd}	.64^{abc}	.77^{abcd}	.72^{abcd}	.46^{abcd}	.65^{abc}	.58^{abd}	.70^{abd}	.66^{abd}	.65^{ab}
	2# CaNO$_3$, b_3	.38^{abcd}	.65^{abcd}	.66^{abcd}	.56^{abc}	.04^{abcd}	.26^{abcd}	.76^{abcd}	.35^{abc}	.21^{abd}	.46^{abd}	.71^{abd}	.46^{ab}
	$(b_1 + b_2 + b_3)/3$	.35^{acd}	.64^{acd}	.63^{acd}	.54^{ac}	.38^{acd}	.64^{acd}	.86^{acd}	.66^{ac}	.36^{ad}	.64^{ad}	.75^{ad}	.58^{a}
Woodshavings, a_2	0# CaNO$_3$, b_1	.27^{abcd}	.33^{abcd}	.18^{abcd}	.26^{abc}	.69^{abcd}	1.04^{abcd}	.32^{abcd}	.68^{abc}	.48^{abd}	.68^{abd}	.25^{abd}	.47^{ab}
	1# CaNO$_3$, b_2	.65^{abcd}	.41^{abcd}	.22^{abcd}	.43^{abc}	.65^{abcd}	2.46^{abcd}	.78^{abcd}	1.30^{abc}	.65^{abd}	1.44^{abd}	.50^{abd}	.86^{ab}
	2# CaNO$_3$, b_3	.68^{abcd}	.85^{abcd}	.56^{abcd}	.66^{abc}	.90^{abcd}	1.75^{abcd}	1.07^{abcd}	1.24^{abc}	.89^{abd}	1.30^{abd}	.82^{abd}	1.00^{ab}
	$(b_1 + b_2 + b_3)/3$	.53^{acd}	.53^{acd}	.32^{acd}	.45^{ac}	.75^{acd}	1.75^{acd}	.72^{acd}	1.07^{ac}	.64^{ad}	1.14^{ad}	.52^{ad}	.77^{a}
Woodchips, a_3	0# CaNO$_3$, b_1	.67^{abcd}	.34^{abcd}	.45^{abcd}	.49^{abc}	1.66^{abcd}	1.94^{abcd}	.98^{abcd}	1.53^{abc}	1.10^{abd}	1.13^{abd}	.72^{abd}	.96^{ab}
	1# CaNO$_3$, b_2	.88^{abcd}	.78^{abcd}	.77^{abcd}	.81^{abc}	.58^{abcd}	1.05^{abcd}	1.97^{abcd}	1.17^{abc}	.73^{abd}	.92^{abd}	1.37^{abd}	1.01^{ab}
	2# CaNO$_3$, b_3	.68^{abcd}	.52^{abcd}	.60^{abcd}	.60^{abc}	.78^{abcd}	1.86^{abcd}	1.72^{abcd}	1.49^{abc}	.73^{abd}	1.19^{abd}	1.16^{abd}	1.03^{ab}
	$(b_1 + b_2 + b_3)/3$	.74^{acd}	.55^{acd}	.57^{acd}	.63^{ac}	1.01^{acd}	1.62^{acd}	1.56^{acd}	1.40^{ac}	.88^{ad}	1.08^{ad}	1.06^{ad}	1.01^{a}
$(a_1 + a_2 + a_3)/3$	0# CaNO$_3$, b_1	.41^{bcd}	.42^{bcd}	.34^{bcd}	.39^{bc}	.89^{bcd}	1.31^{bcd}	.88^{bcd}	1.03^{bc}	.64^{bd}	.86^{bd}	.61^{bd}	.70^{b}
	1# CaNO$_3$, b_2	.64^{bcd}	.62^{bcd}	.42^{bcd}	.63^{bc}	.67^{bcd}	1.41^{bcd}	1.07^{bcd}	1.04^{bc}	.66^{bd}	1.01^{bd}	.75^{bd}	.81^{b}
	2# CaNO$_3$, b_3	.58^{bcd}	.67^{bcd}	.61^{bcd}	.61^{bc}	.57^{bcd}	1.29^{bcd}	1.18^{bcd}	1.03^{bc}	.61^{bd}	.99^{bd}	.90^{bd}	.83^{b}
	$(b_1 + b_2 + b_3)/3$	.54^{cd}	.57^{cd}	.51^{cd}	.54^{c}	.71^{cd}	1.34^{cd}	1.05^{cd}	1.03^{c}	.64^{d}	.95^{d}	.75^{d}	.78

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[1] Superscripts indicate which factors are averaged at a single level; other factors being averaged over all levels.

[2] Each value is a mean of six replications multiplied by the respective level of each factor not shown as a superscript, e. g. a value with a superscript of "ac" is a mean of 54 observations (6 replications x 3 levels of factor B x 3 levels of factor D).

[3] Replications averaged--no statistical analysis made.

