AN ABSTRACT OF THE THESIS OF

James Edward Simon for the degree of Master of Science

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Title: Response of Selected Vegetables to Various Inorganic and Organic Nutrient Sources

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Fertilizer studies at the Oregon State University Vegetable Research Farm were conducted for two years to evaluate the effect of different nutrient sources on yield and selected quality components. Sources of nutrients included sewage sludge, fresh and dried poultry manure, a soybean residue from oil extraction, and several mineral fertilizers. Different rates and time of application were studied to determine optimum response. Most rates were based upon equivalent amounts of total nitrogen. Vegetables grown were bell peppers, cucumbers, radishes, snapbeans, sweet corn, table beets, and tomatoes.

The experimental design included a randomized block design of sixteen treatments and four replications on a Chehalis silty clay loam soil. Soil analysis indicated a reasonably fertile soil.

The organic materials studied, with the exception of the soybean residue, indicated that they produced yields comparable to equivalent rates of mineral fertilizers. The highest yields were obtained with some of the organic materials on many crops. The soybean residue exhibited phytotoxicities depressing plant grown and yield on both direct seeded and transplanted crops. The cause is presently unknown.

Responses to the fertilizer treatments varied from crop to crop. Generally, the main yield response of each crop to nutrient elements

was as follows: Bell peppers, N; cucumbers, N, P and K; radishes, P and K; snapbeans, P; sweet corn, N; table beets, N, P and K; and tomatoes, N.

When high yields were obtained, little difference was found in selected quality components between nutrient sources, as shown in the bell pepper and tomato flavor evaluation and the tomato fruit nutritional analysis.

The chemical analysis of the sewage sludge indicated a low trace element content. Results of the mineral analysis of the radish roots and heavy metal analysis of the sweet corn grain fertilized with sewage sludge compared to an unfertilized control, indicated no trace element and heavy metal accumulation. No strong trends of increased mineral levels from sewage sludge were found from soil and plant tissue analysis.

Response of Selected Vegetables to Various Inorganic and Organic Nutrient Sources

by

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Typed by Illa Atwood for JAMES EDWARD SIMON

DEDICATION

To Robin,

For your interest, patient and special friendship.

1977

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RESPONSE OF SELECTED VEGETABLES TO VARIOUS INORGANIC AND ORGANIC NUTRIENT SOURCES

I. INTRODUCTION

As technology advances and population pressures continue to mount throughout the world, there is a corresponding increase in the amount and diversity of our waste products and a greater pressure to efficiently utilize or dispose of them. Reports from the Federal Government place the production of solid waste in the U.S.A. at 4.3 billion tons in 1969. Six percent is from urban areas, and more than one-third of that is biodegradable (12). Sabey and Hart (115) estimate that a community of 10,000 produces approximately one metric tonne (m. tonne) dry weight of treated sewage sludge per day. While the U.S. population has increased 30 percent since 1950, the accumulation of waste has increased greater than 60 percent (160).

When one considers that about 300×10^6 m. tonnes of dry animal manures, or two billion m. tonnes of fresh manure (85% moisture) are produced annually (45), the magnitude of these wastes become apparent.

Increasing energy pressures, higher fertilizer prices, potential fertilizer shortages, and the realization that the supplies of these raw materials are not infinite, and are in fact subject to social and political factors have made agriculturalists take a closer and more aggressive role in evaluating industrial by-products and waste materials that may have use in agriculture.

The efficient utilization of these wastes, although more ideal than just disposing of them, must be weighed against several factors. These include economic factors, technological feasibility, and adaptability, the inherent properties of the particular waste product, microbial and other forms of contamination, and political-social pressures.

The objective of this research was to investigate and evaluate the response of selected vegetables to various inorganic and organic nutrient sources. Sources of nutrients included sewage sludge, both fresh and dehydrated poultry manure, a soybean residue from oil extraction and several commercial mineral fertilizers. Crops studied were bell peppers, cucumbers, radishes, snap beans, sweet corn, table beets, and tomatoes. This investigation was conducted during the 1975 and 1976 growing seasons, at the Oregon State University Vegetable Research Farm, Corvallis.

With this general objective, several specific questions could be tested:

1. If the availabilities of nutrients are equivalent and no toxicological properties are inherent in the fertilizer materials, then yields between different fertilizer sources will be equivalent.
2. If the above is true, then grades and selected components of quality should also be equal when yields are equal.
3. Are there any mineral elements that would by phytotoxic or detrimental to plant growth immediately or after successive applications to the soil?
4. What is the optimum rate and time of application for these materials in this area?

Some of the above questions were investigated in greater detail than others. It was not the intent nor scope of this research to solve the complex and often confusing problems of "organic vs. inorganic" fertilization and farming methods. Soil and organic matter relationships would need to be studied in more detail and not just nutrient response from fertilizer, as was done here, for this question to be approached. It is hoped that this study can shed additional insight intro nutrient source effects, compliment information on yield response and fertilizer recommendations, phytotoxicities and lead to more basic research questions.

II. REVIEW OF LITERATURE

Factors to Consider in the Evaluation of Nutrient Sources

The many factors that must be considered in the evaluation of nutrient sources can be broadly grouped into three areas: yield, quality and toxicities. Economic factors, though important, will not be included here.

It is not the intention to document the laws of essentiality, the law of the minimum, nor the concept of balance and intensity, as these are well recognized. However, it is valuable to survey the literature regarding crop responses to nutrient sources.

Yield

It has been predicted that by the year 2000, the world population will reach four billion (106). Continued pressures resulting from an increased population seeking food, shelter, and recreational space will put even greater restraints and demands on agriculture and on the necessity of optimizing cultural practices and maintaining high yields. The integral role of fertilizers in increasing yields in food production schemes is partially responsible for allowing the world nations to realize the potential ability in feeding their population and increasing their standard of living. Yield reductions resulting if fertiilizers were not used have been predicted for several U.S.A. regions (49). In the coastal California region including the Salinas Valley, a 48 percent reduction is anticipated. Estimates of yield reductions in food staples would be more disastrous.

Schuphan (120, 121) reported that yields of eight crops, mostly vegetables, dropped by 20 - 56 percent depending on soil type, when fertilized with farmyard manure (FYM) and bacterial activated compost compared to mineral and organo-mineral fertilizers. Peavy and Greig (104) compared feed lot manure and mineral fertilizer on spinach and reported higher yields with mineral fertilizers at identical rates. Other studies have found that the use of mineral fertilizers resulted in higher yields than the specific organic materials, when compared on a wide range of vegetables (23, 124).

Barker (8) reported lower yields from application of dried cow manure compared to both mineral and other organic fertilizers, while no yield difference was observed between the other organic sources (i.e. sewage sludge) and NH_4NO_3 in spinach. Maga, et al. (81) found that spinach yield was similar whether mineral or organically fertilized at similar nitrogen rates. Other studies on a wide range of vegetables have shown similar results (1, 35, 36, 99, 142).

Haworth, Cleaver, and Bray (44) found that FYM gave consistently higher yields than mineral fertilizers and the increases were greater in dry years than in wet. Other studies have reported greater yields with organic fertilizers compared to mineral fertilizers (122).

Williams (159) found that the highest yield and proportion of large heads of cauliflower resulted from fertilization with both mineral fertilizers and cow dung. Many other experiments have shown that superior yields resulted from a combination of organic and mineral fertilizers rather than using either individually (3, 22, 61, 75).

Nutrient Stress

Significant questions can be raised in regard to some of these reports. Many times with manure or other organic materials, factors such as age, stage of decomposition, and storage conditions are not clearly defined. The rates of applications may be given, but no biological basis for comparison between treatments if often found, because no mineral analysis of the materials is reported. Often one cannot tell how their rates were determined. Supplying adequate or excessive amounts of one type of nutrient source and an insufficient amount of another can lead to nutrient imbalances, poor growth and yields, and erroneous conclusions. Reproducible and definable responses can best be achieved by applying sources of fertilizer at equivalent rates of a particular element, such as nitrogen.

Since the nutrient content of many organic products are highly variable with location, year, and season, accurate comparisons at comparable nutrient levels are difficult to obtain.

With some of the above difficulties in mind, Minotti (91) has proposed a classification scheme depicting the relationship found between nutrient concentration applied to the crop and yield. The typical response curve illustrates yield increasing as N or applications of other nutrients increase, and then leveling off at a certain point. Under certain conditions the plateau may continuously rise, but with certain elements, yield would drastically drop at higher rates of application. The curve may shift either way and the breaking points could vary. He characterizes these responses to nutrients into Type I, II, or III, depending on location on the curve, with yield a function of nutrient concentration. Type I includes nutritionally stressed plants. Type II is where optimum yield is realized, and the boundary separating Type I and II is 85 - 90 percent of maximum yield. Nutrient excess, or Type III is twice the boundary of Type I and II.

An understanding of what type or system is operating can make comparisons between studies more meaningful and clarify much of the inconsistency currently found in the literature. Many experiments deal with Type I, where yield potential is not realized, while others do not indicate whether the factors studies are in the deficiency, sub-optimal, optimal, or excessive nutritional range as determined by yield response. Generally, optimum yield has also been associated with high quality, so this curve can also depict the relationship between nutrient concentration and quality, and the interaction of these with yield.

Many times comparisons of different fertilizer treatments are made when they are in different systems and so attempts to elucidate the effects of specific nutrients of different fertilizer sources on yield and quality have often only shown that essential elements are essential.

A major problem in comparing nutrient sources, is the difference of availability, even if equal rates are applied. However, the rate of availability is one of the key characteristics in tailoring and using a certain nutrient source for specific crop needs. The rapid availability of inorganic fertilizers, and the characteristic slow release of nutrients from organic fertilizers can either be advantageous or a drawback depending upon the situation.

Quality

While yield is of primary importance and easily measured, quality is a more rel ative term and is difficult to measure and define. Quality of vegetables has different connotations dependent upon the person and the individual crop. It includes size, shape, appearance, texture, firmness, taste, chemical composition, food value, and keeping quality (84). Freedom from bruises, injury, defects, insects and disease are also important.

Mineral Composition

Many studies have shown that soil, climate and season exert the greatest influence on the mineral composition of plants (9, 31, 54, 74, 98, 112, 128, 130, 137, 146). One of the earlier relationships between soil factors and mineral composition of plants in American agriculture was observed by John Clayton (26) who remarked in 1618:

"The same sort of seed in different earth will produce tobacco much different as to goodness."

Many nutritional diseases are thus caused by deficiencies or excesses of particular minerals in food plants grown in different soil types. This is well recognized with selinium (4), and iodine, (2, 10). Virtanen in 1928 (10), found tuberculosis in Finland to be more prevalent among people who live on acid soils than those on more neutral soils.

As our food sources come from so many different areas, it is quite difficult to trace human dietary deficiencies to a specific soil, yet we can with plant deficiencies and livestock disorders. Varied diets would most likely offset an element deficiency even if it could be traced to the soil. This association may be of greater importance in other parts of the world where the human diet is supplied locally and is not varied. In such agrarian cultures fertilizer usually consists of compost and animal dung and if a particular element is naturally deficient in the soil, these forms of fertilizer could not correct the situation.

Organic matter (74, 128, 130), pH (74, 130), and cation and anion exchange capacity (74), rather than soil texture (6) seem to be the main influencing factors of soil on the mineral composition of the plant. It is well recognized that the availabilities of minerals in the soil change with changes in pH, as well as interactions between elements, and that changes in one element concentration may alter the concentration of another (5, 9, 128, 134). Studies have shown positive correlations between the amount of soil organic matter and certain mineral content in the plant (44, 128, 130, 137). Irrigation has also been reported to positively affect nutrient uptake (128).

The genetic constitution of the plant (2, 146), age (9, 43, 74), and plant parts (9, 10, 27, 74, 128, 130) are also very important.

As far back as 1804, Theodore de Saussure of Switzerland (116), demonstrated that different organs of plants differ in the content and composition of their mineral constituents.

From these studies, it appears that fertilizers are most influential when any essential nutrients are limited. When yield is high and crop performance good, mineral composition in the plant tissue due to fertilizers (aside from excesses) will generally not significantly differ. The small differences that have been reported have generally been inconsistent.

With studies comparing organic and inorganic fertilizers, Beeson (10) and Brandt and Beeson (19) found equal Fe and Cu concentrations of potatoes, whether the soil was fertilized with manure or chemical fertilizer for the 25 years studied. Davidson (27) in 1923, studied American and Chinese rice and found no striking differences in composition between the Chinese rice, grown on soils cropped for thousands of years and fertilized with night soil and the rice grown by the American methods. Other studies also show no significant differences between the effects of fertilizer practices on the mineral composition of the plant (66, 85, 92, 142). Schuphan (120, 121) reported that organically grown foods with FYM had greater K, Ca, P, Fe, and lower Na than when the same vegetables were grown with mineral fertilizers over a 12 year period. Peavy and Greig (104) found that spinach fertilized organically with feedlot manure had higher P, Fe, and Na, while tissue levels of K, Mg, Zn, or Mn showed little or no difference. The mineral fertilizer resulted in higher concentration of N, and Ca was usually higher.

Organic and Vitamin Composition

In this country, vegetables substantially contribute vitamin A and C, thiamine, niacin, iron and roughage or bulk (149), while they may not significantly contribute energy, protein, fat and calcium to our diets. Much of the public awareness with nutrition centers around the organic composition of plants.

Most studies agree that climate, weather, and environmental factors exert the greatest influence on the organic composition of vegetables (43, 53, 67, 74, 98, 138, 146, 149). Lucas (74) includes age as a critical factor and others (146) include cultivar. Undoubtedly, sampling time, the weather prior to harvest, and cultivar exert strong influences. Janes (53) and others (43, 98) found that soil type, cultivar, and fertilizer level exert only small influences in comparison to location and season. Janes also concluded, that while soil moisture has a marked effect on moisture content, it has only minor effects on other constituents.

Lucas (74) found positive correlations of organic matter, cation and anion exchange capacity, and pH, with the concentration of thiamine, carotene, and ether extract, and negative correlations with riboflavin. While the source of N had little effect as N applications increased, the riboflavin content of turnip greens also increased (90).

Leong (69) showed that heavy applications of manure (14 T/A) increased the vitamin B_1 content of barley by 20 - 50 percent compared to mineral fertlizer, yet decreased it in wheat. Vitamin B_{12}, not found in food plants, has been detected in small amounts in turnip greens grown in soil with applied organic matter (4). Maronik (82) in 1964, found that the vitamin B_{12} contained in composts and manures affected vitamin synthesis in corn leaves and kernels.

Carotene concentration can be influenced by seasonal and weekly variation (83, 86), age (53), and cultivar (2, 21). Studies (2, 21, 60, 90, 98, 136, 144) indicate that when the nutritional needs are suboptimal the carotene concentration can be directly related to mineral nutrition. Beeson (10) found that vitamin A was higher when large rather than moderate amounts of chemical fertilizer were applied. The vitamin A of seedling rye, snap beans, and carrots was the same over a 25 year study between different fertilizers sources (FYM, composts, mineral fertilizers (10, 19). Other studies (34, 143) also found no significant differences from fertilizers on the carotene content of selected vegetables.

The amount of illumination on the individual plant part just prior to harvest is a major factor responsible for the ascorbic acid content in that plant part (2, 74, 90, 98, 146, 149). Studies have clearly demonstrated that there are significant differences in vitamin C content from different plant parts, as well as within the specific plant parts (40, 129, 138). Species and cultivar also have a major effect on ascorbic acid content (57, 129, 146). Seasonal variations and locations (20, 57, 74, 98, 111) and diurnal fluctuations (40) are also recognized. Soil temperature and humidity are generally agreed to be of minor influence (2, 57, 146). Some studies of fertilizers per se, have shown relatively little effect on vitamin C (92, 129, 138). However other studies have shown differences in ascorbic acid from fertilizers (57, 87, 94, 98, 113, 119, 138), resulting in increases and decreases of ascorbic acid. Yet, it is unclear whether this was a result of alleviating a nutrient stress, or an indirect effect from additional growth causing a reduction of the surface area of the fruit exposed to light. When harvest was preceded by cloudy weather, N applications did increase the ascorbic acid of turnip greens (90).

The vitamin C content of rye seedlings, potato tubers, snapbeans and carrots was the same over a 25 year period between different organic and inorganic fertilizer sources (10, 19). Luchnik (75) working with cabbage in Russia, found that a combination of both mineral and organic fertilizers gave the highest sugar and vitamin C content.

The plant content of amino acids and other nitrogenous compounds have been shown to be greatly influenced by fertilization practices, especially with N, and by the individual species. There is a positive relationship between the amount of N and other elements (Mo, P) applied and an increase in the seed nitrogen (64), amino acid and protein contents (8, 63, 64, 78, 119, 127, 139).

Schuphan (120) reported that accompanied by a lower total protein content by mineral as opposed to organic fertilization, was an increase in the nutritional value of the protein with potatoes, while the organically grown foods had greater total protein and lower amino acids and nitrates. Barker (8) compared N sources from mineral and several organic sources, including sewage sludge, for plant N content, and found all sources to be equal in total N, except for the feedlot manure, which was substantially lower.

Kattan et al. (58), Moore et al. (93), Wight et al. (158), found no relationship between fertilizer levels and quality of processed tomato products under wide fertilizer ranges. In contrast, Vittum et al. (151) found that extra fertilizer increased the total acidity, soluble solids, total solids, and red coloration, and concluded that the fertilizer level had pronounced effects on tomato quality. Yet Vittum was operating under a Type I system, as his higher fertilizer level significantly increased yields, while the others were not. In Ohio (98) it was found that no difference of total sugars or alcohol insoluble solids resulted from different fertilizer treatments even when yield differences occurred. Excessive N has been shown to depress dry matter and sugar content (119, 136).

Sensory Evaluation

Subjective factors of importance to vegetable quality can be grouped into four components: Appearance, flavor, texture, and physical characteristics.

Appearance

Although in many cases color may be indicative of nutrient content, its importance in quality and marketing is really a reflection of strong consumer preference, although no flavor or nutritional differences may exist.

Fertilization can strongly affect plant color, but this is mainly when the plants are nutritionally stressed. Darkening of foliage can be positively correlated with increasing N rates, and many times excessive N is used to ensure dark, lush, green foliage in leafy green vegetables. Blackmore, et al. (15) reported beet color improvement with higher P rates. Shannon et al. (127) found that higher N rates resulted in decreased soluble solids and red pigment of table beet roots.

Total beet root color is primarily influenced by cultivar (72, 125), location (127), planting and harvesting dates (15, 72), soil moisture (126), age (125), root size (63), soil fertility (15, 127), and temperature (15, 72). Lorenz (72) found an association between poor quality and low sugar, but not between good internal color and sugar. High temperature and abundant foliage can cause a breakdown of anthocyanin pigments, while low temperature results in increased anthocyanin pigments (72).

Generally, the correlation between total carotenoids and color is sufficiently high for predictive purposes (33). Carotenoids are affected by the same factors as carotene and vitamin A. High K and low N, and low K, have resulted in poorer carrot color (73).

The development of yellow color in tomato fruit is due to the synthesis of carotenoid pigments, principally beta-carotene, while the red color is due to lycopene, a xanthophyll pigment. Temperature (117), light (95), and the cultivar are the main influences.

Vittum (151) reported that the red hue of tomatoes as measured by the higher a/b ratios with the Hunter Color Difference meter, could be improved by higher fertility rates. Lorenz (73) stated that N fertilizer had no effect on color.

Ozbun et al. (100) was unable to correlate K fertilizer with carotenoids in tomato fruit. Trudel and Ozbun (144) generally found that most of the carotenoids, lycopene in particular, increased with K concentration and β-carotene decreased in tomatoes.

Studies in Ohio (98) showed that there was no effect of different fertilizer treatments on the intensity of color in tomatoes, as measured by the Hunter Color Difference meter and subjective evaluations. Mok compared organically vs. inorganically grown foods and concluded that inorganic baked potatoes were preferred for color and appearance (92). Maga et al. (81) found that color of spinach was darkened by higher fertilizer rates (420 kg/haN), by organic fertilization as compared to mineral fertilizer rate at both N rates, and especially by late applications of N fertilizer.

Flavor or Taste

Flavor is difficult to define. While one can measure the sugar: acid ratio which affects flavor of tomato, whether the tomato has an acceptable or superior flavor differs with people and their cultural backgrounds.

Tomato and snapbean flavors result from a blend of about 40 volatile compounds (140). Tomato flavor is also affected by the relative amounts and balance of sugars and acids. Acid concentration changes during fruit development (141) and is dependent upon the cultivar (141). Fertilizers can then contribute to tomato flavor at least between cultivars (149) by influencing the acidity or sugar:acid ratio. Fertilizers affect sugar accumulation and taste indirectly through their effect on the growth rate, protein synthesis, and leaf area. In New York, doubling the N-P-K fertilizer rate significantly increased total acid or tritratable acidity, and decreased the sugar: acid ratio (151). Kattan et al. (58) found that tomatoes grown with higher P rate had a higher sugar content, as measured by soluble solids in the raw juice. Lee and Sayre (68) found that a K deficiency decreased acidity, whereas a moisture stress increased the acidity.