APPENDIX TABLE 42

Relation of plant weight of the May 3, 1960, harvest to foliar composition of the May 2, 1960, sampling of the Chrysanthemum 'Arlora'[1]

Treatment[2] and Statistical index	Wgt.	Composition in leaves (dry matter basis) N	P	K	Na	Ca	Mg	Mn
	Gm.	%	%	%	%	%	%	PPM.
Mulch, none	2.98	4.02	.291	3.76	.010	.325	.272	49
Mulch, WS	.52	2.65	.266	3.77	.013	.290	.163	43
Mulch, WC	.94	3.03	.284	3.71	.013	.270	.152	42
F value	**	**	**	N.S.	N.S.	**	**	N.S.
$CaNO_3$, 0#	1.47	3.21	.283	3.83	.012	.293	.196	45
$CaNO_3$, 1#	1.43	3.19	.276	3.61	.010	.303	.200	45
$CaNO_3$, 2#	1.54	3.31	.282	3.80	.013	.288	.191	44
F value	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D.[3] @ .05	.27	.21	.016	.27	.006	.026	.025	7
L.S.D.[3] @ .01	.38	.28	.021	.35	.008	.034	.032	9

[1] Each value other than the L.S.D.'s, is a mean of 18 observations obtained from plants in the respective treatments. (Mulch values are averages of 3 fertilizer levels in 6 replications; fertilizer values are averages of 3 mulch levels in 6 replications.)

[2] Each treatment was a single application, the mulches being applied on June 22-26, 1959, and the $CaNO_3$ fertilizer on September 8, 1959.

[3] L.S.D.'s at .05 and .01 indicate the least differences for significance between any two values with odds of 19:1 and 99:1, respectively.

APPENDIX TABLE 43

Relation of plant weight of the July 8, 1960 harvest to foliar composition of the July 2, 1960, sampling of the Chrysanthemum 'Arlora'.[1]

Treatment[2] and Statistical index	Wgt.	Composition in leaves (dry matter basis)						
		N	P	K	Na	Ca	Mg	Mn
	Gm.	%	%	%	%	%	%	PPM.
Mulch, none	1.82	4.34	.304	5.03	.050	.524	.328	53
Mulch, WS	1.47	4.01	.318	4.68	.052	.392	.214	53
Mulch, WC	2.08	4.39	.333	5.01	.047	.405	.230	51
F value	**	**	**	**	N.S.	**	**	N.S.
CaNO$_3$, 0#	1.63	3.87	.325	4.70	.051	.439	.241	46
CaNO$_3$, 1#	2.16	4.30	.315	4.97	.048	.443	.263	53
CaNO$_3$, 2#	1.58	4.57	.315	5.04	.049	.439	.267	57
F value	**	**	N.S.	**	N.S.	N.S.	*	**
L.S.D.[3] @ .05	.27	.21	.016	.27	.006	.030	.025	7
L.S.D.[3] @ .01	.36	.28	.021	.35	.008	.040	.032	9

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[1] Each value other than the L.S.D.'s, is a mean of 18 observations obtained from plants in the respective treatments. (Mulch values are averages of 3 fertilizer levels in 6 replications; fertilizer values are averages of 3 mulch levels in 6 replications.)

[2] Each treatment was a single application, the mulches being applied on June 22-26, 1959, and the CaNO$_3$ fertilizer on September 8, 1959.

[3] L.S.D.'s at .05 and .01 indicate the least differences for significance between any two values with odds of 19:1 and 99:1, respectively.

APPENDIX TABLE 44

Relation of plant weight of the May 3, 1960, harvest to foliar composition of the May 2, 1960 sampling of the Chrysanthemum 'Chris Columbus'.[1]

Treatment[2] and Statistical index	Wgt.	Composition in leaves (dry matter basis)						
		N	P	K	Na	Ca	Mg	Mn
	Gm.	%	%	%	%	%	%	PPM.
Mulch, none	2.33	3.14	.225	2.58	.010	.300	.221	48
Mulch, WS	.55	2.67	.257	2.07	.010	.298	.172	40
Mulch, WC	.58	3.00	.289	2.39	.011	.278	.163	39
F value	**	**	**	**	N.S.	N.S.	**	N.S.
$CaNO_3$, 0#	1.27	2.96	.259	2.34	.010	.297	.186	42
$CaNO_3$, 1#	1.08	2.90	.257	2.27	.010	.297	.190	41
$CaNO_3$, 2#	1.11	2.95	.255	2.43	.011	.283	.181	44
F value	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D.[3] @ .05	.27	.21	.016	.27	.006	.026	.025	7
L. S. D.[3] @ .01	.38	.28	.021	.35	.008	.034	.032	9

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[1] Each value other than the L.S.D.'s, is a mean of 18 observations obtained from plants in the respective treatments. (Mulch values are averages of 3 fertilizer levels in 6 replications; fertilizer values are averages of 3 mulch levels in 6 replications.)

[2] Each treatment was a single application, the mulches being applied on June 22-26, 1959, and the $CaNO_3$ fertilizer on September 8, 1959.

[3] L.S.D.'s at .05 and .01 indicate the least differences for significance between any two values with odds of 19:1 and 99:1, respectively.