Sucrose, the main storage sugar in table beets, has been used as a flavor index. It and soluble solids vary with cultivar, age, temperature, soil fertility, location, planting, and harvest dates (72, 125). High N rates (127) and irrigation (126) have lowered both sucrose and soluble solids.

There have been several studies comparing effects of nutrient sources on taste. Blackmore et al. (15) compared beets grown under different fertilizer regimes through taste panels and determined that the best flavored beets came from plots receiving high P and K levels, while the check plot and the plot with only N, resulted in a sweet initial taste followed by a bitter after-taste.

Maga et al. (81) grew spinach with $(NH_4)SO_4$ or dried blood and conducted taste panel evaluations. While differences between raw or cooked, and control and highest fertilizer rate were detected, differences between nutrient sources were not detected. Other studies comparing organically vs. inorganically grown food failed to show differences in organoleptic tests (120, 142).

Texture

Kramer (65) defines texture as:

> That one of the three primary sensory properties (others: flavor, appearance) of foods which relates entirely (or in addition to the other primary properties) to the sense of touch or feel and is therefore at least potentially capable of precise measurement

> objectively by mechanical means in units of mass or force. The only drawback in indirect sensory measurement is that it is only accurate to the extent that it is analagous to the human sensory response.

Pre and post harvest conditions are important factors influencing texture as it constantly changes with temperature, growth and maturity, moisture, and soil fertility. Roy (113) found that delaying radish harvest increased pithiness and pungency. Pithiness was also increased by high N at the later harvest. Pyo (109) found that shading the radish plant reduced both root size and pithiness. Singh and Cheema (131) reported that very high P levels within the radish plant advanced maturity while high N and more frequent irrigation delayed it. Haigiya and Takagi (42) concluded that materials which reduced pithiness (i.e., NAA, foliar spray of complete fertilizer) did so by an indirect improvement in the nutrient supply to the roots. Pyo (109) also concluded that pithiness in the field is not related to insufficient carbohydrate production but may be the result of intercellular competition for nutrients in the roots.

Soil fertility was found to influence the crude fiber content of table beet roots. When grown in K deficient conditions, the roots are much more fibrous and woody (15). Patton (103) concluded that the fertilizer status was important to the tenderness of table beet roots. Sistrunk and Bradley (133) found that the texture of canned beets was influenced by cultivar, planting and harvest dates, and irrigation interval. Tenderness in other crops is also influenced by the N level (149).

Turgidity and firmness are closely related to water stress immediately prior to harvest and the post harvest conditions. Vittum (149) remarked that fertilizer per se has little effect on these two textural factors. Turgidity can also be affected by loss of starch from respiration (48).

Physical Characteristics

Fertilizers have an influence in allowing the genetic potential for size of the individual species to be fully expressed. Cultural practices are also important, and plant population and soil moisture can exert greater influences than fertility on the size of the harvested portion (149). High fertility can result in more ears or fruit per plant, which may be equal to or smaller than the older ones (150, 152, 153). Low fertility may result in fewer and smaller fruit per plant or fewer fruit per plant of greater weight.

Fertilizers can influence the shape and appearance of certain crops especially when nutritionally stressed.

Shape is also influenced by the cultivar, season, (79, 89), and with root crops, soil characteristics. Carrots grown on organic soils tend to be rougher and coarser, and long slender fresh market carrots require deep, light, well-drained soils. Undecayed organic matter, rocks, and soil clods can adversely affect root shape by injury to the growing tap root and subsequent branching. Avall (7) found that radish roots tended to become more conical under unfavorable growing conditions. Raleigh (110), in 1942, reported that fresh manure applied immediately before planting can result in lateral branching, making roots unmarketable. The causal agent was found in the liquid portion of the manure, and similar responses were observed with uric acid, urea, and ammonium carbonate.

Cucumber length:diameter ratio is influenced by temperature and fertility. Plants with high N or plants exposed to low night temperature have an increased L:D ratio (89). Seaton (123) found that while abnormal shape of cucumber fruits can be caused by carbohydrate starvation and unfavorable growing conditions, incomplete or lack of fertilization is usually the main cause. Short curved pickling cucumbers resulting from K deficiency have also been reported (17).

Defects

Both the cause and correction of physical defects is largely influenced by fertilizers and growing conditions. Poor tip fill in corn, although commonly due to incomplete pollination, can be caused by P deficiency. Canker or internal black spot in table beets caused by B deficiency can be corrected by additional B. Excessive fertilization can also cause defects. Examples include: bursting of cabbage head from excessive N, cracked or hollow-cored radishes, and excessive fruit rotting.

Toxicities

Fertilizers can be associated with pollution and toxicity problems, including nitrate in plant tissue or in the ground water (dependent upon level and form on nitrogen applied), salt injury, salinity, ammonium toxicity, and changes in the pH. Excessive soluble salts from K, Ca, and Mg, and high salinity have been the main cause of depressed yields of crops with higher application rates of poultry manure (18). Ammonia toxicity, resulting in reduced emergence and stand establishment has also been reported (76).

Organic materials may also supply trace elements in high enough concentrations to be either phytotoxic or accumulate in the human food chain.

Work by Lunt (77), and Berrow and Webber (11, 155) established that trace elements in sewage sludge are often in large enough quantities to be toxic to the plant and detrimental to soil productivity. Although sludges vary in mineral content, generally Zn, Cd, Ni, Cu, Pb, and Cr are commonly associated with toxicity problems. Toxicity can also result from Cu, Zn, Ni, or Mn induced Fe deficiency (41, 77).

The availability of trace elements in sludge is dependent on the nature and application rate of the sludge, pH, amount of fixation of metals and release by organic matter (56), and the native soil metals. Metals can be so strongly bound and fixed by the organic matter and soil, that although retained in the soil for many years, they may not be available in toxic amounts to plants. Once heavy metal accumulates to the point of suppressing plant growth, it is quite difficult to eliminate. The addition of organic matter and raising the soil pH may be partial solutions.

There is a relationship between Zn and Cd. Both can be toxic when available at high levels. Cadmium, a nonessential plant nutrient, can build up in the human food chain, and should not exceed 2 kg/ha of total Cd applied per year (51), or >70.5 percent of the Zn concentration. Some sludges have as high as 1500 ppm Cd (11). Although Cd may be restricted in its movement within plants, as >50 percent of Cd taken up is retained in most roots (55), it is removed from the soil in proportion to the amount in the soil (14), and influenced by the species (110). Other workers (16, 41) report Cd as readily translocatable. Increased Zn uptake with higher Cd uptake has been noted in solution culture (145) but not in the soil, possibly due to a more continuous immobilization of Cd (28). Bingham et al. (14) found that Zn concentrations of plant tissues are significantly reduced at higher Cd treatment rates.

Zn, commonly found in high concentrations (3,000 ppm dry wt.), regardless of amount of industrial effluent, is thought to come from galvanized metal, rainwater, pharmaceuticals, cosmetics, and rubber (11). Zinc toxicity is often found when the acetic-acid soluble Zn level reaches about 100 ppm in the soil (11), and with a low Cd concentration with respect to Zn concentration (51).

III. MATERIALS AND METHODS

General

Two field experiments were conducted during the 1975 and 1976 seasons at the Oregon State University Vegetable Research Farm, Corvallis. Both experiments, although in different areas, were on a Chehalis silty clay loam soil. Land preparation included plowing, disking, and harrowing prior to planting and fertilizing. Weeds were controlled manually to ensure no interaction between fertilizer and herbicide and because the diversity of plant genotypes would not allow effective control with any one herbicide. Diazinon was applied for insect control when necessary. To control symphylans (*Scutigerella immaculata* (Newport)), dyfonate was applied as a preplant soil treatment to the 1976 experimental site. Overhead irrigation was applied as needed at weekly to ten day intervals.

Plant growth was measured by yield and dry matter accumulation of above ground plant parts (fresh weight of plants, number of fruit or roots, including portion of marketable ones). Harvesting was done manually from the middle of plots to avoid border effects. Phytotoxic responses as well as differences in selected qualitative aspects were recorded.

Sixteen fertilizer treatments were replicated four times in a randomized block design (RBD). There was some variation in fertilizer materials and crops used each year, although some were common to both years.

Experiment - 1975

In 1975, bell peppers (*Capsicum annum*), cucumbers (*Cucumis sativus*), radishes (*Raphanus sativus*), table beets (*Beta vulgaris* L.), and tomatoes (Lycopersicon esculentum) were grown. All crops except the tomatoes were grown in single rows (east-west) in each of the 64 plots. Each plot was 5.2 x 9.5 meters. The tomatoes in a different location were also grown in single rows in each of 64 plots, each 1.8 x 9.1 meters. Table 1 lists the fertilizer treatments, sources of materials, and the time and rates of application. Rates of the various treatments were based on comparable amounts of total nitrogen from inorganic and organic sources. Appendix A illustrates the field layout and row spacing for each crop. Between May 20 and May 27, all fertilizer material was applied at the designated preplant rates by hand broadcasting or by a lawn fertilizer spreader. The organic materials were applied during the early daylight hours to ensure minimum drift from the wind. All materials were then rototilled 10-13 cm. into the soil prior to planting. Sidedressed fertilizer on the selected treatments was applied on July 17, between rows about 15 cm. from the plants. Observations or rating scores were recorded for each crop for plant health, foliage color, phytotoxicity, and the degree of insect and disease damage.

Experiment - 1976

Vegetables grown in 1976 were cucumbers, radishes, snapbeans (Phaseolus vulgaris), sweet corn (Zea mays var. rugosa), table beets, and tomatoes. The layout of the six vegetables, each in single rows (east-west) was identical in all 64 plots. Table 2 lists the fertilizer treatments, sources of materials, and application rates. Appendix B illustrates the field layout and crop spacing. Between 5-27 and 6-17, all fertilizer material was applied preplant by broadcasting and then rototilling into the upper 10-13 cm. of soil. The bulk chicken manure (B.C.M.) was from current days wastes of commercial Shaefer and Babcox layers. The B.C.M. was stored

Table 1. Fertilizer Treatments, 1975

TRT No.	Treatment	Rate kg/Nha Preplant	Rate kg/Nha Sidedress	Actual Elemental Application: Preplant (kg/Ha) N-P-K	Sidedress (kg/Ha) N-P-K	Preplant (Lbs/Acre) N-P-K	Sidedress (Lbs/Acre) N-P-K
1	15-20-14[1] H	146	0	146-86-113	---	131-76-101	---
2	18-24-6[2] H	146	0	145-85-40	---	130-76-36	---
3	18-24-6[3] HS	146	49	148-85-40	49-4-17	130-76-36	44-4-15
4	Org A.C.M.[4] L	98	0	101-58-58	---	91-51-52	---
5	Org A.C.M. LS	98	49	101-58-58	51-29-29	91-51-52	45-26-26
6	Org A.C.M. H	146	0	152-86-87	---	136-77-78	---
7	Org A.C.M. HS	146	49	152-86-87	51-29-29	136-77-78	45-26-26
8	OrgB. Soybits[5] L	98	0	110-11-28	---	99-10-25	---
9	OrbB. Soybits LS	98	49	110-11-28	55-6-14	99-10-25	49-5-13
10	OrgB. Soybits H	146	0	164-17-42	---	146-15-38	---
11	OrgB. Soybits HS	146	49	164-17-42	55-6-14	146-15-38	---
12	N-P-K[6] H	146	0	146-74-75	---	131-66-67	---
13	Control	0	0	---	---	---	---
14	N H	146	0	146-0-0	---	131-0-0	---
15	N-P-K HS	146	49	146-74-75	49-25-25	131-66-67	44-22-22
16	N-P-K 2S	0	98	---	98-50-50	---	87-44-44

1. Code name F-7606
2. Code name F-5314
3. For sidedress application, a 22-4-9 fertilizer was substituted.
4. Org A.C.M.: Dehydrated poultry manure
5. Org B. Soybits: Soybean residue from oil extraction
6. Sources of elements NH_4NO_3 (34-0-0), triple super phosphate (0-45-0), and muriate of potash (0-0-60).
7. Materials for treatments, TI - TII, were supplied by O. M. Scott and Sons Co.
   L: Low rate; H: High rate; S: Sidedress.

Table 2. Fertilizer Treatments, 1976

TRT No.	Treatment	Rate kgN/ha	Actual Elemental Application Preplant (kg/ha) N-P-K	Actual Elemental Application Preplant (Lbs/Acre) N-P-K
1	Control	0	---	---
2	15-20-15[1] L	146	146-86-122	131-77-109
3	15-20-15 H	293	293-172-244	261-158-218
4	18-24-6[2] L	146	146-86-41	131-77-36
5	18-24-6 H	293	293-172-81	261-154-73
6	Org A.C.M.[3] L	146	149-70-67	133-63-60
7	Org A.C.M. H	293	299-141-135	267-126-120
8	N[5] L	146	146-0-0	131-0-0
9	N-P L	146	146-74-0	131-66-0
10	N-P-K L	146	146-74-75	131-66-67
11	P-K	0	0-74-75	0-66-67
12	N-P-K H	293	293-74-75	261-66-67
13	B.C.M.[6] L	146	328-169-143	293-151-127
14	B.C.M. H	293	656-337-285	586-301-255
15	Sewage Sludge[7] H	293	474-98-26	423-88-23
16	Control	0	---	---

1. Code name F-7817.
2. Code name F-5314.
3. Org A.C.M.: Dehydrated chicken manure.
4. Materials for treatments, T2-T7, were supplied by O. M. Scott and Sons Co.
5. Sources included Ammonium nitrate (34-0-0), triple super phosphate (0-45-0), and muriate of potash (0-0-60).
6. B.C.M.: Bulk or fresh poultry manure. From Willamette Egg Farms, Molalla, Oregon.
7. Sewage sludge supplied by Biogro, City of Salem, Willow Lake Sewage Treatment Plant, Salem, Oregon.

   Total Nitrogen: 474 kg/ha; NH_3 - N= 122 kg/ha.

outside between layers of black plastic to minimize volatilization and leaching losses until applied manually. The sewage sludge was applied with a machine designed by Dr. Willrich, Agricultural Engineering Department, Oregon State University, through a 4.6 meter boom manually moved to cover the area. Sludge was applied to the boom via a hose from a trailer tank (1, 140 liter capacity) that accurately measured the volume of sludge entering the hose by a free-floating centimeter-measuring 'dipstick.' By using a conversion factor of kg. of nitrogen (N)/cm. of dipstick movement, sludge could be metered on the basis of N content.

To minimize settling and uneven dispersion of liquids:solids, a diaphragm pump was used in the sewage sludge truck (9, 120 liter capacity) to ensure adequate mixing. A 0.6 x 1.8 meter screen was used to filter the sludge from the truck into two waiting stock tanks from which the trailer tank was filled. The sludge was sampled for analysis from each trailer-tank load.

Analysis of Soil Samples

Soil samples were taken at a 0-15 cm. depth with a soil probe. Sampling was done toward the end of each season. Five probes per plot were taken, bulked together (20/treatment) and stored in plastic bags to avoid boron contamination. Analyses of pH, major elements, and selected minor elements were conducted by the Soil Testing Laboratory, O.S.U., by the methods described by Kauffman and Gardner (59).

Analysis of Organic Fertilizers

Chemical analyses were made on all organic fertilizers, and fertilizer rates were based upon the nitrogen content.

For most of the organics (soybits, bulk and dried poultry manure), samples were oven-dried, ground, and analyzed for their nutrient elements. Nutrient status was determined by direct-reading spectrograph (24), except that N was measured using an automated Kjeldahl technique (118). These analyses were conducted by the Plant Analysis Laboratory, Horticulture Department, O.S.U. The sewage sludge was analyzed by the O.S.U. Soil Science Department through the cooperation of Dr. V. Volk.

Individual Vegetable Crops

Bell Peppers, 1975

Sweet bell peppers, cv. 'Early Yollow Wonder L.' were transplanted to the field, 6-3. Twelve were planted at 0.8 meter within row spacing and 0.9 meter between rows. Ten representative plants were harvested three times: 57, 74, and 79 days from transplanting (7-30, 9-16, 17; 9-22, 23). The first harvest (H1), was to remove mature fruit that would be detrimental to further growth and flowering and to measure early bearing. Weight and number were obtained at each harvest for green fruit with four lobes (fancy or stuffers), green fruit without four lobes, red fruit, and culls. Fruit < 6.4 cm. length are not acceptable as U.S. #1 (147) and were grouped with the culls. During the last harvest, all peppers >2.54 cm. and < 6.4 cm. in length, were considered potential yield and were placed in a separate category. Yield calculations were based on 0.9 meter spacing between rows.

Visual and field observations were recorded at four different dates (7-14, 15; 7-28; 8-19; 9-10). Wall thickness, an important characteristic in bell pepper quality and shipping ability, and an index of maturity, was also measured. Five green peppers with four lobes of the same size were randomly sampled from several of the fertilizer treatments. Using a 4.8 mm. cork borer, four probes were made in the same position in each pepper. The probe was taken at the middle section of uniform wall area and immediately weighed.

Cucumbers, 1975

On June 2, cucumbers, cv. 'Pioneer,' were seeded with a belt planter and later plants were thinned to approximately 23 cm. spacing. Final stands were recorded. Visual field observations on plant growth were recorded at four dates (7-15; 7-30; 8-19; 9-10).

Every plant in each plot was harvested on each of the four harvest dates. After the initial harvest (8-13, 14), the subsequent harvests were about one week apart (8-20; 8-25; 9-28). Where the entire field couldn't be harvested in one day, two replications were harvested per day. All fruit $\geq$ 3.8 cm. length was harvested and graded into different sizes; #1, #2, #3 (4 cm. x 1.5 cm. to 8 cm. x 2.5 cm; 8 cm. x 2.5 cm. to 12 cm. x 3.5 cm.; 12 cm. x 3.5 cm. to 13.5 cm. x 4.5 cm., respectively), OS (oversize), and MS (misshapen, including culls and nubbins). Sizes were from the official chart of Pickle Packers International, Inc. Straight Pickles from Steinfelds Packing Co., Portland, Oregon. Weight of each size was recorded as well as the number of fruit of OS and MS of each harvest. Yield calculations were based upon a 2.4 meter spacing between rows.

Cucumber fruit were also scored for the condition of their seed cavity. Any placental separation from the pericarp, visible at harvest for 'Pioneer' or any other pickling type, would indicate that further deteriorating from the brining process would occur, reducing the quality of the pickle. Five random cucumbers from each #2, #3, and OS grades from every plot were evaluated to determine if any separation was visible.

Cucumbers, 1976

Cold weather, wet soils, and pathological problems resulted in such poor emergence and stands that two replications were eliminated and the results of the other two are questionable due to differences in within row spacing. Final stands were recorded after thinning to 23 cm. apart where possible. Further information can be found in Appendix C.

Radishes, 1975 - 76

Radishes, cv. 'Comet,' a red globular spring type, were planted with a Planet Junior Seeder at about 28 seeds/ 0.3 meter, at a depth of 19 mm. In 1975, plant growth observations were recorded on 7-3, the stand rating on 6-17, and plant height ratings on 7-14. In 1975, 3.1 meters and in 1976, 4.6 meters were harvexted from plot rows of 9.5 and 10.7 meters, respectively. Radishes were harvested 33 days after planting (5-31 to 7-3) in 1975, and 37 and 39 days (6-22 to 7-28, 30) in 1976. In 1975, the plots were harvested prior to sidedressing other crops.

Roots were separated into two sides (< and > 2.54 cm.). Yield calculations were based upon a 0.9 and 1.1 meter between row spacing. Roots were also observed for their visual quality and whole plant weight and root weight were recorded.

Radishes, 1975

Ten random samples of marketable roots (5 < 2.54 cm. and 5> 2.54 cm.) were measured for crown size. The marketable roots of

>2.54 cm. to 5.1 cm., of several treatments were sampled for pH, soluble solids, and specific gravity. These tests were performed through 7-9, 10 and 16. Procedures are listed in Appendix I.

Determination of selected textural characteristics was also made for several of the treatments. The shear press instrument was used to measure the shear-press maximum peak force (Fm), work (W), and the force increase rate (FIR). These measurements are associated with the textural components of firmness, turgidity, toughness, and fibrousness of the product.

The radishes evaluated for texture were of similar size, diameter, and shape, with diameters of marketable roots ranging from 2.54 cm. to 5.1 cm. The measurements were made by a Allo-Kramer Shear Press, Model 5-2HE, equipped with a single cell. The downward movement of the ram speed was twenty seconds and 375 psi and the recorder chart advanced 5.72 cm. each downward movement. The test ring had a capacity of 2268 kg, and a range of 20 was used. The instrument was set to a full scale of 454, 000 kgs (1, 000 lbs.).

Roots were trimmed directly below the crown and above the taproot. They were then placed into a modified commercial carrot slicer for uniform slicing (3.2 cm.). One hundred gram samples were carefully placed into the cell to ensure equal placement and sample size with every treatment. Three replicates of each treatment were evaluated on 7-10, and a replicate of each treatment was tested on 7-11. The roots were kept in cold storage (0.6° C - 1.7° C) after harvest.

The methodology of measurement used here, described by Mackey, et al. (80), has been modified slightly as indicated below.

1. The Fm was directly read from the graph and is expressed in kgs. FM = maximum peak height of graph in cm. x kg. equivalent/chart division.

2. Work was determined by using a planimeter from Keuffel & Esser, Co. W = force rate (force/cm.) x area (under the curve in cm.^{2}). In this experiment the force rate = 174 kg-cm. Work is expressed in cm-kgs.
3. The angle of force increase rate (< FIR) was determined by passing a line through the compressibility portion of the graph to express the rate of increase or compression. The angle of the line was then read directly as degrees.
4. The force increase rate (FIR) is associated with the <FIR. It is determined by moving a defined distance from the angle and measuring the height directly from that point, therefore expressed in kgs. In this experiment one cm. was used. Not enough samples were available to correlate the Shear-press values with organoleptic evaluations.

Radishes, 1976

Radish roots of both the control and sewage sludge treatments were sampled for their nutrient content as a composite of all the replications for a treatment. Root size ranged 2.54 to 5.1 cm. in diameter. Nutrient content was determined by the same method described for organic fertilizer materials.

Snap Beans, 1976

Snap beans, cv. 'Oregon 1604' were planted on 6-23, with a belt planter, 4.5 cm. apart with 240 seeds/plot. Percent emergence was determined between 7-21 and 7-22. Date of 50 percent open bloom was on 8-5-76. Harvest was 64 days from planting (8-26), from 4.6 meters of a 10.7 meter row, spaced 0.9 meters apart. Total yield was recorded for each plot, and pods from two replications were bulked and graded into sieve sizes 1-7 with a commercial bean grader. The results are the means of two replications per treatment.

Five representative plants were sampled at harvest at the same fixed distance within every plot. Determinations were made on plant height (soil line to top leaf), plant weight, pod weight per plant, stem and foliage weight and the leaf area index (L. A. I.). Leaves were stripped from the plants and placed fully opened and flattened through a recording device measuring the leaf area in cm^2. The leaf area was calculated as follows:

$$\text{L. A. I.} = \frac{\text{leaf area } (cm^2)}{\text{ground space } (cm^2) \text{ occupied by the plants}}$$

Sweet Corn, 1976

Seventy seeds per plot of sweet corn, cv. 'Jubilee,' were sown about 15 cm. apart by a belt planter on June 23. Percent emergence and silking date were recorded. Plant height was measured at mid-season (8-20) and late (10-14) in the season.

Harvest was from 7.6 meters of the 10.7 meter plot at 111 and 113 days from planting (10-12, 14). The ears were weighed, husked, and separated into acceptable ears and culls. Yield weight and ear number were based on 1.2 meter spacing between rows. Percent cutoff and percent moisture were obtained from 15 graded acceptable husked ears per plot (30 ears per treatment) for each of the two replications harvested each day.

Kernels were removed by a commercial cutter. Percent moisture was determined by oven drying two samples of about 450 grams from each treatment and is reported as the mean of two samples. At both harvests, grading was completed the same day and the samples were then held in plastic bags in cold storage (4.4° C) until the following morning when the percent cut-off and moisture were determined.

Samples of dried kernels from the control and sewage sludge treatments were analyzed for lead, cadmium, and mercury by the Agricultural Chemistry Department, O. S. U. Appendix H contains the methods of analysis.

Table Beets, 1975-76

Table beets, cv. 'Detroit Dark Red' (Morse strain) were planted with a Planet Junior Seeder at $\simeq$ 22 seeds per 0.3 meter. Visual field observations were recorded at two separate dates (7-18, 7-30), in 1975. Table beets were grown for 68 days (5-31 to 8-7) in 1975, and for 82 days (6-23 to 9-13) in 1976. Harvest was from 4.6 meters of row. Row lengths were 9.5 and 10.7 meters in 1975 and 1976, respectively. During both years, whole plant weight was recorded and after topping roots were graded into the following sizes: < 2.54 cm.; 2.54 - 3.8 cm.; 3.8 - 5.1 cm.; 5.1 - 6.4 cm.; and >6.4 cm. Weights (1975, 1976) and number of roots (1976) of each size were recorded. Roots were also scored for other quality characteristics in 1975. Presence of canker or internal black spot in beet roots, caused by boron deficiency was noted. Roots (2.5 - 5.1 cm. in diameter) were scored for shape and configuration, excessive rootlet formation, number of multiple crowns, crown sizes, and for visual internal color.

Tomatoes, 1975 - 76

Tomatoes, cv. 'Willamette,' were transplanted to the field on June 5, 1975, and on June 17, 1976. In both years, 12 plants were transplanted in each plot at 0.8 meter apart and 1.8 meters between rows. Plant growth observations were made on four dates (7-14, 8-1; 8-19; 9-12) in 1975.

Harvest data were from ten plants in 1975, and six in 1976.

Tomatoes, 1975

The first flower clusters were hand-pinched on 6-18. Plants were harvested four times; 90, 111, 119, and 135 days from transplanting (9-3; 9-24; 10-2; 10-18). Ripe fruit and culls were harvested during the first three harvest dates, but the final harvest included all fruit and culls. The fruit were separated into the following sizes: < 3.8 cm.; 3.8 - 5.1 cm.; 5.1 - 6.4 cm.; 6.4 - 7.6 cm.; and >7.6 cm. Weight and number of fruit for each size were recorded, except for the last harvest, when only total weights and number of culls were recorded.

Fruit from several treatments were analyzed for several nutritional components. Samples of marketable tomatoes of two size grades (5.1 - 6.4 cm.; 6.4 - 7.6 cm.) were measured for pH, percent moisture, calcium, phosphorus, iron, and ascorbic acid. The pH and percent moisture were performed by Dr. Z. A. Holmes, Department of Foods and Nutrition, O.S.U., by direct reading from the pH meter and oven drying. The mineral analyses were conducted by the Department of Agricultural Chemistry, O.S.U. The ascorbic acid, measured as fresh and solids, were assayed in triplicate by Dr. Miller, Department of Foods and Nutrition, O.S.U. Ascorbic acid was determined by the 2, 4-dinitrophenylhydrazine method, measuring both dehydroascorbic acid and reduced ascorbic acid.

Tomatoes, 1976

Tomatoes were harvested three times; 96, 112, 124 and 126, days from planting (9-21; 10-7; 10-19, 21). Only at the first harvest (H1) were the fruit separated into the following size grades: Culls, < 3.8 cm.; 3.8 - 7.6 cm.; and >7.6 cm. and weight and number of fruit were recorded. For H2 and H3, total fruit and marketable fruit number and weight were recorded. At H3, fruits were separated into physiologically mature and immature fruit. The immature fruit is expressed as potential yield. Fruits were harvested at H1 in the ripe stage, H2 in the pink stage and at H3 all fruit >2.54 cm. Cull weights were not recorded except at H1.

Plant weight was determined after final harvest by cutting the plants at the soil line and recording the weight. Every plant in the experiment was sampled and results are on a fresh weight basis.

Flavor Evaluation of Bell Peppers and Tomatoes, 1975

Peppers and tomatoes from four treatments (control, Org. A.C.M. (L.S.), Org. B. Soybits (LS), and N-P-K (HS)) were evaluated for flavor by a taste panel of 25 judges who were not screened for tasting acuity, but were experienced in this type of flavor evaluation. Evaluations and methodology were conducted and described by Mrs. Louis A. McGill, In Charge, Sensory Evaluation Program, Department of Food Science and Technology, O.S.U.

The fresh fruit was stored at 4.4^{o} C immediately after harvest. Fancy, four lobed fruit of peppers of similar size and shape were chosen to minimize any sampling error. Ten pounds of the control and five pounds of the other treatments were sampled. Six to eight peppers of each treatment were then washed, halved, and then diced into approximately 6.4 mm. pieces and thoroughly mixed.

Marketable tomato fruits of 5.1 - 6.4 cm. diameter were sampled the same as with the peppers. The fruit was washed, blanched for one minute, peeled, diced gently into approximately 13 mm. sections, and then mixed to get a uniform serving sample.

Two replicate tests were conducted using the same procedure for each vegetable. Fifty-seven gram portions from each sample were served into small paper cups, the cups randomly placed in a tray and served to judges in individual testing booths.

Each tray contained five sample cups. The control treatment was served both as a marked reference (REF) and as an unknown with the other treatments. The unknowns were coded with three digit numbers, to prevent any bias toward single and double digit numbers. The judges were asked to score the three digit coded samples in direct relation to the reference sample from 7, same flavor, to 1, extremely different flavor, and then score the desirability from 7, very desirable, to 1, very undesirable. A sample ballot of the Reference-Difference and Overall Desirability tests used is in Appendix F.

Plant Analysis

Each year, plant analyses were conducted to determine the nutrient status of selected vegetables. In 1975, cucumbers, table beets, and tomatoes were sampled and snap beans and tomatoes were sampled in 1976. Recently matured fully expanded leaves with petioles were sampled. For cucumbers, table beets, and tomatoes, five leaves and petioles per plot and fifteen leaves and petioles of snap beans were randomly taken per plot. Cucumbers were sampled twice, both early and late in the season, while other crops were sampled once. Snap beans were sampled two weeks after full bloom, tables beets and tomatoes were sampled at midseason. Samples of each of the four replications of each treatment were bulked together and analyzed as one. The samples were oven-dried, ground, and analyzed for their nutrient elements by the same methods used to analyze the organic fertilizers.

Statistical Analysis

An analysis of variance was used with replications, treatments, and replication X treatment contributing to the degrees of freedom. The replication X treatment being the error term, usually with 45 df. L. S. D. .01 was chosen as the minimum limit of acceptable significant differences with all the yield and grading data. An L. S. D. .05 was accepted as the minimum with the flavor evaluation of bell peppers and tomatoes and the radish texture evaluations.

The experiment in 1976 was designed to accommodate a second sewage sludge rate, but because of short supply the plots were not used and designated as control (T16). Since there already was a control (T1), only T1 will be discussed in the results and discussion to avoid confusion.

IV. RESULTS AND DISCUSSION

Soil Analysis, 1975-1976

Soil samples from each replication of a treatment were composited and analyzed together, hence, no statistical analyses were conducted.

In 1975, there were no marked differences in soil analyses from the fertilizer applications in Area 1 (Table 3). Analysis of the control indicated a fairly fertile soil.

Samples from Area 2, where tomatoes were located, also indicated no marked differences from the addition of fertilizers, although there is an indication that soil P and K levels were slightly higher due to applications of these elements. The greater K supplied however is not clearly associated with the greater K soil levels in comparison to other treatments.

Area 2 was higher in soil P and K levels while Area 1 was higher in total N. Soil N was not associated with the actual amount of N applied in the fertilizers.

Calcium and Mg levels were similar and no association with pH and treatments could be found.

At the different locations in 1976, soil analyses indicated lower values for P, Ca, Mg, and N than in 1975 (Table 4). Soil N was again not associated with the amount of N applied. Application of higher rates of P and K fertilizers generally raised the soil P and K levels.

Soil levels of Zn, Fe, and Cu did not appear to be related to the amount applied. Sewage sludge resulted in lower levels of Zn, Fe, and Cu than the control.

Soil tests were only taken once during each season. To better evaluate long term effects on soil fertility from different rates and

Table 3. Effect of Fertilizer Treatment on the Soil Analysis, 1975.

TRT No.	Treatment	pH	P (ppm)	Extractable cation K (ppm)	Ca (meq/100g)	Mg (meq/100g)	Total N
	Area 1[1]						
1	15-20-14 H	5.6	44	216	17.9	6.5	.20
2	18-24-6 H	5.9	46	204	18.7	6.7	.20
4	OrgA.C.M. L	5.7	43	164	19.1	6.7	.20
6	OrgA.C.M. H	5.7	43	208	19.1	6.7	.21
8	OrgB.Soybits L	5.6	39	180	19.1	6.7	.20
10	OrgB.Soybits H	5.6	38	198	18.9	6.7	.21
12	N-P-K H	5.5	40	192	16.9	5.9	.20
13	Control	5.7	40	216	18.5	6.6	.21
14	N H	5.6	36	164	17.7	6.3	.20
	Area 2						
1	15-20-14 H	5.6	70	320	16.5	7.0	.11
2	18-24-6 H	5.8	71	336	15.3	6.7	.15
4	OrgA.C.M. L	5.7	62	326	15.9	6.6	.16
6	OrgA.C.M. H	5.7	73	380	16.1	6.9	.16
8	OrgB.Soybits L	5.8	60	292	15.7	6.5	.16
10	OrgB.Soybits H	5.6	64	346	15.9	6.9	.16
12	N-P-K H	5.8	73	346	16.5	6.9	.16
13	Control	5.7	64	316	15.9	6.9	.15
14	N H	5.6	62	280	15.7	6.7	.15

1. Included all crops except tomatoes which were in Area 2. Previous crop in Area 1 was wheat, in Area 2 broccoli.

2. Sampled 7-15-75. Soil sample depth 15 cm. 5 probes/plot (20 probes/trt).

3. B content prior to planting Area 1: .60 ppm; Area 2: .50 ppm.

4. Initial soil analysis of Area 1 was: pH: 6.4, P: 34; K: 174; Ca: 19.6; Mg: 7.3
   of Area 2 was: pH: 6.4, P: 60; K: 262; Ca: 17.9; Mg: 6.3.
   Sampled 4-75.

Table 4. Effect of Fertilizer Treatment on the Soil Analysis, 1976[1]

TRT No.	Treatment	pH	P (ppm)	Extractable Cations K (ppm)	Extractable Cations Ca (meq/100g)	Extractable Cations Mg (meq/100g)	B (ppm)	Total N	Zn (ppm)	Fe (ppm)	Cu (ppm)	Na (meq/100g)
1	Control	6.1	28	232	11.4	5.5	.40	.10	8.4	540.0	13.0	.26
2	15-20-15 L	5.7	38	268	10.6	5.3	--	.11	--	--	--	--
3	15-20-15 H	5.8	50	320	10.1	4.6	--	.10	--	--	--	--
4	18-24-6 L	5.8	40	262	11.6	5.7	--	.11	--	--	--	--
5	18-24-6 H	5.4	52	298	10.4	5.2	--	.10	--	--	--	--
6	Org A.C.M. L	6.2	32	240	11.0	5.0	.30	.07	7.6	410.0	9.7	--
7	Org A.C.M. H	6.2	40	280	12.2	5.5	--	.11	--	--	--	--
8	N L	5.9	30	232	11.4	5.3	--	.10	1.7	120.0	2.4	--
9	N-P L	5.9	40	228	11.8	5.8	--	.11	--	--	--	--
10	N-P-K L	5.9	37	330	10.8	5.1	--	.09	1.3	132.2	2.5	--
11	P-K	6.1	42	320	11.2	5.3	--	.11	--	--	--	--
12	N-P-K H	5.6	38	286	10.4	5.2	--	.10	--	--	--	--
13	B.C.M. L	5.9	33	320	10.1	4.8	.33	.10	1.9	142.0	2.8	--
14	B.C.M. H	5.8	39	340	10.1	4.6	--	.10	--	--	--	--
15	Sewage Sludge H	5.9	35	268	11.8	5.5	.36	.12	5.2	134.2	3.6	.28
16	Control	6.1	28	250	11.2	5.5	.34	.10	1.7	108.0	2.5	.30

1. Sampled: 8-18-76
2. Soil sample depth 15 cm.
3. T1-T16: 5 probes/plot= 20 probes/trt.
4. Previous crop: Brassica.
5. Initial soil analysis in March, 1976, indicated: pH: 6.2; P: 28; K: 156; Ca: 13.3; Mg: 6.3.

sources of fertilizers, soil samples should be taken at different depths, and a greater number of times during each season and over a number of years. Effects on soil structure, organic matter content, pH and C. E. C., could also be studied and would be of value in interpreting fertilizer responses.

Analysis and Characterization of the Organic Fertilizers 1975-1976

The organic materials were analyzed for their nutrient content and application rates were based on their total N. The actual elemental applications of the organics were different in some cases from the application rates based on preliminary estimates. These are noted in Tables 1 and 2.

Chicken Manure, 1975-1976

In 1975, the estimated N content of Org. A. C. M. was 3.9%, and in 1976, 5.0%. The estimated analysis of the B. C. M., in 1976, was 2.0%. The actual analyses are in Tables 5 and 6.

Poultry manure, typical of organic materials, will vary not only from different sources but within the same source, being influenced by age, feed, and storage conditions. Characteristics of poultry manure is its high nitrogen content and rapid mineralization rate (154). Poultry require nitrogen, usually as high protein feeds, carbon sources, sulfur, phosphorus, vitamins, minerals, etc. in a form usable by the bird (97). It can be estimated that 3/4 of the N, 4/5 of the P, and 9/10 of the K are not utilized by the bird and are excreted (18). Some of the nitrogen excreted is in a nonprotein form (uric acid) and this is readily available to the plant. Rubins and Bear (114) reported that C:N ratio of washed chicken manure at 36. When unwashed, chicken manure had a nitrification rate of 22 to 30% at 20 and 40 days (114).

Most manures are unbalanced in N-P-K analysis due to their low P levels. Yet poultry manure when unleached can contain 4% P (154), averaging three to four times higher than other manures.

A distinct advantage of poultry manure is its low moisture content (62%) compared to other manures (18), for drying, shipping, and quality control standards. Yet more work needs to be done in obtaining supply of a uniform and consistently high quality fertilizer product.

No adverse effects from excessive soluble salts, NH_3 toxicity, or depression of Mg and Ca uptake were observed from the chicken manures with any crop in this study.

Soybits, 1975

The estimated N content was 7.6% and the actual analysis was 8.64% N (Table 5). Soybean meal is known to be slowly available and results in a slightly acidic soil reaction. The nitrification rate has been reported to be 61 to 65% in 20 and 40 days respectively for unwashed soybean meal and a C:N ratio of 4.7 (114). The soybean residue had exceptionally low P and Ca levels (Table 5).

Sewage Sludge, 1976

The estimated application rate was based on 4.4% solids and 3.5% total N dry weight. The actual analysis of the anaerobically digested sewage sludge is given in Table 7. The means of two samples indicate 5.84% solids, 4.45% total N dry weight, and 1.15% NH_3-N dry weight.

Sewage sludge has been used for many years both as a soil amendment and fertilizer. Values for N-P-K on a dry weight basis range from 1-15% N, 1-6% P, and .05-1% K (102). The elemental status of sewage sludge varies quite markedly, being dependent on the specific treatment process, the diversity, quantity, and nature of

Table 5. Chemical Analysis of the Organic Fertilizers used in 1975[1].

No.	Compound	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	Org A.C.M.	3.97	2.25	2.28	4.48	.53	212	565	19	32	208	340
2	OrgB.Soybits	8.64	0.87	2.22	0.16	.24	34	129	15	43	69	6

1. N, P, K, Ca, Mg as % dry wt.
   Mn, Fe, Cu, B, Zn, Al as ppm dry wt.

Table 6. Chemical Analysis of the Chicken Manure used in 1976[1].

No.	Compound	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	Org A.C.M.[2]	5.03	2.88	2.18	8.55	.41	298	771	22	26	579	406
2	Org A.C.M.	5.16	1.94	2.42	7.03	.44	237	804	26	43	206	243
3	B.C.M.[3]	4.89	1.80	1.32	3.34	.46	335	4752	20	26	201	7200
4	B.C.M.	4.06	2.81	2.57	7.17	.59	393	1094	29	35	320	967

1. N, P, K, Ca, Mg as % dry wt.
   Mn, Fe, Cu, B, Zn, Al as ppm. dry wt.
2. Org A.C.M.= shipment 1
3. B.C.M.= load 1

Table 7. Chemical Analysis of the Sewage Sludge used in 1976[1].

No.	Compound	% solids	N	NH_3-N	P	K	Ca	Mg	Mn	Cu	Zn	Cd	Na	Cr	Ni	Pb	Mo
1	S.S.- A	5.62	4.50	1.2	.93	.24	3.4	.36	300	450	1800	14	1100	100	46	790	15
2	S.S.- B	6.06	4.40	1.1	.92	.25	4.1	.48	300	450	1800	12	1200	90	50	800	19

1. N(total of micro-kjedahl N), NH_3-N, P, K, Ca, Mg as % dry wt. All others as ppm, dry wt.
   The third and eighth of nine trailer loads were sampled.
   Elemental applications are based on two means.

material in the effluent. Seasonal and weekly fluctuations are common even within the same sewage treatment plant, due to weather conditions and changes in industrial activity. Storage conditions, and methods of application (i.e. surface applied vs. soil incorporated) are influential in determining the percent of nutrients lost to leaching and volatilization. Only $\simeq$ 28 - 48% of the total nitrogen is immediately available (115). The remainder is in the organic form and must be converted to either ammonium or nitrate for plant utilization. Pratt et al. (107), estimated 20 - 30% organic-N released the first growing season, 10% the second and 1-2% each of the next three. In addition to the inorganic-N, this brings the availability near to 50% the first year. Assuming that 50% of the N is available the first growing season, the amount of actual N applied and available in this study (Table 2) was very close to the amount of actual N applied with the mineral fertilizers, and this can partially explain the high yields of most crops with sewage sludge.