APPENDIX TABLE 45

Relation of plant weight of the July 8, 1960, harvest to foliar composition of the July 2, 1960, sampling of Chrysanthemum 'Chris Columbus'.[1]

Treatment[2] and Statistical index	Wgt.	Composition in leaves (dry matter basis)						
		N	P	K	Na	Ca	Mg	Mn
	Gm.	%	%	%	%	%	%	PPM.
Mulch, none	2.78	3.72	.318	4.50	.039	.508	.343	67
Mulch, WS	2.26	3.68	.365	4.29	.036	.388	.247	66
Mulch, WC	1.96	3.89	.389	4.65	.033	.382	.276	62
F value	**	*	**	**	N.S.	**	**	N.S.
CaNO$_3$, 0#	1.92	3.41	.259	4.27	.042	.444	.276	58
CaNO$_3$, 1#	2.62	3.75	.257	4.49	.033	.407	.273	62
CaNO$_3$, 2#	2.46	4.13	.255	4.68	.032	.427	.291	75
F value	**	**	N.S.	**	**	**	N.S.	**
L.S.D.[3] @ .05	.27	.21	.016	.27	.006	.026	.025	7
L.S.D.[3] @ .01	.38	.28	.021	.35	.008	.034	.032	9

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[1] Each value other than the L.S.D.'s, is a mean of 18 observations obtained from plants in the respective treatments. (Mulch values are averages of 3 fertilizer levels in 6 replications; fertilizer values are averages of 3 mulch levels in 6 replications.)

[2] Each treatment was a single application, the mulches being applied on June 22-26, 1959, and the CaNO$_3$ fertilizer on September 8, 1959.

[3] L.S.D.'s at .05 and .01 indicate the least differences for significance between any two values with odds of 19:1 and 99:1, respectively.

APPENDIX TABLE 46

Relation of the aggregate 1960 linear shoot growth to foliar composition of the Oct. 5, 1960, sampling of the *Feijoa*.

Treatment[2] & Statistical index	Aggregate Length	Composition in leaves (dry matter basis)						
		N	P	K	Na	Ca	Mg	Mn
	cm.	%	%	%	%	%	%	PPM.
Mulch, none	515.83	1.98	.168	.64	.039	1.08	.36	73
Mulch, WS	823.78	1.57	.202	.76	.031	.94	.29	80
Mulch, WC	860.17	1.88	.181	.75	.030	.98	.28	53
F value	**	**	N.S.	**	N.S.	**	**	N.S.
$CaNO_3$, 0#	589.83	1.67	.213	.72	.031	.97	.33	65
$CaNO_3$, 1#	756.28	1.78	.165	.71	.037	1.01	.29	74
$CaNO_3$, 2#	852.67	1.98	.173	.71	.032	1.01	.30	67
F value		**	*	N.S.	N.S.	N.S.	**	N.S.
L.S.D.[3] @ .05		.11	.044	.08	.015	.10	.03	33
L.S.D.[3] @ .01		.15	.059	.11	.020	.13	.04	44

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[1] Each value other than the L.S.D.'s, is a mean of 18 observations obtained from plants in the respective treatments. (Mulch values are averages of 3 fertilizer levels in 6 replications; fertilizer values are averages of 3 mulch levels in 6 replications.)

[2] Each treatment was a single application, the mulches being applied on June 22-26, 1959, and the $CaNO_3$ fertilizer on September 8, 1959.

[3] L.S.D.'s at .05 and .01 indicate the least differences for significance between any two values with odds of 19:1 and 99:1, respectively.

APPENDIX TABLE 47

General change in the concentration of certain foliar nutrients with diminishing concentrations of foliar nitrogen.[1]

Plant	Factor[2]	Sampling date	Nutrient element[3]					
			P	K	Na	Ca	Mg	Mn
'Arlora'	Mulch	5/60	-	0	0	-	-	0
"	"	7/60	(-)	-	0	-	-	0
'Chris Columbus'	"	5/60	(-)	-	0	0	-	0
"	"	7/60	-	-	0	-	-	0
'Arlora'	Fertilizer	5/60	0	0	0	0	0	0
"	"	7/60	0	-	0	0	-	-
'Chris Columbus'	"	5/60	0	0	0	0	0	0
"	"	7/60	0	-	+	-	(-)	-
Feijoa	Mulch	10/60	(+)	+	0	-	-	0
"	"	6/61	(+)	+	0	0	-	-
"	"	7/61	+	+	0	-	-	0
Ligustrum	"	10/60	(+)	+	-	(-)	(-)	+
"	"	6/61	(+)	+	0	-	-	0
"	"	7/61	+	+	0	-	-	0
Feijoa	Fertilizer	10/60	+	0	0	0	-	0
"	"	6/61	0	+	0	0	0	0
"	"	7/61	0	0	0	0	0	0
Ligustrum	"	10/60	0	+	0	-	-	-
"	"	6/61	0	+	0	0	-	0
"	"	7/61	+	+	0	0	-	0

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[1] Increase in foliar concentration of a nutrient element indicated by +; decrease by -; no change by 0. Symbols in paranthesis indicate trends rather than significant changes.

[2] Treatment factor for which all three levels are compared.

[3] Direction of nutrient element change determined from data of the respective master two-way tables of the Appendix.

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