In the mineralization of nitrogen in soil-spplied liquid sludge, King (62) reported NO_3-N accumulation as 38% of the applied N after 18 weeks, when the sludge was incorporated with the soil. Of this, 70% of the NO_3-N was present at four weeks, indicating that low application rates at the beginning of the season may not provide a continuous supply of mineralized nitrogen for optimum plant growth. Jackson et al. (51) indicate that sludge generally contains very little NO_3-N, about 1-4% dry wt, ammonium-N, and that the majority is combined in slowly mineralized organic constituents. The bulk of the organic-N is probably associated with the solid fraction of sludge, is less variable, and of selected sludge the predominant for being α-amino acid N with small amounts of hexosamine-N (135). In contrast, it is the variable inorganic N, including NH_4^+ and NO_3^- (which represents > 90% of the total inorganic N) that when on a dry weight basis is reported to be inversely related to the solids contents (135).

Phosphorus is predominantly in the inorganic form (64-84% to total P) and is only slowly available as it precipitates rapidly with Fe or Al under acid soil conditions (51, 135).

Potassium is generally very low in sludge since much is lost in the sewage treatment process due to its highly soluble state. The K content in this sludge averaged .25% dry weight (Table 7).

The elemental analysis of the sludge in this study was low and safe for all elements (11, 102). This sludge could be characteristic of many small cities where light industry and residential sludge contribute largely to the total effluent, and has the greatest potential for utilization in crop production as trace element concentrations are sufficiently low. The actual amount of trace elements applied with the sludge (kg element/ha) are shown in Table 8.

LeRiche (70) found no detrimental effects on crop yields from a residential sludge, over a 19 year period, although there was an increase in the Zn, Cu, and Ni contents of many vegetables. Berrow and Webber (11) found no correlation between town size and any element except Cr, which increased with population. Sommers et al. (135) found a significant correlation between the degree of industrialization and elevated metal levels.

No adverse effects of any trace elements were observed in this study.

Individual Crop Response

Bell Peppers, 1975

There was a significant increase in yield (total gross weight) from application of N (H) compared to the control (Table 9). No additional response from P or K was found, and the yield from

Table 8. Calculated Rates of Trace Elements from Application of Sewage Sludge[1]

Element	Added to Soil kg/ha	lb/acre
Total N	473.55	422.81
NH_3-N	122.39	109.27
P	98.43	87.89
K	26.07	23.28
Ca	399.06	356.30
Mg	44.69	39.91
Mn	3.19	2.85
Cu	4.79	4.28
Zn	19.15	17.10
Cd	0.14	0.12
Na	12.24	10.93
Cr	1.01	0.90
Ni	0.51	0.46
Pb	8.46	7.55
Mo	0.18	0.16

1. Means of two sludge samples

Table 9. Effect of Fertilizer Treatments on the Grades and Total Yield of Bell Peppers, 1975.[1]

TRT No.	Treatment	Total Gross Wt.[2]	% of Total gross wt.[3] % Stuffers	% Nonstuffers	% Red Peppers	% Culls	Total Yield[4] H1	H2	H3	Potential	Total Yield H1-H3	Total[5] Green Fruit Yield	Total Fruit Number
1	15-20-14 H	36.8	15.3	77.5	6.2	.43	.16	22.8	10.8	3.1	33.8	31.5	391171
2	18-24-6 H	32.2	16.7	66.5	15.0	.82	.28	21.9	7.5	2.5	29.7	25.0	298480
3	18-24-6 HS	34.4	18.0	65.9	14.7	.64	.24	23.1	7.2	3.9	30.5	25.5	322158
4	Org A.C.M. L	33.0	20.4	69.6	9.9	.06	.02	22.3	6.3	4.4	28.6	25.7	300274
5	Org A.C.M. LS	36.6	18.1	70.1	11.7	.12	.00	24.0	10.0	2.6	34.0	30.1	341171
6	Org A.C.M. H	33.7	20.5	63.9	13.1	1.50	.34	23.2	7.0	3.2	30.5	26.0	290229
7	Org A.C.M. HS	34.2	22.4	66.8	9.4	.93	.13	19.5	10.0	4.6	29.6	26.5	354445
8	OrgB.Soybits L	31.1	13.9	75.2	9.1	.32	.44	18.8	8.6	3.2	27.8	25.3	294175
9	OrgB.Soybits LS	32.8	18.0	69.3	10.9	.72	.33	21.0	8.1	3.3	29.4	26.0	297763
10	OrgB.Soybits H	31.6	19.1	72.8	7.1	.64	.11	17.2	9.7	4.6	27.0	24.9	313906
11	OrgB.Soybits HS	32.0	16.5	76.6	6.0	.54	.11	21.6	7.8	2.5	29.5	27.5	292740
12	N-P-K H	35.6	15.1	68.4	14.2	1.00	.44	25.0	7.7	2.5	33.1	28.0	303503
13	Control	30.4	15.8	70.3	12.5	.33	.29	20.4	7.0	2.6	27.8	24.2	312471
14	N H	35.8	12.5	75.5	10.3	.84	.33	25.0	9.4	1.0	34.8	30.8	301709
15	N-P-K HS	35.0	15.0	72.7	10.8	.62	.29	23.9	8.4	2.4	32.6	28.8	318211
16	N-P-K 2S	34.2	17.5	72.2	9.5	.27	.16	21.8	8.9	3.3	30.8	27.9	325745
	LSD .01	5.4	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	6.0	5.3	NSD

TRT No.	Treatment	% of Total Fruit Number Stuffers	Nonstuffers	Red Peppers	Culls	Total Number of Fruit H1	H2	H3	Potential	H1-H3	Green Fruit
1	15-20-14 H	15.2	78.8	4.6	0.9	1435	144218	110136	85383	255789	241798
2	18-24-6 H	17.9	68.3	10.4	2.5	1794	132379	80360	83948	214533	186909
3	18-24-6 HS	19.0	67.6	11.0	1.9	1435	139913	77131	103679	218479	187268
4	Org A.C.M. L	20.7	70.9	8.0	0.2	359	137401	59553	102961	197313	181886
5	Org A.C.M. LS	18.3	73.7	7.8	0.2	0	141706	109419	90046	251125	232111
6	Org A.C.M. H	21.3	65.9	9.6	2.2	2153	134890	71033	82154	208075	183680
7	Org A.C.M. HS	23.4	66.8	7.0	2.4	1076	120181	106190	126998	227448	206281
8	OrgB.Soybits L	14.8	76.2	7.0	0.8	2511	124128	91123	76414	217761	200900
9	OrgB.Soybits LS	17.5	72.5	7.5	1.8	1794	127715	81795	86459	211304	192290
10	OrgB.Soybits H	20.8	72.5	5.1	1.3	718	113724	86459	113006	200900	188344
11	OrgB.Soybits HS	16.7	78.1	4.0	0.6	1076	139554	77490	74620	218120	207716
12	N-P-K H	15.6	70.4	10.4	2.3	3229	153545	81078	65651	237851	207716
13	Control	17.0	71.9	9.6	0.7	1794	128791	80360	101526	210945	189420
14	N H	12.8	78.5	6.5	1.5	2153	162514	104755	32288	269421	246820
15	N-P-K HS	15.1	75.2	7.4	1.6	1794	152469	91481	72468	245744	223501
16	N-P-K 2S	17.9	73.7	6.3	1.6	1076	135966	96145	92558	233188	214533
	L.S.D. .01	3.3	NSD	NSD	NSD	NSD	NSD	NSD	53374	51861	47555

1. Results are means of treatment replications in m. tonnes/ha, or number of ruits/ha.
2. Includes total yield of harvest 1-3 (H1-H3) and potential yield.
3. Stuffers include all green fruit with four lobes; nonstuffers are without four lobes.
4. All fruit <6.4 cm. in length, horticulturally immature at last harvest (H3).
5. Total green fruit yield (marketable peppers) harvested through the entire season (H1-H3).

application of N-P-K (H) was slightly lower than from N (H). Although an increased yield was observed from N-P-K (2S) compared to the control, it was less than from preplant or preplant plus sidedress treatments of N-P-K. Applications of 15-20-14 (H) and Org A. C. M. (LS) yielded significantly higher than the control.

There was a general trend, though not significant, for the side-dressing applications to increase yields over the corresponding treatments which received only preplant applications for both the low and high rates. An exception was for the N-P-K treatment where yield was slightly less from the sidedress treatment.

No significant benefits were found from the higher rates of both organic materials and neither was significantly different from the control. N. S. D. were found when comparing the high rates of any of the organic and mineral sources.

Similar trends are found with total yield, H1 - H3 (excluding potential yield) and with total green fruit yield, including stuffers and nonstuffers. This is expected, since there was N. S. D. between any treatments when yields of red peppers, culls, and potential fruit are considered. No treatments promoted earlier maturing fruits. Increased yield was the result of the production of a larger number of fruit per plant or per hectare. While the control had significantly greater number of potential fruit than the higher yielding N (H) treatment, associations between yield and potential fruit are not always clear.

No striking differences between treatments were found in the plant growth observations (Table 11). Wall thickness was not affected by the selected treatments, but likely was a reflection of the stage of physiological maturity.

Table 10. Percent of Individual Grades of Total Yield of Bell Peppers at H2 and H3, 1975.

TRT No.	Treatment	% of Total Weight of H2				% of Total Weight of H3			
		% Culls	% Red Pepper	% Stuffer	% Non-stuffer	% Culls	% Red Pepper	% Stuffer	% Non-Stuffer
1	15-20-14 H	0.4	8.4	15.4	75.9	0.4	1.8	15.4	82.4
2	18-24-6 H	0.8	19.1	15.3	64.8	1.2	4.3	21.9	72.6
3	18-24-6 HS	0.4	18.2	16.9	64.5	1.5	4.5	21.5	72.6
4	OrgA.C.M. L	0.7	10.8	20.0	69.1	0.0	3.7	25.2	71.2
5	OrgA.C.M. LS	0.2	16.1	15.3	68.5	0.0	0.9	25.0	74.1
6	OrgA.C.M. H	1.3	15.9	20.6	62.3	1.8	4.0	21.3	72.9
7	OrgA.C.M. HS	0.7	13.2	21.4	64.7	1.5	1.2	25.0	72.3
8	OrgB.Soybits L	0.4	11.7	13.3	74.6	0.2	3.0	15.4	81.5
9	OrgB.Soybits LS	0.6	14.7	17.2	67.5	1.0	1.1	17.2	80.7
10	OrgB.Soybits H	0.4	10.5	15.7	73.4	1.2	0.9	25.1	72.8
11	OrgB.Soybits HS	0.7	7.6	14.5	77.2	0.2	1.4	20.4	78.0
12	N-P-K H	0.6	17.0	13.9	68.6	2.6	6.2	19.8	71.5
13	Control	0.3	16.5	15.4	67.8	0.2	3.0	18.1	78.7
14	N H	1.0	13.4	11.3	74.3	0.4	2.5	15.4	81.8
15	N-P-K HS	0.6	14.2	15.0	70.3	0.6	1.3	17.7	80.4
16	N-P-K 2S	0.7	13.3	16.1	70.5	0.8	0.5	21.4	77.3
	LSD .01	NSD	NSD	NSD	NSD	2.0	NSD	NSD	NSD

TRT No.	Treatment	% of Total Fruit Number of H2				% of Fruit Number of H3			
		% Culls	% Red Pepper	% Stuffer	% Non-Stuffer	% Culls	% Red Pepper	% Stuffer	% Non-Stuffer
1	15-20-14 H	0.5	6.7	14.7	78.1	1.2	2.0	15.6	81.2
2	18-24-6 H	2.9	13.9	15.3	67.9	2.3	5.3	22.8	69.6
3	18-24-6 HS	1.1	14.1	16.7	68.0	3.4	6.0	23.0	67.7
4	OrgA.C.M. L	0.3	8.9	19.5	71.4	0.0	3.0	29.1	67.9
5	OrgA.C.M. LS	0.4	13.0	15.3	71.4	0.0	1.2	22.4	76.4
6	OrgA.C.M. H	1.8	12.2	20.3	65.8	3.2	4.6	23.8	68.5
7	OrgA.C.M. HS	1.6	11.0	21.9	65.5	3.4	1.6	25.7	69.3
8	OrgB.Soybits L	0.9	9.5	13.7	75.9	0.6	3.4	16.8	79.2
9	OrgB.Soybits LS	1.6	11.1	16.0	71.3	1.9	1.0	18.2	79.0
10	OrgB.Soybits H	.5	7.5	15.8	76.2	2.7	1.5	28.9	67.0
11	OrgB.Soybits HS	0.8	5.6	13.4	80.2	0.5	1.1	22.1	76.4
12	N-P-K H	1.2	12.8	13.2	72.9	4.5	6.7	20.2	68.7
13	Control	0.8	13.7	15.2	70.3	0.4	3.9	20.3	75.5
14	N H	2.0	9.1	11.1	77.8	0.7	2.9	14.9	81.6
15	N-P-K HS	1.4	10.7	14.7	73.3	1.6	2.0	17.4	79.1
16	N-P-K 2S	1.4	10.8	15.1	72.7	2.0	0.4	22.3	75.4
	LSD .01	NSD	NSD	NSD	NSD	NSD	NSD	NSD	13.6

Table 11. Effect of Fertilizer Treatments on Plant Growth Observations of Bell Peppers, 1975[1]

TRT No.	Treatment	Plant Quality[2]	Leaf Injury[3]	Leaf Color[4] Upper Foliage	Leaf Color[4] Lower Foliage	Visual Plant Ht. Comparisons[5]	Wall Thickness[6] (grams)
1	15-20-14 H	7.2	8.7	6.6	7.8	4.2	--
2	18-24-6 H	5.5	8.3	6.8	7.9	4.0	--
3	18-24-6 HS	7.2	8.9	6.7	7.9	4.1	--
4	Org. A.C.M. L	6.8	8.4	6.0	7.2	4.1	--
5	Org. A.C.M. LS	7.0	8.3	6.6	7.7	4.3	0.46
6	Org. A.C.M. H	7.1	8.8	6.4	7.5	3.9	--
7	Org. A.C.M. HS	7.0	8.8	6.5	7.5	4.5	--
8	OrgB.Soybits L	6.7	8.5	6.3	7.3	3.9	--
9	OrgB.Soybits LS	6.5	7.9	5.8	6.9	4.1	0.45
10	OrgB.Soybits H	6.8	8.2	6.3	7.4	3.9	--
11	OrgB.Soybits HS	7.0	8.2	6.3	7.5	4.0	--
12	N-P-K H	7.2	8.1	6.4	7.4	4.0	--
13	Control	6.0	8.5	5.5	6.5	4.0	0.46
14	N H	7.2	8.8	6.7	7.7	3.9	0.46
15	N-P-K HS	7.4	8.5	6.7	7.9	4.0	0.45
16	N-P-K 2S	6.4	8.1	6.0	7.0	4.0	--

1. Results are means of treatment replications at four observation dates.
2. Overall appearance including color of foliage, vigor, degree of disease-free foliage and general plant health. Scale 1-10. 1= very poor; 10= excellent.
3. Injury from N. Scale 1-10. 1= death; 10= non injury.
4. Based on the intensity of green color. Scale 1-10. 1= chlorotic; 10= excellent.
5. Each plant compared to others within each replication. Scale 1-5. 1= smallest; 5= largest.
6. Mean weight of 20 samples per treatment. LSD .01= NSD.

Cucumbers, 1975

There was a slight increase in gross yield from added N (H) compared to the control, and from P and K, but these were not statistically significant (Table 12).

There was a trend for sidedressing to be beneficial at both low and high rates of all fertilizers except with Org. B. Soybits (H) where a sidedressing decreased yields. However, this was associated with a slight stand reduction. There was N. S. D. between the H and HS rates of any of the nutrient sources, although yields were depressed by both Org. B. Soybit rates.

Both Org. B. Soybits (L and LS) treatment yields were significantly lower than the control. Low yields from application of Org. B. Soybits is a reflection of the significantly lower plant stands as compared to nearly all the other treatments. This can also be seen as the reduction of the number of fruit per hectare. However, individual yield per plant was slightly higher than the other treatments. There was N. S. D. in plant stand among any of the other treatments. Fertilizer treatments caused no differences in early maturity of fruit at the first harvest.

The Org. B. Soybits treatments also scored lower on the plant growth ratings indicating poor growth. No differences were found in seed cavity of fruit from different fertilizer treatments.

Radishes, 1975

Results on radish root yield in Table 14 indicate that treatment 12, N-P-K (H), was significantly different from the control, T13, by 2.6 m. tonnes/ha, and approached being significantly higher than T14, N (H).

The 15-20-14 (H) and 18-24-6 treatments were similar and

Table 12. Effect of Fertilizer Treatments on the Grades and Total Yield of Cucumbers, 1975.

Trt. No.	Treatment	Gross Yield	% of Gross Yield[2] H1	H2	H3	OS	MS	Total Yield H1	H2	H3	H4	Total Marketable Fruit Yield[3]
1	15-20-14 H	57.5	3.2	30.1	42.1	14.3	10.3	15.2	16.3	5.7	20.2	43.3
2	18-24-6 H	55.4	2.8	29.8	41.3	16.0	10.2	12.4	14.8	6.2	22.0	40.8
3	18-24-6 HS	55.6	4.4	32.1	37.3	14.0	12.2	14.7	15.1	6.1	19.6	40.8
4	Org A.C.M. L	52.4	3.7	33.0	38.5	15.2	9.6	11.9	16.2	5.8	18.4	39.5
5	Org A.C.M. LS	60.0	3.6	29.6	37.0	17.9	11.8	13.5	14.8	5.8	25.9	42.2
6	Org A.C.M. H	56.6	3.3	33.1	34.5	19.6	9.6	14.1	14.2	7.5	20.8	40.1
7	Org A.C.M. HS	60.3	4.1	34.9	35.1	14.7	11.3	13.9	17.8	6.4	22.3	44.6
8	OrgB.Soybits L	35.0	5.3	35.9	38.6	11.2	9.1	6.4	10.1	3.4	15.1	27.7
9	OrgB.Soybite LS	37.6	3.8	34.7	39.1	12.0	10.4	6.0	11.1	3.4	17.1	29.2
10	OrgB.Soybits H	46.5	3.9	31.9	42.3	12.7	9.1	9.2	13.0	5.9	18.4	36.1
11	OrgB.Soybits HS	39.9	4.4	31.5	39.3	10.9	14.0	8.2	12.3	4.9	14.6	29.8
12	N-P-K H	56.8	3.4	32.5	36.8	15.5	11.7	14.8	14.5	6.0	21.5	41.2
13	Control	50.7	3.8	31.3	41.3	14.5	9.1	11.0	14.5	5.3	19.9	38.7
14	N H	51.6	3.7	33.4	40.8	11.6	10.6	11.5	15.8	4.9	19.3	40.3
15	N-P-K HS	58.6	3.6	28.9	40.9	15.3	11.2	13.3	17.7	6.1	21.4	43.1
16	N-P-K 2S	52.4	3.3	34.3	40.5	11.5	10.3	11.3	15.4	6.5	19.2	40.9
	LSD .01	12.5	NSD	NSD	NSD	6.5	NSD	4.8	4.2	2.9	6.2	9.1

TRT No.	Treatment	Total MS Fruit Yield	# Fruit/ha	Average Size, gms	Total OS Fruit Yield	# Fruit/ha	Average Size, gms	% of H1 Yield #1	#2	#3	OS	MS	Plant Stand[4]
1	15-20-14 H	5.9	83627	71	8.2	26199	313	0.0	23.7	41.1	30.0	5.2	35
2	18-24-6 H	5.7	85362	67	9.0	29669	303	0.1	25.9	35.5	32.9	5.6	33
3	18-24-6 HS	6.8	98895	69	7.9	25505	310	1.2	19.7	43.6	30.4	5.1	34
4	OrgA.C.M. L	5.0	77728	64	7.9	25852	306	0.4	26.0	37.7	31.4	4.6	32
5	OrgA.C.M. LS	7.0	92996	75	10.9	32271	338	0.8	21.4	35.3	33.7	8.7	30
6	OrgA.C.M. H	5.4	89006	61	11.1	26719	415	0.2	21.2	35.1	36.9	6.6	31
7	OrgA.C.M. HS	6.8	106703	64	8.9	28454	313	0.5	27.9	33.0	34.6	4.1	34
8	OrgB.Soybits L	3.3	49621	67	4.0	13013	307	0.8	22.0	42.1	32.1	3.0	20
9	OrgB.Soybits LS	4.0	60378	66	4.4	15615	282	3.8	27.5	36.4	30.0	2.2	19
10	OrgB.Soybits H	4.3	62460	69	6.1	20300	300	0.5	25.6	39.2	32.5	2.2	23
11	OrgB.Soybits HS	5.6	71135	79	4.6	14574	316	0.5	30.7	34.0	26.0	8.8	19
12	N-P-K H	6.8	101324	67	8.8	32271	273	0.4	24.2	40.2	30.0	5.2	35
13	Control	4.6	69400	66	7.5	22902	327	0.1	24.1	41.5	30.2	4.1	34
14	N H	5.4	87965	61	5.9	19259	306	0.5	28.7	38.2	24.9	7.7	34
15	N-P-K HS	6.6	89700	74	8.9	30363	293	0.5	19.9	44.2	28.7	6.8	32
16	N-P-K 2S	5.4	78075	69	6.1	18912	323	0.3	27.0	36.1	28.1	8.5	34
	LSD .01	2.9	40478	--	4.3	10965	---	NSD	NSD	NSD	NSD	NSD	7

1. Results are means of treatment replications in m. tonnes/ha or number of fruit/ha.
2. #1: 4 cm. x 1.5 cm to
   #2: 8 cm. x 2.5 cm to
   #3: 12 cm. x 3.5 cm. to
   OS: (oversize), > 13.5 cm. to 4.5 cm. MS: Misshapen (culls and nubins)
3. Excludes OS and MS from all four harvests.
4. Number of plants per plot.

Table 13. Effect of Fertilizer Treatments on Plant Growth Observations and Certain Fruit Characteristics of Cucumbers, 1975

TRT No.	Treatment	Plant Quality[2]	Leaf Injury[3]	Leaf Color[4] Older Foliage	Leaf Color[4] Younger Foliage	Visual Plant Spread & Height Comparisons[5]	Seed Carpel[6]	Fruit Number % of Total OS at - H1	H2	H3	H4	% of total MS at H1	H2	H3	H4
1	15-20-14 H	6.4	6.4	6.2	7.2	4.0	4	48.0	17.8	3.4	30.8	8.1	24.0	16.2	51.7
2	18-24-6 H	6.4	6.2	6.4	7.6	4.2	3	37.0	26.5	5.5	31.1	7.0	20.7	15.4	56.9
3	18-24-6 HS	6.5	6.5	6.5	7.5	4.1	4	46.9	20.6	1.8	30.7	7.2	34.8	13.6	44.5
4	Org A.C.M. L	6.3	6.6	6.2	7.5	4.1	5	37.1	26.2	7.1	29.6	6.5	31.2	12.5	49.9
5	Org A.C.M. LS	6.5	6.5	6.5	7.5	4.2	5	38.3	18.3	2.5	40.9	10.5	28.6	8.1	52.8
6	Org A.C.M. H	6.5	6.2	6.0	7.5	4.0	5	52.6	14.2	7.7	25.5	7.9	27.2	19.8	45.1
7	Org. A.C.M. HS	6.6	5.9	6.4	7.6	4.3	4	50.3	20.4	8.1	21.2	3.7	32.0	22.2	42.1
8	OrgB.Soybits L	5.7	5.6	6.0	7.1	3.2	6	45.9	14.2	2.9	37.0	2.7	20.6	14.5	62.2
9	OrgB.Soybits LS	5.8	5.8	6.0	7.1	3.3	4	30.6	21.2	6.3	42.0	2.4	21.3	19.5	56.8
10	OrgB.Soybits H	6.3	6.6	6.3	7.5	3.8	5	37.0	13.5	5.3	44.3	2.2	25.8	17.5	54.6
11	OrgB.Soybits HS	5.8	5.8	6.0	7.1	3.2	4	36.9	32.6	7.1	23.4	2.7	22.6	17.9	56.8
12	N-P-K H	6.7	5.9	6.2	7.3	3.8	5	45.0	21.1	3.9	30.0	5.7	34.5	19.1	40.7
13	Control	6.1	6.5	5.9	7.1	3.9	4	39.6	21.0	6.3	33.1	6.4	24.2	19.7	49.7
14	N H	6.7	6.6	6.1	7.5	4.1	5	38.2	30.3	1.7	29.9	5.7	15.5	29.7	49.1
15	N-P-K HS	6.5	6.7	6.4	7.4	4.0	6	35.9	25.6	5.4	33.1	8.0	30.5	11.6	49.9
16	N-P-K 2S	6.5	6.4	6.4	7.4	3.9	5	42.8	30.1	12.1	15.0	9.9	22.1	21.6	46.5
	LSD .01	-	-	-	-	-	-	NSD	NSD	NSD	NSD	6.0	NSD	NSD	NSD

1. Visual ratings are means of four observation dates for each treatment replication.
2. Overall appearance including color of foliage, vigor, degree of disease-free foliage and general plant health, Scale 1-10. 1= very poor; 10= excellent.
3. Injury from N. Scale 1-10. 1= death, 10= no injury.
4. Based upon the intensity of green color. Scale 1-10. 1= chlorotic, 10= excellent.
5. Each plot compared to others per replication. Scale 1-5. 1= smallest, 5= largest.
6. Seed carpel separation score. Scale 0-15. 0= no separation of seed cavity from pericarp; 15= each sampled fruit with a visible separation.

N. S. D. than the control. Yield of the low rate of Org. A. C. M. was slightly above the control. The higher rates, although greater than either the control or lower rates, were N. S. D. from them. Lower yields than the control resulted from application of Org. B. Soybits, treatment 8 and 9.

When comparing Org. A. C. M. (H), Org. B. Soybits (H), and N-P-K (H), they were N. S. D., although highest yield was from N-P-K (H).

Similar trends to that found for root yield can be seen with total plant weight.

Laboratory measurements indicate no marked or consistent differences, but the Org. B. Soybits (H) treatment resulted in the lowest soluble solids content.

Roots were graded into US #1 commercial and culls, and N. S. D. was observed from fertilizer treatments. Culls were also observed for color variation, insect and disease damage, shape, degree of cracking and pithiness, and excessive rootlet formation but no relationships with treatments were found.

The only striking difference among the plant growth observations (Table 15) was the poorer stand rating from all four Org. B. Soybits treatments. Although percent emergence was not recorded, germination and stand were poorer than any other treatments and no doubt accounts for the reduced yields.

For texture ratings, the greater the Fm the more fibrousness and toughness of roots. The treatment of 15-20-14 (H) resulted in the highest Fm values, significantly different from the control and all other measured treatments (Table 16). Treatments of N-P-K (H), Org. A. C. M. (H), and the control were N. S. D. from each other. The 15-20-14 (H) treatment produced the highest total plant weight, foliage weight, and foliage:root ratio. The increased rapid growth,

Table 14. Effect of Fertilizer Treatments on Yield, and Selected Observations on Radishes, 1975[1].

TRT No.	Treatment	Total Plant Wt.[2]	Foliage Wt.	(Yld) Root Wt.	% Foliage	% Root	Laboratory Measurements: Av. Crown sz. in mm	pH[3]		Soluble Solids		Spec. Gravity		Salable Roots: US #1 Wt.	#
1	15-20-14 H	18.7	11.5	7.3	61	39	9.1	-	-	-	-	-	-	1.8	38.3
2	18-24-6 H	17.6	10.7	6.8	61	39	10.3	-	-	-	-	-	-	1.6	33.0
3	18-24-6 HS	17.2	10.2	7.0	60	40	9.9	-	-	-	-	-	-	2.1	40.3
4	Org A.C.M. L	15.3	8.8	6.5	58	42	9.5	6.1	5.67	3.5	3.8	1.3383	1.3385	1.5	34.0
5	Org A.C.M. LS	15.8	8.6	7.2	55	45	9.5	-	-	-	-	-	-	2.0	37.0
6	Org A.C.M. H	17.6	9.9	7.6	57	43	9.5	6.2	5.98	3.6	3.7	1.3383	1.3384	2.4	44.5
7	Org A.C.M. HS	16.8	9.1	7.6	55	45	8.7	-	-	-	-	-	-	2.0	34.5
8	OrgB.Soybits L	13.5	8.0	5.5	59	41	9.5	6.2	5.71	3.5	3.8	1.3382	1.3385	1.8	37.0
9	OrgB.soybits LS	12.7	7.2	5.5	56	44	10.3	-	-	-	-	-	-	1.8	31.5
10	OrgB.Soybits H	15.3	8.8	6.7	57	43	10.3	6.1	5.75	3.2	3.6	1.3378	1.3383	1.8	35.3
11	OrgB.soybits HS	14.5	8.1	6.5	56	44	9.5	-	-	-	-	-	-	2.1	41.0
12	N-P-K H	18.1	9.3	8.6	52	48	9.9	6.1	5.51	3.3	3.6	1.3380	1.3383	2.8	46.3
13	Control	12.7	6.7	6.0	53	47	8.3	6.2	5.70	3.7	3.7	1.3386	1.3385	1.8	39.3
14	N H	15.9	9.3	6.7	58	42	9.5	6.2	5.90	3.7	3.7	1.3383	1.3384	2.1	39.3
15	N-P-K HS	17.4	9.6	7.8	55	45	9.5	-	-	-	-	-	-	2.1	39.5
16	N-P-K 2S	12.2	7.0	5.2	58	42	9.5	-	5.98	-	3.7	-	1.3383	1.6	38.0
	LSD .01	3.7	2.6	2.3	-	-	-	-	-	-	-	-	-	NSD	NSD

1. No sidedress application was applied for indicated treatments.
2. Results are means of treatment replications in m.tonnes/ha.
3. Two sampling dates. Left column 7-9, 10; Right column 7-16.

Table 15. Effect of Fertilizer Treatments on Plant Growth Observations on Radish, 1975

TRT No.	Treatments	Plant Quality[2]	Leaf Injury[3]	Leaf Color[4] Old Foliage	Leaf Color[4] Young Foliage	Visual Stand Rating[5]	Conformity of Stand[6]	Visual Plant Ht. Comparison[7]
1	15-20-14 H	8.0	8.3	7.8	7.5	4.5	8.5	5.0
2	18-24-6 H	8.5	8.5	7.5	6.8	5.0	8.8	5.0
3	18-24-6 HS	8.8	8.3	7.8	7.3	4.3	9.0	5.0
4	Org A.C.M. L	8.0	8.0	7.8	6.8	4.5	8.5	5.0
5	Org A.C.M. LS	8.3	8.5	8.0	7.5	4.8	8.5	5.0
6	Org A.C.M. H	8.0	7.0	7.5	7.0	4.3	9.0	5.0
7	Org A.C.M. HS	7.5	7.3	7.8	7.3	4.5	8.8	5.0
8	OrgB.Soybits L	7.8	8.8	8.0	7.3	3.3	8.8	4.0
9	OrgB.Soybits LS	6.8	8.8	7.5	7.0	3.3	7.0	3.0
10	OrgB.Soybits H	7.8	8.3	7.8	7.3	3.8	8.0	3.0
11	OrgB.Soybits HS	7.0	7.3	7.0	6.5	2.5	7.3	2.0
12	N-P-K H	7.5	7.0	7.5	7.0	4.8	8.8	5.0
13	Control	8.0	8.3	7.5	6.8	4.5	8.0	3.0
14	N H	7.8	7.8	7.8	7.3	4.0	8.5	3.0
15	N-P-K HS	7.5	8.0	7.5	6.8	4.5	8.0	3.0
16	N-P-K 2S	7.3	7.8	7.8	7.3	3.8	8.0	2.0
	LSD .01	NSD	-	-	-	-	-	-

1. Visual ratings expressed as treatment means.
2. Overall appearance including color of foliage, vigor, degree of disease-free foliage and general plant health. Scale 1-10, 1= very poor; 10= excellent.
3. Injury from N. scale 1-10, 1= death, 10= no injury.
4. Based on the intensity of green color. Scale 1-10. 1= chlorotic; 10= excellent.
5. Based on uniformity and germination. Scale 1-5. 1= poorest, 5= best.
6. Each plot compared to others per replication. Scale 0-10. 0= no stand; 10= excellent uniform stand.
7. Each plot compared to others per replication. Scale 1-5. 1= smallest; 5= largest.

Table 16. Effect of Selected Fertilizer Treatments on the Texture[1] of Radish Roots, Sample 1, 1975[1].

TRT No.	Treatment	Work cm-kg	Fm kg	FIR kg	∠FIR
1	15-20-14 H	3475.7	320.6	225.3	81.3°
5	Org A.C.M. LS	2650.3	253.3	176.9	78.3°
6	Org A.C.M. H	2997.7	285.4	210.9	80.6°
8	OrgB.Soybits L	3020.0	293.9	196.5	79.6°
10	OrgB.Soybits H	3236.7	304.7	216.2	81.0°
12	N-P-K H	3050.0	283.7	206.4	80.6°
13	Control	3143.7	290.8	216.2	81.0°
	LSD .05	164.2	15.1	33.5	--
	LSD .01	227.9	21.0	46.5	--

1. Three observations per treatment, 7-10-75 Analyzed as a completely randomized design with error term of 14 df.

Table 17. Effect of Selected Fertilizer Treatments on the Texture[1] of Radish Roots, Sample 2, 1975[1].

TRT No.	Treatment	Work cm-kg	Fm kg	FIR kg	∠FIR
4	Org A.C.M. L	2677.0	251.8	162.2	78.5°
6	Org A.C.M. H	2638.0	254.5	188.3	80.0°
8	OrgB.Soybits L	2626.5	256.8	172.4	78.5°
10	OrgB.Soybits H	2531.5	244.3	188.7	79.5°
12	N-P-K H	2738.0	263.8	173.5	79.0°
13	Control	2649.0	268.1	168.9	78.5°
14	N H	2755.0	259.7	183.7	79.0°
	LSD .05	NSD	NSD	NSD	--
	LSD .01				

1. Two observations per treatment, 7-11-75 Analyzed as a completed randomized design with error term of 7 df.

characterized by the top growth, perhaps reduced the carbohydrate accumulation of the enlarged storage root and with age possibly lead to the development of more fiber or thickening of the interior tissue. The two rates of Org. B. Soybits were not different from each other in texture.

The work values (W) follow a similar trend and are more associated with the firmness of the sample. The only difference is that the two rates of Org. B. Soybits differ by the L. S. D. .05 level.

FIR and ∠FIR, less used components, reflect differences in the rate at which force was required to compress or deform (bend) the sample prior to shearing, hence, another measure of firmness. N. S. D. was found between any of the treatments except for Org. A. C. M. (LS). Org. A. C. M. (LS) has the lowest values for all measured components, and is statistically different from the control at the 5% level for FIR and at the 1% level for W and Fm, indicating that these roots were more tender. Only the Org. B. Soybits (H) were significantly different from the N-P-K (H) of all the treatments.

At a second date, several treatments were analyzed again for the same components (Table 17). N. S. D. was found for any component between any treatments. There may have been greater sample variability and there were fewer degrees of freedom in the error term, so N. S. D. between treatments were evident.

Radishes, 1976

Results of root yield in Table 18 indicate N. S. D. among any of the treatments. Little response from N (L) or P-K over the control was seen, while N-P (L), N-P-K (L), and (H) depressed yields below the control. Radishes need only small but a continuously available supply of nutrients and excess fertilizer can result in excessive top growth, growth cracks (root splitting) as will excessive moisture.

Table 18. Effect of Fertilizer Treatments on the Yield, and other Characteristics of Radishes, 1976[1].

TRT No.	Treatment	Total Plant Weight	Foliage Weight	Yield Root Weight	% Foliage	% Root	% of Roots <2.54 cm	% of Roots >2.54 cm	Weight of Culls	Visual Rating of Roots[2] Insect Damage	Quality	Comparison
1	Control	7.5	4.6	2.9	62	38	37	63	0.0	2	8	1
2	15-20-15 L	9.2	6.7	2.5	73	27	48	52	0.7	3	4	3
3	15-20-15 H	11.3	8.8	2.5	78	22	55	45	0.7	3	5	3
4	18-24-6 L	9.8	7.1	2.8	72	28	44	56	0.5	3	6	3
5	18-24-6 H	10.3	8.0	2.3	77	23	62	38	0.8	3	5	3
6	Org A.C.M. L	7.8	5.3	2.5	68	32	49	51	0.7	3	6	3
7	Org A.C.M. H	9.8	7.4	2.4	75	25	52	48	1.0	3	4	4
8	N L	10.9	8.0	3.0	73	27	53	47	0.7	4	4	3
9	N-P L	10.0	7.3	2.7	73	27	52	48	0.7	3	4	3
10	N-P-K L	10.6	8.2	2.4	77	23	51	49	0.5	4	4	3
11	P-K	8.9	5.9	3.1	66	34	43	57	0.4	3	7	2
12	N-P-K H	9.6	7.2	2.4	75	25	56	44	0.5	3	4	3
13	B.C.M. L	9.9	7.6	2.3	76	24	51	49	0.8	3	5	3
14	B.C.M. H	12.1	9.5	2.6	79	21	56	44	0.7	4	4	4
15	Sewage Sludge H	12.3	9.1	3.2	74	26	53	47	0.8	3	5	3
16	Control	6.1	4.0	2.1	65	35	57	43	0.5	3	5	3
	L.S.D. .01	NSD	3.9	NSD	-	-	-	-	-	-	-	-

1. Results are means of treatment replications in m. tonnes/ha

2. Insect damage: Scale 1-5; 1= no damage, 5= total damage
Marketable quality= overall appearance: Scale 0-10; 0= culls, 10= excellent quality (U.S. #2)
Overall comparison; Scale 1-5; 1= best, 5= worst treatment

The soil in this test appeared to be sufficiently fertile so that fertilizer applications did not significantly increase yields. High yields from the control may also be related to the fact that 63% of roots were over 2.54 cm in diameter, the highest of all treatments. The sludge treatment produced the highest yield, but averaged only 47% roots over 2.54 cm in diameter. Stands were fairly uniform, but harvested roots were not counted. Most of the low yielding treatments were characterized by a high percentage of roots being less than 2.54 cm in diameter. Lunt (77) reported that fresh sludge generally delays germination of radishes and is associated with an increase in total soluble salts. No delay was observed here.

Although the N (L), N-P (L), N-P-K (L) treatments were not significantly different than the control, increases in foliage weight from N and K are evident. Each of the high rates, except for N-P-K, gave increases in foliage weight, while not necessarily giving increases of root weight. The B. C. M. (H) and sewage sludge (H), produced significantly higher foliage weights, total plant weights, and root weights than any of the other treatments. Planting later in the season can also affect the root:top ratio.

Root damage from cabbage maggot was a problem and the cull weights are shown in Table 18. Culls were also observed for size, shape, excessive rootlet formation, and degree of cracking. No differences due to treatment were found. The roots were also rated for certain visual characteristics such as insect damage and overall quality. The control (T1) was rated best in all cases and also had no culls. Culls comprised rotted roots, which most likely became rotted after damage to the pericycle and inner tissue from the cabbage maggot. No apparent association between fertilizer source, application rate, or yield is evident with the visual ratings.

Table 19. Mineral Analysis of Radish Roots, 1976[1].

TRT No.	Treatment	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
T1[2]	Control	2.52	.36	5.20	.54	.24	3	225	2	16	45	242
T15	Sewage Sludge H	3.45	.42	4.82	.50	.21	9	241	2	19	44	281

1. N, P, K, Ca, Mg as % dry wt., all others as p.p.m. dry wt.

2. Samples were a composite of the four plots/trt., after yield data obtained.

Analysis of the radish roots from the control and sewage sludge treatments indicate that roots from the sludge treatment were higher in N, P, Mn, Fe, B, and Al content, lower in K, Ca, Mg, and Zn, compared to the control (Table 19).

Statistical tests were not performed since the samples are a composite of all the replications.

The slightly decreased soil pH (Table 4) from the sludge may have decreased the Ca and Mg levels. The inherent low K in the sludge and the additions of N and P from the sludge may partially explain the decreased K and increased N and P.

In the soil analysis (Table 4), the Zn, Cu, and Fe levels were higher in the control, and in the radish roots, but no marked differences in any of the trace metals can be seen.

Dowdy and Larson (29) found that while the Fe and Mn content of radish roots were not affected by sludge applications, increases in Ca, Mg, Na, Cu, Cd, and B, and a decrease in P were reported. The rise in the pH (5.3 to 6.5) accompanied all three sludge rates they used and would explain the increased Ca, Mg, and Na. Le Riche (70) reported no increase in Zn in potato tubers receiving sludge applications.

Although the Zn levels were not high, the Cu levels were very low and the Zn:Cu ratio was 22.5.

Snapbeans, 1976

Yields from application of 18-24-6 (H), Org. A. C. M. (H), and sewage sludge (H) were significantly higher than the control (Table 20).

The main yield response appears to be from P when comparing treatments 8-12. There was a 0.8 m. tonnes/ha decrease in yield with N (L) compared to the control. The N (L) treatment also had the highest percentage of smallest pods, accounting for at least part of the lower yield. Although NSD, growth was also reduced compared to the control. This is the only treatment that had a lower yield than the control. There was no yield response from K, since the N-P-K (L) treatment yielded about that of N-P (L).

While nitrogen fixation is usually not very efficient with snapbeans, excessive nitrogen can depress yields. Yield responses to the higher rates of fertilizer were not consistent with their comparable lower rates, and both increases and reductions were found.

Additional measurements taken on growth and yield responses from fertilizer treatments indicate N. S. D. for most of them. Both the sewage sludge and Org. A. C. M. (H) produced significantly taller plants than the control. Excessive plant height and foliage can depress yields. However, while the average pod weight was N. S. D. between any treatments, sewage sludge and Org. A. C. M. (H) also had high yields compared to all the other treatments. The lowest yielding treatments, N (L) and the control, also had the shortest plants.

Sewage sludge and the other organic materials did not detrimentally affect emergence and stands.

Sweet Corn, 1976

Yields from all treatments, except the P-K treatment, were

Table 20. Effect of Fertilizer Treatments on Yield and Other Characteristics of Snap Beans, 1976[1].

TRT No.	Treatment	Yield	% Sieve Size[2] 1-2	3	4	5	6&7	1-4	Growth Measurements: Leaf Area Index	Plant Ht. mm.	Average Plant Wt. (grams)	Average Pod Wt. (grams)	Average Stem & Foliage (gram) Wt.	% Emergence
1	Control	10.2	18.7	16.4	34.9	25.7	4.3	70.0	1.9	43.7	110.0	64.6	45.4	78.5
2	15-20-15 L	12.1	11.3	14.3	33.7	34.1	6.6	59.3	2.2	47.3	134.9	83.9	51.0	87.6
3	15-20-15 H	10.8	17.0	14.0	29.1	30.8	9.1	60.1	2.4	48.4	124.7	66.9	57.8	77.3
4	18-24-6 L	11.9	14.5	13.6	32.6	30.9	8.4	60.7	2.0	46.3	122.5	76.0	46.5	86.3
5	18-24-6 H	15.9	12.8	11.8	27.8	37.3	10.4	52.4	2.9	47.4	141.8	82.8	59.0	85.2
6	Org A.C.M. L	11.5	18.5	16.2	31.5	26.4	7.4	66.2	2.4	48.6	122.5	71.4	51.0	86.7
7	Org A.C.M. H	13.7	15.1	17.3	31.8	30.8	4.9	64.2	2.3	50.0	117.9	56.7	61.2	90.7
8	N L	9.4	27.0	21.8	34.4	15.0	1.8	83.2	1.8	42.1	83.9	45.4	38.6	86.8
9	N-P L	12.5	15.5	16.2	33.4	28.8	6.1	65.1	2.1	46.9	115.7	71.4	44.2	86.4
10	N-P-K L	12.6	14.7	15.5	35.5	29.4	4.9	65.7	2.1	45.5	121.3	68.0	53.3	87.7
11	P-K	11.3	11.5	14.1	35.3	33.6	5.4	60.9	1.7	46.6	102.1	64.6	37.4	85.6
12	N-P-K H	11.7	16.9	14.0	31.2	30.5	7.4	62.1	2.0	48.1	105.5	56.7	48.8	90.0
13	B.C.M. L	13.2	17.9	14.1	31.5	30.8	5.6	63.5	2.4	46.7	129.3	70.3	59.0	89.9
14	B.C.M. H	10.5	16.9	14.9	30.0	32.2	5.9	61.8	2.5	45.5	130.4	70.3	60.1	80.2
15	Sewage Sludge H	14.0	13.7	14.2	34.3	32.7	5.1	62.2	2.4	49.2	141.8	85.1	56.7	89.3
16	Control	9.9	17.0	15.8	33.9	29.4	3.9	66.7	1.7	45.2	91.9	63.5	28.4	87.1
	LSD .01	3.3	9.2	5.6	NSD	12.7	NSD	-	NSD	5.3	NSD	NSD	NSD	NSD

1. Results are means of Treatment replications, yield in m.tonnes/ha.
2. Results are means of two replications graded together.
3. Date of 50% bloom: 8-5-76.

Table 21. Effect to Fertilizer Treatments on Yield and other Characteristics of Sweet Corn, 1976 [1]

		Mean Plant[2]		Laboratory Data[3]					Culls			Good Ears		
TRT No.	Treatment	Ht. (Meter) A	B	% Cutoff A	B	% Moisture A	B	Gross Wt.	No. ears/ha	Total Wt.	gram/ ear	No Ears/ha	Total Wt.	gram/ ear
1	Control	1.1	2.0	53.9	54.0	70.9	70.4	28.1	18,030	2.1	117	75,348	17.0	226
2	15-20-15 L	1.3	2.2	54.3	54.6	72.2	69.0	37.0	19,913	2.4	121	93,109	24.0	258
3	15-20-15 H	1.3	2.0	52.9	-	73.5	-	38.1	31,485	3.5	111	92,840	22.7	245
4	18-24-6 L	1.2	2.1	54.2	54.8	71.1	70.3	36.6	18,299	2.2	120	97,414	23.4	240
5	18-24-6 H	1.2	2.1	53.4	-	72.4	-	39.0	26,372	3.0	114	97,145	23.7	244
6	Org A.C.M. L	1.2	2.1	53.3	54.5	73.2	70.2	35.6	18,299	2.0	109	93,647	22.0	235
7	Org A.C.M. H	1.3	2.1	55.0	-	71.7	-	36.7	20,721	2.3	111	96,876	22.6	233
8	N L	1.1	2.2	53.4	54.0	76.4	71.8	38.4	25,295	3.0	119	103,065	23.0	223
9	N-P L	1.2	2.1	52.8	54.5	72.7	70.1	35.8	15,877	2.1	132	94,723	22.3	235
10	N-P-K L	1.2	2.2	54.7	53.2	73.9	73.7	36.7	15,608	2.0	128	93,647	23.0	246
11	P-K L	1.2	2.0	52.7	54.3	70.1	69.3	25.8	23,143	2.4	104	67,275	15.2	226
12	N-P-K H	1.2	2.1	54.1	-	74.3	-	40.3	28,525	3.3	116	101,989	24.0	235
13	B.C.M. L	1.2	2.1	54.5	-	73.9	-	38.5	19,913	2.5	126	100,913	24.1	239
14	B.C.M. H	1.2	2.1	54.9	-	72.9	-	39.9	23,681	2.9	123	104,680	25.0	239
15	Sewage Sludge H	1.3	2.2	54.9	55.2	73.1	71.0	39.3	10,495	1.3	124	105,756	25.9	245
16	Control	1.1	2.0	-	-	-	-	27.1	23,143	2.8	121	69,428	15.6	225
	LSD .01	0.13	0.15	-	-	-	-	6.2	NSD	NSD	-	16,629	4.2	-

1. Results are means of treatment replications inm. tonnes/ha or number of ears/ha.
2. Plant height at A: 8-20; B10-14, 1976.
3. Two sampling dates.
4. Date of 10% silk: 9-6.

significantly higher than the control. When comparing treatments 8-12, the main yield response is from N. There appears to be no response from P or K. The increased yield is primarily from a larger number of ears per plant being produced and not from increased ear size.

Most of the high rates of fertilizer only slightly increased yields compared to their low rates except for the decrease with 15-20-15 (H). Both the number and weight of culls were N. S. D. between any treatments, with sewage sludge having the lowest.

Sewage sludge produced the highest yields of total good ears. Sludge and all the other organic treatments were significantly different from the control, resulting in increased yields. There was N. S. D. between N-P-K and any of the organics.

Plant heights differed slightly and both the control and P-K were also characterized by their shorter height and chlorotic foliage.

Although not statistically analyzed, the control and P-K treatments had the lowest percent of kernel moisture content at harvest indicating that these treatments were more mature than the others Percent cutoff did not appear to be associated with fertilizer treatments.

Table 22. Heavy Metal Analysis of Sweet Corn Grain, 1976.[1]

TRT No.	Treatment	Cd	Pb	Hg
T1	Control	0.1	1.0	0.2
T15	Sewage Sludge H	0.1	1.0	0.1

1. Reported as p. p. m.

There was no difference in the accumulation of Cd, Pb, and Hg in the sweet corn grain from control and sewage sludge treatments (Table 22). Only one composite sample was analyzed, therefore no statistical tests were performed. These results are in agreement with Dowdy and Larson (29) who reported little or no increases in the Fe, Mn, Cu, Pb, and B contents with sludge treatments.

Giordano, et al. (38) also found that Pb concentrations in sweet corn forage and grain were not affected by different rates of sewage sludge compared to the control. Usually only a plant subjected to extremely high levels of Pb will translocate it from the roots to the leaves or grain (2). With the sludge rates studied, differences would more likely be found in the roots, and would be of greater concern with root crops.

Although Cd is accumulated least in the tuber, seed and fruit as compared to vegetative tissue, Cd can accumulate in toxic quantities in the edible portion (i. e. sweet corn grain) with sewage sludge application (14). Giordano, et al. (38) did show an increase of Cd in sweet corn grain with sewage sludge compared to the control.

Table Beets, 1975

The root yield data indicate the control produced the lowest yield (Table 23). Although not statistically significant, a 1.3 m. tonnes/ha yield increase is evident with the addition of N (H). The addition of P and K in N-P-K (H) increased the yield another 1.7 m. tonnes/ha and is significantly greater than the control. Beets require fairly large amount of fertilizers and generally respond to N-P and K.

The beets responded little to only a sidedress fertilizer application without any preplant application. Sidedressing was generally not effective and depressed yields, except with the Org. B. Soybits, and the low rate of Org. A. C. M., where slight increases were found. Data from New York also shows depressed yields of beets with sidedressing (91, 105).

Table 23. Effect of Fertilizer Treatments on Yield and other Characteristics of Table Beets, 1975[1].

TRT No.	Treatment	Total Plant Wt.	Total Foliage Wt.	Total Root Wt.	% Foliage	% Roots	% size Distribution of Roots (cm. in diameter) <2.5	2.5-3.8	3.8-5.1	5.1-6.4	>6.4	Total Root Wt. 2.5-5.1 cm[2]
1	15-20-14 H	24.7	15.5	9.2	63	37	4.8	17.2	40.8	30.9	6.3	5.3
2	18-24-6 H	21.8	13.7	8.1	63	37	4.5	19.6	38.3	35.0	2.7	4.6
3	18-24-6 HS	19.0	11.7	7.3	61	39	4.5	17.9	34.4	37.3	6.0	3.8
4	Org A.C.M. L	21.7	13.4	8.3	62	38	4.5	21.3	38.7	28.5	7.0	4.8
5	Org A.C.M. LS	26.7	16.5	10.2	62	38	4.5	19.7	43.8	24.4	7.7	6.5
6	Org A.C.M. H	30.1	18.9	11.2	63	37	5.4	22.7	41.9	26.9	3.1	7.0
7	Org A.C.M. HS	28.3	18.2	10.1	64	36	5.4	22.7	39.8	29.7	2.4	6.2
8	OrgB.Soybits L	15.6	9.4	6.2	60	40	1.9	14.2	41.8	31.9	10.2	3.1
9	OrgB.Soybits LS	18.1	10.5	7.6	58	42	1.5	8.6	26.8	42.4	20.7	2.6
10	OrgB.Soybits H	16.9	10.0	6.9	59	41	2.6	7.6	27.5	49.9	12.4	2.3
11	OrgB.Soybits HS	19.5	11.6	8.0	59	41	2.8	13.3	29.1	37.2	17.6	3.5
12	N-P-K H	26.3	16.7	9.7	63	37	3.8	20.3	44.6	25.7	5.6	6.1
13	Control	17.5	10.8	6.7	62	38	4.6	23.1	38.9	28.6	4.9	4.0
14	N H	21.3	13.4	8.0	63	37	4.8	22.0	38.0	26.1	9.1	4.6
15	N-P-K HS	23.1	14.3	8.7	62	38	3.3	15.4	34.7	37.5	9.2	4.2
16	N-P-K 2S	19.7	12.3	7.4	62	38	4.0	21.5	37.5	27.8	9.2	4.2
	LSD .01	8.2	5.5	2.9	-	-	NSD	NSD	NSD	NSD	12.8	2.5

1. Results are means of treatment replications inm. tonnes/ha.

2. Premium size for canning.

The higher rate of Org. A. C. M. significantly increased the yield while the higher rate of Organic B. Soybits increased it only slightly.

Both Org. A. C. M. (H) and N-P-K (H) resulted in higher yields, with Org. A. C. M. being significantly greater than Org. B. Soybits (H). All of the Org. B. Soybits treatments produced low yields and had the lowest percent foliage and highest percent roots. They also had the lowest total plant and foliage weights. The Org. B. Soybits treatment also had a higher percent of roots > 6.4 cm. The low P and K content of the soybits may not have been adequate for growth, yet tissue analysis (Table 32) indicates adequate levels. An unknown phytotoxic agent or compound appeared to be present in the soybits which suppressed growth and resulted in poor yields of all the crops. The soybits treatments also reduced stands, resulting in greater space per plant, hence faster growth from reduced competition. Although the individual beets were larger, the reduction in the total number harvested reduced yield.

No marked differences were found in the visual ratings related to growth of beets (Table 24). The control had the smallest percentage of long beets and misshapen roots.

Table Beets, 1976

Application of N fertilizer slightly increased root yield over that of control (Table 25). There was also a slight response from P, N-P, and to a greater extent from K in N-P-K which is significantly different from the control. Only a very slight increase from P-K over the control was found.

Yield response was inconsistent and there was N. S. D. between high and low rates. There was N. S. D. between treatments within each high and low application rate. Organic A. C. M. (H), B. C. M. (L),

Table 24. Effect of Fertilizer Treatments on Plant Growth Observations and Other Characteristics of Table Beets, 1975.

TRT No.	Treatment	Plant Quality 1	Leaf Injury 2	Leaf Color 3 Younger	Leaf Color 3 Older	Visual Plant Height Comparisons 4	Color of Root 5	Shape 6	ERF 7	Long Beet %8	% of Misshapen Roots 9	% Roots w/multiple crowns10	Ave. Crown size
1	15-20-14 H	7.3	7.1	7.5	7.0	4.0	-	-	-	-	-	-	2.1
2	18-24-6 H	6.4	7.4	7.0	6.8	3.0	3.3	3.0	2.9	7.5	17.8	10.1	2.1
3	18-24-6 HS	6.5	6.9	7.0	6.6	3.0	3.1	3.0	3.0	10.6	24.2	12.4	2.1
4	Org A.C.M. L	6.4	6.4	7.0	6.5	4.0	3.3	2.9	3.0	5.9	12.0	9.8	2.2
5	Org A.C.M. LS	6.9	6.9	7.3	7.0	3.0	2.9	3.0	3.0	7.9	17.0	8.7	2.1
6	Org A.C.M. H	7.4	7.3	7.3	7.0	5.0	3.4	2.9	3.0	6.2	11.1	4.2	2.0
7	Org A.C.M. HS	6.6	6.6	6.9	6.6	4.0	3.0	3.0	3.0	7.2	12.2	6.1	2.2
8	OrgB.Soybits L	6.1	6.4	7.1	6.5	3.0	3.1	2.9	2.9	10.3	19.2	9.2	1.8
9	OrgB.Soybits LS	7.1	6.8	7.3	6.8	3.0	2.9	3.0	3.0	9.8	18.8	22.8	2.1
10	OrgB.Soybits H	6.5	7.3	7.4	6.8	3.0	3.0	3.1	3.0	7.1	22.6	29.9	1.7
11	OrgB.Soybits HS	6.9	7.4	7.1	7.0	4.0	3.0	2.6	3.0	10.2	20.7	17.7	2.2
12	N-P-K H	7.1	7.6	7.4	7.3	4.0	3.4	3.0	2.9	11.0	15.5	7.3	2.1
13	Control	6.5	6.6	7.0	6.6	3.0	3.0	3.0	2.9	3.6	7.7	14.1	2.1
14	N H	6.5	7.0	7.3	7.1	3.0	3.4	3.0	3.0	9.4	14.1	24.1	2.2
15	N-P-K HS	7.1	7.4	7.4	7.1	4.0	3.0	3.0	2.5	9.2	10.8	18.9	2.1
16	N-P-K 2S	6.5	7.3	7.1	6.9	3.0	3.5	2.9	3.0	4.8	13.9	12.5	2.1

1. Overall appearance, including color of the foliage, vigor, degree of disease-free foliage and general plant health. Scale 1-10; 1= very poor; 10= excellent.
2. Injury from N Scale 1-10; 1= death, 10= no injury.
3. Based on the intensity of green color. Scale 1-10, 1= chlorotic, 10= excellent
4. Each plot compared to others per replication. Scale 1-5, 1= smallest, 5= largest
5. Internal zoning color differences. Scale 1-5, 1= distintive zoning, 5= inconspicuous zoning.
6. Shape based on conformity to cultivar, particularly bottom half of the root. Scale 1-5, 1=undersirable, 5=optimum
7. Excessive rootlet formation. Scale 1-5, 1= excessive, 5= none
8. Beet length > width by 19 mm.
9. % of misshapen beetroots, including long beets from all harvested beets within 2.54 - 3.8 cm
10. From all harvested beets within 2.54 - 3.8 cm.
11. B deficiency was not noted in any treatments.

Table 25. Effect of Fertilizer Treatments on Yield and Other Characteristics of Table Beets, 1976[1].

TRT No.	Treatment	Total Plant Weight	Total Foliage Weight	Total Root Weight	% Foliage	% Roots	Total Number of Roots
1	Control	22.1	13.1	9.1	59	41	279313
2	15-20-15 L	29.6	18.6	11.1	63	37	286488
3	15-20-15 H	29.9	19.0	11.0	63	37	245488
4	18-24-6 L	26.8	16.0	10.8	60	40	282900
5	18-24-6 H	32.8	21.6	11.2	66	34	287000
6	Org A.C.M. L	28.2	17.0	11.2	60	40	314163
7	Org A.C.M. H	34.2	21.5	12.7	63	37	302375
8	N L	28.4	18.1	10.3	64	36	283925
9	N-P L	28.2	17.5	10.7	62	38	309038
10	N-P-K L	31.2	18.8	12.5	60	40	272138
11	P-K	26.0	16.7	9.3	64	36	306475
12	N-P-K H	27.3	17.1	10.2	63	37	244975
13	B.C.M. L	35.0	21.5	13.5	61	39	299813
14	B.C.M. H	32.7	20.9	11.8	64	36	315700
15	Sewage Sludge H	32.9	20.2	12.7	61	39	314675
16	Control	22.1	13.6	8.6	61	39	275725
	L.S.D. .01	8.5	6.0	3.1	-	-	NSD

TRT No.	Treatment	% of Total Weight Size Distribution of Roots (cm in diameter)					% Numbers of Total Roots					Total Wt Roots	Total Number Roots
		2.5	2.5-3.8	3.8-5.1	5.1-6.4	6.4	2.5	2.5-3.8	3.8-5.1	5.1-6.4	6.4	2.5-5.1	2.5-5.1
1	Control	4.7	24.8	47.3	19.8	3.5	31.5	32.3	28.7	6.7	0.9	6.4	169638
2	15-20-15 L	4.3	19.9	40.5	30.2	5.1	29.8	30.4	27.6	10.9	1.4	6.6	166563
3	15-20-15 H	3.2	15.0	33.7	38.6	9.4	25.9	26.6	27.9	17.0	2.6	5.4	133250
4	18-24-6 L	5.7	21.3	38.9	27.1	7.1	33.0	30.1	24.8	10.2	1.9	6.3	155288
5	18-24-6 H	4.6	22.4	36.5	24.9	11.6	31.7	33.4	22.6	9.4	2.9	6.4	159388
6	Org. A.C.M. L	4.2	23.2	46.8	23.3	2.6	29.3	33.5	28.6	8.1	0.5	7.9	194750
7	Org. A.C.M. H	3.6	20.3	32.9	35.2	8.0	29.0	31.6	23.9	13.9	1.7	6.7	167588
8	N L	4.1	19.8	51.8	22.6	1.8	29.3	29.9	32.3	7.7	0.8	7.4	177325
9	N-P L	6.4	28.7	38.1	18.2	8.8	33.4	35.3	22.5	6.5	2.3	6.8	180400
10	N-P-K L	2.7	17.4	37.8	32.9	9.2	25.6	29.4	28.6	14.0	2.4	6.9	156825
11	P-K	7.4	27.2	37.4	24.3	3.7	38.8	33.4	20.1	6.9	0.8	6.1	166050
12	N-P-K H	3.4	18.7	36.9	35.5	5.5	28.0	31.0	26.1	13.5	1.4	5.6	139913
13	B.C.M. L	2.6	17.5	38.2	32.6	9.2	24.6	30.9	28.4	13.9	2.3	7.6	179888
14	B.C.M. H	4.3	20.4	38.4	33.1	3.8	30.5	31.1	25.7	11.7	1.0	6.9	176813
15	Sewage Sludge H	3.8	21.0	37.8	28.9	8.6	27.8	33.0	24.9	12.0	2.3	7.3	181425
16	Control	5.6	25.9	50.3	17.0	1.2	29.9	34.1	29.6	5.6	0.8	6.5	171175
	L.S.D. .01	NSD	NSD	10.9	14.2	NSD	NSD	NSD	NSD	7.2	NSD	NSD	NSD

1. Results are means of treatment replications in m. tonnes/ha and number of roots/ha.

and sewage sludge (H), were all significantly different from the control. The yields of the other organics were slightly lower.

Similar trends in response to fertilizer are seen in the total plant weight. Stands were uniform and there was N.S.D. in total number of harvested roots.

The control (T1), aside from being the lowest in yield, also had the lowest plant weight, total foliage weight, and the greatest percent roots:foliage.

Tomatoes, 1975

There was N.S.D. between treatments in the gross yield of tomato fruit, indicating that the level of soil fertility appeared adequate without fertilization (Table 26). Although not significant, there was a 2.5 m. tonne increase from nitrogen application. Slight yield responses were achieved from the application of N-P-K (H) as compared to N alone.

With only a sidedressing and not a preplant fertilizer application rate, a large depression in yield resulted compared to the preplant N-P-K (H) and (HS), and the control. Sidedressing also adversely affected yield in both the low and high preplant applications of the other treatments. The exception was Org. B. Soybits (H) and Org. A. C. M. (H) which slightly increased yields. High levels of nitrogen during bloom with tomatoes can reduce fruit set. When nitrogen is provided by translocation within the plants and not from the soil, more uniform fruit ripening and no significant yield loss will result (73).

The higher rates of both organics depressed yields. Comparing different nutrient sources with the (H) and (HS) rates, N.S.D. were found, although the Org. B. Soybits had the lowest yield.

Greater differences were seen in marketable yield, although the general trend was similar to the gross yield. Sidedressing

Table 26. Effect of Fertilizer Treatments on Yield of Tomatoes, 1975[1].

TRT No.	Treatment	Gross Yld.[2]	Marketable Yield[3]	Total Cull Wt.	Total Number Culls/ha	% of Gross Yield H1	H2	H3	H4	Marketable Fruit H1-H4	Cull Wt. H1-H4	% of Marketable Yield H1	H2	H3	H4
1	15-20-14 H	73.4	61.4	12.0	104649	0.5	6.2	25.1	68.3	83.1	16.9	0.6	6.4	28.9	64.2
2	18-24-6 H	72.2	63.0	9.2	73595	0.8	6.4	24.1	68.7	87.0	13.0	0.9	6.9	27.4	64.8
3	18-24-6 HS	61.2	48.8	12.3	101418	0.5	4.5	25.9	69.1	79.8	20.2	0.6	4.6	30.5	64.4
4	Org A.C.M. L	69.0	57.5	11.5	98007	0.7	6.4	24.4	68.5	83.2	16.8	0.8	6.6	28.1	64.5
5	Org A.C.M. LS	67.1	55.5	11.6	92443	1.2	5.8	24.3	68.7	82.6	17.4	1.4	6.2	27.7	64.8
6	Org A.C.M. H	68.1	60.5	7.6	74134	0.5	6.2	25.3	67.9	88.6	11.4	0.6	6.3	28.1	65.0
7	Org A.C.M. HS	69.3	57.9	11.5	98007	1.0	6.7	25.5	66.8	83.6	16.4	1.2	6.8	29.4	62.7
8	OrgB.Soybits L	65.4	53.3	12.1	101777	0.6	6.2	25.6	67.7	81.2	18.8	0.8	6.3	29.9	63.0
9	OrgB.Soybits LS	63.9	51.7	12.2	102315	0.8	5.5	25.2	68.5	80.9	19.1	1.0	5.4	29.6	64.0
10	OrgB.Soybits H	62.2	52.5	9.7	79339	0.7	5.7	23.7	69.9	84.8	15.2	0.8	5.2	27.4	66.5
11	OrgB.Soybits HS	62.2	52.7	9.5	77724	0.7	5.3	23.3	70.7	84.3	15.7	0.8	5.3	25.7	68.2
12	N-P-K H	68.0	58.9	9.1	75211	0.8	7.4	28.9	62.9	86.8	13.2	0.9	7.8	32.3	59.1
13	Control	65.1	54.5	10.6	96033	0.6	6.6	30.3	62.4	83.7	16.3	0.8	6.0	34.4	58.8
14	N H	67.6	57.3	10.3	86340	1.2	6.0	25.4	67.5	84.6	15.4	1.3	6.1	28.9	63.7
15	N-P-K HS	66.3	52.3	14.0	116855	0.8	7.1	24.6	67.5	78.8	21.2	1.0	7.8	29.8	61.5
16	N-P-K 2S	55.2	43.9	11.3	93879	1.1	6.4	19.6	72.9	79.7	20.3	1.4	6.4	22.7	69.6
	LSD .01	NSD	5.4	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD

1. Results are means of treatment replications in m. tonnes/ha or number of fruit/ha.

2. Yield= H1 - H3 ripe fruit harvested.
   H4 - everything >2.54 cm in diameter harvested. Includes ripe and green fruit.

3. Includes cracked fruit.

significantly depressed yields in the N-P-K and 18-24-6 treatments. Greater yield depression from sidedressing with the mineral fertilizers may have been because of their greater availability and more rapid solubility for plant uptake.

Significant differences in marketable yield that were not found in gross yield can be accounted for by the greater number and weight of culls (i.e., from N-P-K) and the already large differences that did exist in gross yields.

A similar conclusion is reached as with gross yield when comparing different nutrient sources of (H) and (HS) rates on marketable yield. The Org. B. Soybits treatments were significantly different from several of the other treatments. They were significantly lower in marketable yield than both Org. A. C. M. (H), (HS), and N-P-K (H). The treatment 18-24-6 (HS) was significantly lower in marketable yield compared to all the other (H) and (HS) treatments.

Early fruit maturation at the first harvest was not influenced differently by treatments.

The control treatment usually averaged slightly lower than the other treatments in most of the plant growth ratings (Table 27), and could easily be distinguished in the field by its lighter color foliage.

Sources of nutrient elements had little effect on the nutritional components of the tomato fruit (Table 28). Calcium was increased by both organic materials over the N-P-K (H) and control treatments. Phosphorus content in the fruit was positively related to the amount of P applied to the soil. The control had the highest Fe concentration in the fruit, but not in the vegetative tissue sampled earlier in the season (Table 35). The lower Fe content from Org. A. C. M. (H) may have been due to a greater amount of organic matter tieing up the Fe, yet vegetative tissue sampled earlier resulted in comparable Fe contents between treatments.

Table 27. Effect of Fertilizer Treatments on Plant Growth Observations of Tomatoes, 1975[1]

TRT No.	Treatments	Plant Quality[2]	Leaf Injury[3]	Foliage Color[4]		Visual Plant Comparisons[5]	
				Upper	Lower	Height	Spread
1	15-20-14 H	7.9	8.2	7.6	8.5	4.5	4.2
2	18-24-6 H	7.5	8.2	7.5	8.5	4.8	4.0
3	18-24-6 HS	7.7	8.2	7.7	8.8	4.5	4.3
4	Org A.C.M. L	7.1	7.6	7.1	8.2	4.2	4.1
5	Org A.C.M. LS	7.1	7.9	6.9	7.9	3.7	4.0
6	Org A.C.M. H	7.5	7.9	7.4	8.4	4.4	4.1
7	Org A.C.M. HS	7.4	8.4	7.3	8.5	4.3	4.4
8	OrgB.Soybits L	7.3	7.7	7.3	8.5	4.3	4.0
9	OrgB.Soybits LS	7.2	7.9	7.3	8.2	4.4	4.2
10	OrgB.Soybits H	7.3	7.7	7.5	8.4	4.2	4.0
11	OrgB.Soybits HS	7.3	8.1	7.4	8.5	4.2	4.4
12	N-P-K H	7.8	8.3	7.5	8.4	4.3	4.3
13	Control	6.5	8.3	6.3	7.4	3.5	3.9
14	N H	7.6	7.7	7.7	8.7	4.4	4.0
15	N-P-K HS	8.1	7.7	7.7	8.7	4.8	4.2
16	N-P-K 2S	7.2	8.2	7.0	7.9	4.0	4.1
	LSD .01	-	-	-	-	-	-

1. Results are means of treatment replications of four observation dates.
2. Overall appearance, including color of foliage, vigor, degree of disease-free foliage and general plant health. Scale 1-10. 1= very poor; 10= excellent.
3. Injury from N. Scale 1-10. 1= death; 10= zero injury.
4. Based upon the intensity of green color. Scale 1-10. 1= chlorotic, 10= excellent.
5. Each plot compared to others within each replication. Scale 1-5. 1= smallest, 5= largest.

Table 28. Effect of Selected Fertilizer Treatments on the Nutritional Quality of Tomato Fruits, 1975[1].

TRT No.	Treatment	Size, cm.	pH[2]	Percent Moisture[2]	Calcium[3] %	Calcium[3] mg/100gm	Phosphorus %	Phosphorus mg/100gm	Iron %	Iron mg/100gm	Ascorbic Acid[4] mg/100g fresh	Ascorbic Acid[4] mg/100g solids
6	Org A.C.M. H	5.1-6.4	4.36	94.89	0.12	120	0.12	120	0.005	5	16.39	321.92
6	Org A.C.M. H	6.4-7.6	4.31	--	--	--	--	--	--	-	16.50	--
10	OrgB.Soybits H	5.1-6.4	4.26	95.06	0.12	120	0.10	100	0.006	6	16.45	331.98
10	OrgB.Soybits H	6.4-7.6	4.38	--	--	--	--	--	--	-	16.34	--
12	N-P-K H	5.1-6.4	4.31	95.08	0.10	100	0.11	110	0.006	6	16.34	333.74
12	N-P-K H	6.4-7.6	4.35	--	--	--	--	--	--	-	16.50	--
13	Control	5.1-6.4	4.28	94.94	0.10	100	0.08	80	0.010	10	19.52	382.75

1. Tomatoes from H2. 9-24-75.
2. Analyzed by Dr. Z. A. Holmes, Dept. Foods and Nutrition, O.S.U.
3. Mineral content analyzed by the Dept. Agricultural Chemistry, Ca, P, Fe on dry weight basis.
4. Analyzed by Dr. Miller, Dept. Foods and Nutrition, O.S.U.

The ascorbic acid content did not vary from application of any of the fertilizers. This was expected, since the content is principally determined by the amount of illumination reaching the fruit and will vary from both the fruit position on the plant and within the individual fruit. Fertilizer can influence the ascorbic acid by its influence on plant growth (i. e., excessive foliage growth shading the fruit).

Fruit from the control had the greatest amount of ascorbic acid and this may be a reflection of less vegetative growth produced, therefore less shade and a greater amount of light.

In addition to the tomato fruit nutritional analyses, fruit of tomatoes and bell peppers were evaluated for both flavor differences and overall desirability. The results (Table 29) indicate that there were N. S. D. at the L. S. D. .05 in the flavor evaluation due to fertilizer treatments.

Table 29. Flavor Evaluation: Bell Peppers and Tomatoes, 1975[1].

			Green Bell Peppers		Tomatoes	
TRT No.	Treatment		Reference - Difference[2]	Overall Desirability[3]	Reference - Difference	Overall Desirability
T5	Org. A, C, M,	LS	5.86	5.30	6.02	4.90
T9	Org. B.	LS	6.14	5.58	5.94	4.80
T13	Control		6.20	5.56	5.92	5.04
T15	N-P-K	HS	5.88	5.28	5.84	4.76
	L. S. D. .05[4]		NSD	NSD	NSD	NSD

1. Date tested Green Bell Peppers: 9-22-75; Tomatoes 9-29-75.

2. Score range: 1-7; 7: same flavor, 1: extremely different flavor.

3. Score range 1-7; 7: very desirable, 1: very undesirable.

4. Analyzed by a 3 factor analysis of variance with TXJ, RXJ, and TXRXJ as the error term with 168 df. (J: judges, 25; T: treatments, 4; R: replications, 2).

Tomatoes, 1976

Responses from N, P, and K were much more striking than in 1975, since the soil had initially lower exchangeable cations (Tables 3 and 4).

There was a large, but N. S. D. response in gross yield from N, and lesser responses from P and K when combined with nitrogen (Table 30). The treatments N-P (L), N-P-K (L) and (H) were significantly greater than the control. The application of P-K, without N, resulted in a depression of yield significantly lower than with N-P-K, and less than the control.

Excessive nitrogen fertilization is known to depress tomato yields. The higher rate of N-P-K yielded > 13 m. tonnes less than the lower rate. However, when comparing all the low vs. high rates of all other treatments, gross yields were greater at the higher rates, though not significant.

When comparing different nutrient sources at both the low and high rates they were N. S. D. from each other, and all were significantly different from the control. The increase in yield is due to a greater number of fruit per plant. The higher yielding treatments also had greater mean plant weights. The low gross yield of the control and P-K is due to insufficient N and tissue analysis (Table 36) indicates low N and K levels. The foliage was also somewhat chlorotic.

Less marked differences are found in marketable yield, where the combinations of N-P-K were N. S. D. from the control. When comparing the low vs. high, or the different nutrient sources at the low and high rate, N. S. D. were found.

The differences found in the gross yield, but not found in the marketable yield, are because of the wide range of responses of the green fruit or potential yield. Many of the organics that had quite

Table 30. Effect of Fertilizer Treatments on Yields of Tomatoes, 1976.[1]

TRT No.	Treatment	Gross Yield[2]	Marketable[3] Yield	Green Fruit Yield	# Fruit of Gross	# Fruit of Marketable	# Fruit of Green	Mean Plant wt. kg.
1	Control	69.6	43.4	26.3	558831	277771	281060	1.3
2	15-20-15 L	103.3	52.7	50.6	894608	344149	550459	2.2
3	15-20-15 H	118.7	62.5	56.2	1101217	431158	670059	2.4
4	18-24-6 L	99.8	55.8	44.0	889226	377637	511589	1.8
5	18-24-6 H	104.4	59.1	45.3	994773	389298	605475	2.5
6	Org A.C.M. L	95.5	58.6	37.0	805207	365079	440128	1.8
7	Org A.C.M. H	111.2	54.0	57.2	978627	335777	642850	2.7
8	N L	91.2	41.2	50.0	824044	260429	563615	1.9
9	N-P L	101.0	61.3	32.7	845572	400660	444912	2.1
10	N-P-K L	113.9	62.8	51.1	1004341	426972	577369	2.3
11	P-K	68.6	50.0	18.6	561821	330096	231725	1.3
12	N-P-K H	100.1	47.6	52.6	914342	316641	597701	2.1
13	B.C.M. L	111.2	58.0	53.2	924209	361491	562718	2.3
14	B.C.M. H	114.6	49.6	64.9	1048892	344448	704444	2.5
15	Sewage Sludge H	111.0	48.2	62.8	988195	296010	692185	2.5
16	Control	79.9	54.1	25.8	673946	354913	319033	1.4
	L.S.D. .01	24.3	20.4	23.1	210420	NSD	244615	0.7

TRT No.	Treatment	Mean Fruit wt. grams		% of Total Gross Yield of				% of Total Gross wt. of			
		Gross	Marketable	H1	H2	H3	Green Fruit	H1	H2	H3	Green Fruit
1	Control	125	156	1.4	23.2	38.3	37.1	1.2	18.2	31.8	48.8
2	15-20-15 L	116	153	0.8	19.9	30.4	49.0	0.6	14.2	24.9	60.3
3	15-20-15 H	108	145	0.7	19.6	33.3	46.5	0.4	13.4	26.6	59.7
4	18-24-6 L	112	148	1.7	21.8	33.5	43.0	1.1	15.7	26.4	56.8
5	18-24-6 H	105	152	1.2	20.2	35.4	43.1	0.9	14.3	23.9	61.0
6	Org A.C.M. L	119	161	2.5	24.5	34.9	38.1	1.7	17.1	26.7	54.4
7	Org A.C.M. H	114	161	0.3	16.8	31.3	51.5	0.2	11.0	23.4	65.3
8	N L	111	158	1.3	17.3	27.0	54.4	1.0	11.2	19.5	68.3
9	N-P L	120	153	0.8	24.9	33.9	40.3	0.7	18.7	29.1	51.6
10	N-P-K L	113	147	1.0	21.1	33.5	44.4	0.8	14.3	27.9	57.0
11	P-K	122	152	2.0	34.8	34.9	28.3	1.5	25.8	30.5	42.2
12	N-P-K H	110	150	1.0	17.9	28.1	53.1	0.9	12.2	21.4	65.6
13	B.C.M. L	120	161	1.0	18.2	33.3	47.4	0.9	13.8	25.2	60.1
14	B.C.M. H	109	144	0.6	13.6	29.7	56.2	0.5	10.6	22.0	66.8
15	Sewage Sludge H	112	163	1.1	13.4	28.6	56.9	0.7	9.8	19.4	70.2
16	Control	119	152	2.5	28.4	36.5	32.7	1.9	19.6	31.2	47.3
	L.S.D. .01	-	-	NSD	12.2	NSD	17.9	NSD	10.0	10.4	18.2

1. Results are means are treatment replications in m. tonnes/ha or number of fruit/ha.
2. Includes both marketable and green fruit.
3. All fruit harvested at H1=ripe stage; H2= pink stage; H3= any physiologically mature. Includes cracked fruit.
4. All fruit > 2.54 cm. at final harvest not physiologically mature.

Table 31. Effect of Fertilizer Treatments on Tomato Fruit Characteristics, 1976[1].

TRT No.	Treatment	% of H1 of Fruit Wt. in cm. Cull	$<1\frac{1}{2}$	$1\frac{1}{2}$-3	> 3	% of H1 of Number of Fruit in cm. Cull	$<1\frac{1}{2}$	$1\frac{1}{2}$-3	> 3	Average Fruit Weight by Harvest (grams) H1	H2	H3	Green Fruit	Av.[2]
1	Control	28.4	0	58.8	12.7	25.8	0	63.1	11.1	152	163	152	94	140
2	15-20-15 L	0	0	59.9	40.1	0	0	67.8	32.2	149	167	146	92	139
3	15-20-15 H	12.0	0	58.2	29.8	17.1	0	63.8	19.1	178	162	136	84	140
4	18-24-6 L	2.4	0	48.4	49.2	3.9	0	62.2	33.8	178	151	145	86	140
5	18-24-6 H	17.9	0	57.3	24.9	12.5	0	69.2	18.3	154	147	154	75	133
6	Org A.C.M. L	15.0	0	60.7	24.3	15.6	0	65.6	18.8	167	168	156	84	144
7	Org A.C.M. H	27.5	0	51.7	20.8	28.3	0	55.0	16.7	143	175	154	89	140
8	N L	4.8	0	74.1	21.2	3.3	0	83.4	13.3	143	169	152	89	138
9	N-P L	11.2	0	73.6	15.2	8.3	0	82.5	9.2	151	168	144	89	138
10	N-P-K L	1.8	0	80.3	17.9	1.8	0	87.1	11.2	142	174	134	89	135
11	P-K	8.1	0	58.9	33.0	14.1	0	61.8	24.1	160	168	138	80	137
12	N-P-K H	4.4	0	74.2	21.4	5.6	0	80.0	14.4	129	161	145	88	131
13	B.C.M. L	7.5	0	77.2	15.3	7.7	0	83.3	8.9	142	164	160	95	140
14	B.C.M. H	4.9	0	52.9	42.1	5.6	0	63.9	30.6	130	140	147	92	127
15	Sewage Sludge H	5.6	0	61.9	32.5	8.6	0	72.6	18.8	175	157	166	91	147
16	Control	14.1	0.8	49.4	35.7	13.0	2.2	58.6	26.2	156	173	139	81	137
	L.S.D. .01	-	-	-	-	-	-	-	-	-	-	-	-	-

TRT No.	Treatment	Total Marketable Fruit Weight at H1	H2	H3	Green Fruit	Total Number of Fruit/ha at H1	H2	H3	Green Fruit	Total # Culls/ha H1 and H2
1	Control	1.0	15.9	26.4	26.3	6578	97773	173420	281060	14950
2	15-20-15 L	0.8	20.6	31.4	50.6	5382	123188	215579	550459	10764
3	15-20-15 H	0.8	22.3	39.4	56.2	4485	137839	288834	670059	26013
4	18-24-6 L	1.7	20.0	34.1	44.0	9568	132158	235911	511589	16445
5	18-24-6 H	1.2	20.4	37.5	45.3	7774	138437	243087	605475	19136
6	Org A.C.M. L	2.3	23.2	33.1	37.0	13754	138437	212888	440128	18538
7	Org A.C.M. H	0.3	18.7	34.9	57.2	2093	107042	226642	642850	19435
8	N L	1.2	15.6	24.3	50.0	8372	92092	159965	563615	8372
9	N-P L	0.9	25.7	34.7	39.7	5980	153387	241293	444912	29601
10	N-P-K L	1.1	23.7	38.0	51.1	7774	136344	282854	577369	22126
11	P-K	1.1	24.6	24.3	18.6	6877	146809	176410	231725	23920
12	N-P-K H	1.0	17.9	28.7	52.6	7774	111228	197639	597701	13455
13	B.C.M. L	1.1	19.9	37.1	53.2	7774	121394	232323	562718	14651
14	B.C.M. H	0.7	15.4	33.5	64.9	5382	110331	228735	704444	22724
15	Sewage Sludge H	1.2	15.0	32.1	62.8	6877	95680	193453	692185	11661
16	Control	2.0	22.9	29.2	25.8	12857	132457	209599	319033	19435
	L.S.D. .01	NSD	NSD	12.7	23.1	NSD	NSD	94075	244615	NSD

1. Results are means of treatment replications in m. tonnes/ha or number of fruit / ha
2. Average of H1, H2, H3 and green fruit in grams.

high gross yields, but were in the mid to low range in marketable yield, had a large percent of green fruit (i.e. B.C.M. (H)). This can be seen when comparing marketable and green fruit yield and ranking the treatments from high to low.

No treatments were promotive of earlier fruit maturation, as there was N.S.D. in the first harvest, and the first flowering occurred at the same time regardless of treatments.

To obtain the maximum marketable yield under Willamette Valley conditions, it appears that the low rates of N-P-K and of the organic materials would be satisfactory.

Plant Analysis of Crops

Results of chemical analyses of plant tissues from several crops are presented in Tables 32-36. Samples from each of four replications per treatment were composited so that no statistical analyses were made. Some trends from fertilizer treatments may be evident, and may be of value in interpreting growth and yield measurements shown earlier. The data also indicate ranges or levels of composition of the nutrient elements analyzed in the plant parts sampled in these experiments and can serve as a reference for future studies.

Beets, 1975

Chemical analyses of plant tissue of beets are shown in Table 32 and were not consistently related to fertilizer applications. For example, N content ranged from 3.94 to 4.70 percent with the control having 4.44 percent N. Both application rates and time of application do not show consistent results in affecting the N content. Yet, the higher rates generally resulted in higher N and K and lower P levels.

Table 32. Effect of Fertilizer Treatments on the Mineral Content of Table Beet Leaves, 1975[1]

TRT No.	Fertilizer Treatment	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	15-20-14 H	4.37	3.66	.32	1.20	1.49	193	132	9	33	55	46
2	18-24-6 H	4.66	3.73	.36	1.15	1.33	167	154	10	40	57	75
3	18-24-6 HS	4.63	3.76	.33	1.22	1.43	199	141	9	40	56	53
4	Org.A.C.M. L	4.11	3.83	.39	1.16	1.29	141	137	10	45	61	47
5	Org.A.C.M. LS	4.31	3.65	.33	1.14	1.13	120	137	9	41	57	53
6	Org.A.C.M. H	4.37	3.86	.34	1.11	1.20	123	165	10	44	59	73
7	Org.A.C.M. HS	4.31	3.63	.32	1.30	1.39	136	170	10	43	60	72
8	Org.B.Soybits L	4.63	3.99	.36	1.25	1.28	162	203	10	44	67	109
9	OrgB.Soybits LS	4.53	3.98	.37	1.24	1.35	158	180	11	44	62	83
10	OrgB.Soybits H	4.70	4.07	.31	1.31	1.29	150	175	10	41	62	103
11	OrgB.Soybits HS	4.50	3.57	.32	1.25	1.36	155	165	10	38	58	70
12	N-P-K H	3.94	3.59	.28	1.30	1.56	208	120	8	41	49	43
13	Control	4.44	3.96	.37	1.15	1.06	131	131	8	40	58	48
14	N H	4.31	3.69	.28	1.27	1.34	142	143	9	31	51	65
15	N-P-K HS	4.70	3.54	.31	1.31	1.52	259	127	9	36	55	34
16	N-P-K 2S	4.02	3.35	.30	1.21	1.34	137	135	10	38	54	48

1. Sampling date: 7-30-75

N, K, P, Ca, Mg as % dry wt.
Mn, Fe, Cu, B, Zn, Al as ppm. dry wt.

With some of the elements (i.e. Mn and Al) large differences in range across the treatments were found, but they show no apparent relationship to the treatments.

Cucumbers, 1975

Analysis of cucumbers shown in Table 33 indicate that the high and low rate of the organic products show inconsistent results and the range between them is small. The preplant and sidedress applications for the selected treatments also shows inconsistency. The range of values was close for N (5.21 - 6.12), K (2.54 - 2.94), P (.50 - .60) and Ca (3.11 - 3.73).

The control had the lowest N levels at both sampling dates except for Org. A. C. M. (H), which had a slightly lower N level at the first sampling date. Highest N content at the first sampling date was from N-P-K (2S) (6.12 percent N) and this may be a result of the recently applied high rate of sidedressing application.

No consistent differences can be observed for concentrations of the trace elements. The Fe and Al content of N-P-K (2S) at the first sampling date was about two times the amount of any of the other treatments and of the same treatment at the second harvest date. This may be from contamination.

At the second sampling date, N, P, K, Cu, and Zn levels decreased, while Ca, Mg, Mn, Fe, B, and Al increased, compared to the first sampling date.

As plants mature, large amount of N, P, K, and carbohydrates are known to be exported and translocated to meristematic parts and so decrease with age. In contrast, calcium tends to increase with age. An Arkansas study (17), reported 0.32 - 0.45 percent P and 2.7 to 3.5 percent K dry weight, in the oldest healthy leaves of cucumbers with the highest yield. Correspondingly, medium and low

Table 33. Effect of Fertilizer Treatments on the Mineral Content of Cucumber Leaves at Two Sampling Dates, 1975[1]

Sampling Date I: 7-30-75

TRT No.	Treatments		N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	15-20-14	H	6.01	2.70	.55	3.41	1.00	63	324	10	40	57	277
2	18-24-6	H	5.91	2.65	.50	3.32	1.04	63	493	10	39	51	552
3	18-24-6	HS	5.37	2.65	.63	3.32	1.12	77	531	13	48	75	440
4	Org.A.C.M.	L	5.37	2.77	.62	3.11	1.00	59	517	13	48	68	473
5	OrgA.C.M.	LS	5.77	2.75	.63	3.24	1.00	53	386	12	48	70	317
6	OrgA.C.M.	H	5.13	2.94	.62	3.10	1.02	54	339	12	49	68	263
7	OrgA.C.M.	HS	5.50	2.54	.57	3.61	1.07	61	440	13	46	67	368
8	OrgB.Soybits	L	5.81	2.80	.59	3.56	.93	60	485	13	47	66	410
9	OrgB.Soybits	LS	5.54	2.70	.58	3.51	.93	60	550	12	45	65	538
10	OrgB.Soybits	H	6.01	2.85	.55	3.41	.88	57	403	12	46	67	374
11	OrgB.Soybits	HS	5.91	2.70	.54	3.73	1.04	59	581	11	47	60	580
12	N-P-K	H	5.68	2.63	.57	3.52	1.04	75	567	12	46	65	536
13	Control		5.21	2.72	.60	3.46	.89	58	507	12	48	70	438
14	N	H	6.01	2.76	.58	3.48	.93	53	371	12	45	68	315
15	N-P-K	HS	5.82	2.61	.55	3.61	1.03	79	387	12	40	62	322
16	N-P-K	2S	6.12	2.56	.54	3.60	.93	73	1060	12	43	63	1196

Sampling Date II: 9-15-75

TRT No.	Treatments		N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	15-20-14	H	4.49	1.91	.39	3.64	1.19	72	434	9	59	54	532
2	18-24-6	H	4.56	2.24	.39	3.55	1.16	70	515	10	54	53	599
3	18-24-6	HS	4.76	2.16	.37	3.60	1.05	73	556	10	59	51	625
4	OrgA.C.M.	L	4.40	2.08	.39	3.68	1.17	63	573	9	60	50	656
5	OrgA.C.M.	LS	4.94	2.08	.42	3.30	1.12	65	513	9	64	55	591
6	OrgA.C.M.	H	4.18	2.10	.35	3.76	1.15	59	432	8	65	50	478
7	OrgA.C.M.	HS	4.69	1.93	.40	3.72	1.19	69	643	11	57	53	728
8	OrgB.Soybits	L	5.09	2.29	.41	3.84	1.00	70	634	10	54	52	663
9	OrgB.Soybits	LS	4.90	2.46	.42	3.75	1.01	74	626	10	53	54	724
10	OrgBSoybits	H	4.76	2.16	.42	3.59	1.09	72	619	10	56	53	676
11	OrgB.Soybits	HS	4.87	2.17	.38	3.62	1.08	66	573	9	56	50	655
12	N-P-K	H	4.98	1.90	.35	3.74	1.15	69	417	9	55	47	456
13	Control		4.04	2.22	.43	3.88	1.11	63	461	11	67	54	422
14	N	H	4.83	2.08	.40	3.58	1.19	65	507	11	51	49	560
15	N-P-K	HS	4.98	2.02	.39	3.68	1.16	102	699	11	50	50	794
16	N-P-K	2S	4.49	1.89	.37	3.75	1.13	69	617	10	55	47	695

1. N,K,P,Ca,Mg as % dry wt.; Mn, Fe, Cu, B, Zn, Al as ppm dry wt.

yielding treatments had a lower concentration of each element. Miller and Carolus, et al. (88) reported that there appeared to be little relationship between the amount of an element in the soil, and the amount found in cucumber petioles.

Snapbeans, 1976

The high application rates (H) of fertilizer generally resulted in higher levels of N, P, and K, than the lower rates (Table 34). Manganese concentration was greatest with 15-20-15 (H), B. C. M. (H) and with N-P-K (H). This is in agreement with Smith (134) who reported that Mn concentration was greatest from the highest rate of N-P-K (56 kg/ ha of N, P, K) and that Mn toxicity can result in poor responses from higher fertilizer rates. Page (101) found that heavy applications of FYM decreased the Mn concentration in the plant. The Org. A. C. M. rates had low Mn levels, while the B. C. M. had high levels. Asif and Greig (5) found that higher N applications increased K, Ca, Mg, Zn, and NO_3 in pods.

When comparing treatments 8-12, the N (L) treatment had the highest N and K. With the addition of P and K, in N-P-K (L) or as P-K, the N and K contents decreased. The highest P level (.36 percent P) resulted from the application of P-K. The control was generally lower in most elements. The organic fertilizers produced the highest Ca levels.

Peavy and Greig (104) found plant tissue concentrations of N greater and P lower in spinach fertilized with mineral compared to organic fertilizers (feedlot manure). They noted that the slow mineralization rate of N with feedlot manure could explain the difference in N uptake. This agrees with Barker's (8) study, who also found that other organic fertilizers with more rapid mineralization

Table 34. Effect of Fertilizer Treatments on the Mineral Content of Snap Bean Leaves, 1976[1]

TRT No.	Treatment	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	Control	4.11	1.99	.31	2.14	.46	39	392	6	27	32	401
2	15-20-15 L	4.29	2.13	.31	2.95	.57	104	822	8	23	42	740
3	15-20-15 H	4.54	2.24	.40	2.86	.68	303	413	6	29	44	346
4	18-24-6 L	3.68	2.18	.30	2.38	.60	70	349	6	24	42	290
5	18-24-6 H	4.11	2.44	.30	2.43	.57	133	242	6	25	55	206
6	Org A.C.M. L	3.94	2.37	.32	3.01	.58	45	413	10	25	47	376
7	Org A.C.M. H	4.32	2.64	.31	3.10	.58	40	386	7	26	47	359
8	N L	4.17	2.71	.31	2.76	.57	55	228	8	23	60	171
9	N-P L	4.11	2.31	.35	2.90	.80	109	495	15	30	51	406
10	N-P-K L	3.84	2.62	.33	2.98	.67	91	543	12	28	47	511
11	P-K	3.02	1.66	.36	2.99	.53	58	342	7	30	33	265
12	N-P-K H	4.00	2.70	.32	2.43	.58	173	215	7	28	58	169
13	B.C.M. L	3.61	2.43	.34	3.08	.60	106	479	8	24	50	413
14	B.C.M. H	4.05	2.29	.36	3.13	.63	233	493	7	25	52	422
15	Sewage Sludge H	3.84	2.41	.31	3.06	.67	50	381	8	25	61	332
16	Control	3.16	1.93	.34	2.95	.57	46	392	8	25	39	329

1. Sampling date: 8-19

N, K, P, Ca, Mg as % dry wt.

Mn, Fe, Cu, B, Zn, Al as ppm. dry wt.

rates had approximately equal N concentrations. Peavy and Greig (104) suggest that greater P levels may be due to greater availability as much of the Fe and Al that would have precipitated P, was fixed by the chelating effects of organic matter. They also reported increased Fe levels from the organic fertilizers.

No marked differences generally can be seen with trace elements. The application of sewage sludge (H) resulted in the highest Zn levels (61 ppm.), and the 15-20-15 (L) treatment resulted in the highest Al level and about two times greater Fe level than other treatments. Giordano (38) concluded that there was little or no correlation between plant uptake and soil extraction of Pb, Ni, Cr, and Zn by 0.5 NHc.

Tomatoes, 1975

In Table 35, it can be noted that the control had the lowest N and K levels, while the application of N (H) produced the lowest P level.

The high application rates are not consistent in increasing mineral contents of plants over lower rates.

Slightly higher Al levels are found from the application of Org. A. C. M. but no marked differences occurred in trace elements content because of sources or rates of fertilizer.

Tomatoes, 1976

Plant analysis of tomatoes in Table 36 show somewhat similar trends as found in 1975. Lowest N content resulted from the P-K and control treatments.

Generally, the higher rates of fertilizer application resulted in higher N and P values, but not K values, than the lower rates.

Table 35. Effect of Selected Fertilizer Treatments on the Mineral Content of Tomato Leaves, 1975[1]

TRT No.	Treatments	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
2	18-24-6 H	4.90	3.09	.44	3.09	.72	70	340	11	34	41	266
4	Org. A.C.M. L	4.53	3.03	.51	2.46	.61	46	337	12	40	43	290
6	Org. A.C.M. H	4.87	3.13	.44	2.75	.63	43	362	11	36	38	307
8	Org. B. soybits L	4.84	3.01	.49	2.59	.66	53	333	12	41	48	262
10	Org. B. soybits H	4.77	3.11	.42	2.88	.69	58	335	12	39	42	270
12	N-P-K H	5.06	3.01	.45	2.75	.69	83	326	12	35	43	258
13	Control	4.41	2.68	.47	2.48	.65	56	309	14	37	33	234
14	N H	4.90	3.30	.39	2.82	.68	75	294	12	35	45	235

1. Sampling date: 7-18-75
   N, K, P, Ca, Mg as % dry wt.
   Mn, Fe, Cu, B, Zn, Al as ppm dry wt.

Table 36. Effect of Fertilizer Treatments on Mineral Content of Tomato Leaves, 1976[1]

TRT No.	Treatment		N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
1	Control		3.45	3.51	.44	3.11	.60	70	315	19	46	30	262
2	15-20-15	L	4.96	4.47	.44	3.36	.94	118	193	13	37	38	129
3	15-20-15	H	5.19	4.71	.63	3.36	.89	206	158	12	37	36	71
4	18-24-6	L	4.81	4.37	.49	3.25	.93	102	180	12	36	37	109
5	18-24-6	H	4.85	3.09	.66	3.29	1.01	242	327	16	39	35	182
6	Org A.C.M.	L	3.66	3.85	.41	3.27	.79	61	218	15	39	37	149
7	Org A.C.M.	H	5.19	3.82	.58	3.53	1.05	61	215	14	41	42	111
8	N	L	4.41	3.68	.43	3.43	.97	133	250	19	41	41	127
9	N-P	L	5.19	2.89	.48	3.35	.89	141	396	13	45	34	295
10	N-P-K	L	4.32	3.92	.48	3.41	.93	151	200	13	42	37	116
11	P-K		2.45	3.22	.58	3.07	.79	65	345	14	49	23	284
12	N-P-K	H	4.11	3.75	.55	3.36	.91	264	342	16	41	44	209
13	B.C.M.	L	4.78	3.58	.44	3.39	.85	106	239	14	42	34	147
14	B.C.M.	H	5.19	3.85	.50	3.36	.86	133	333	13	42	33	274
15	Sewage Sludge	H	3.79	4.32	.51	3.48	1.13	64	149	17	42	69	80
16	Control		4.11	3.56	.41	3.22	.64	68	345	17	47	29	282

1. Sampling date: 8-19

N, K, P, Ca, Mg reported as % dry wt.

Mn, Fe, Cu, B, Zn, Al reported as ppm. dry wt.

No consistent differences in trace element content are evident from fertilizer applications. The sewage sludge treatment had higher Zn values than the control and other treatments. The lower Mn levels of the Org. A. C. M. treatments were also seen with the plant tissue analysis of snapbeans, 1976. Possibly the higher soil pH, making Mn less available, can partially account for it, although this is not that evident.

V. GENERAL DISCUSSION AND CONCLUSIONS

There were usually no striking differences from fertilizer applications to vegetable crops in this study mainly due to the reasonably high initial fertility of the soils, as indicated by the soil analysis and plant tissue analysis data. However, the control, without fertilizer application during both years, and the P-K treatment in 1976 were characterized by their smaller plant growth and somewhat yellowed foliage. Yet, obvious mineral deficiency symptoms were not evident. It would be of advantage to select sites of low fertility to conduct further tests.

Responses to the fertilizer treatments varied from crop to crop. Generally, the main yield response of each crop to nutrient elements was as follows: Bell peppers, N; cucumbers, N, P and K; radishes - 75, P and K; radishes - 76, none; snapbeans, P; sweet corn, N; table beets, N, P and K; and tomatoes, N. Sidedressing application in addition to the preplant applications for both the high and low rates generally increased yields of bell peppers and cucumbers, while yields of table beets and tomatoes were depressed.

The higher rates of fertilizer application were not beneficial for snapbeans - 76 and tomatoes - 76. Application of many of the organic sources resulted in high gross yields of tomatoes - 76, but a large percent of fruit was green. For Willamette Valley conditions, or for shorter seasons, the low rate of fertilizer application appears satisfactory since reduced plant growth and a greater percentage of marketable fruit will result.

Increased yields were usually the result of a greater number of fruit or ears being produced per plant and not because of a marked increase in the individual size.

The organic materials studied, with the exception of the soybits produced yields similar to the N-P-K or mineral formulations used at comparable rates. In fact, the highest yields with many crops were obtained by using the organic materials. The soybits exhibited phytotoxicities with all crops, resulting in reduced stands and suppressed growth. The phytotoxic agent is presently unknown and may have been introduced or formed during processing. Neither the sewage sludge nor the manures detrimentally affected emergence and plant stands.

No trace element or heavy metal accumulation from application of sewage sludge was evident, as indicated by the soil analysis, plant tissue analysis, and chemical analysis of radish roots and sweet corn grain. Thus the sewage sludge source used at rates in this study appears to be no major problems for trace element toxicities if used on similar soils. The significance of microbial contamination by pathenogenic organisms, industrial pollutants (i.e. PCB's), and other presently unknown contaminants needs to be more clearly ascertained prior to formulating recommendations for utilization of sewage sludge.

When comparing effects of fertilizer application upon yield or certain quality parameters different conclusions can be reached depending upon the nutrient levels or nutritional ranges that are present. A better understanding of what system or range exists can make comparisons within and between studies more meaningful. For example, a different yield response will result depending upon whether the plant is grown under a deficient, suboptimal, optimal, or excessive nutrient range. In this study, plants apparently were in the suboptimal or the optimal range resulting in no significant differences between nutrient sources being observed in early fruit maturation and the quality components measured.

One of the main limitations in comparing nutrient sources such as organic materials with mineral fertilizers is the difficulty in standardizing them so as to be able to achieve definite and reproducible results. For example, by applying various nutrient sources at equivalent rates of a particular element, such as nitrogen, a biological basis of comparison can be made. Yet the organic materials may vary in content of other major and trace elements that may also influence growth and yield responses. Additionally, the form, amount, and rate of availability of the elements can vary with different organic sources. Decomposition rates also make it difficult to estimate the chemical analysis and to be able to obtain material with the same analysis at a future date. This study has dealt primarily with nutrient response yet other soil and organic matter relationships affected by fertilizer sources are also very important to consider. To better be able to determine the specific response to a certain element, different combinations of N, P, and K were used in 1976. While this was some improvement over earlier work, additional investigations should be conducted.

It would be quite interesting to elucidate the possibility and significance that organic materials may supply natural chelating agents for several minerals in the xylem. Perhaps the unknown vitamin-like property of manure, as described in the literature, can be linked to this concept.

High yields and quality of vegetables can be obtained by different nutrient sources in so far as no toxicological properties are inherent in the fertilizer material or produced as a by-product of the material. Much of the literature suggests that a combination of organo-mineral sources can be better than either individually. When high yields are obtained, there is usually little difference in selected quality components between nutrient sources. This was illustrated in the tomato nutritional results and the flavor evaluation of green peppers and tomatoes. Although fertilizer can increase the vitamin and mineral content of vegetables under certain conditions, the overriding effects of climate, soil, cultivar, and age, usually mask any effects from fertilizer, especially when plants are not nutritionally stressed.

The fact that one of the greatest influences of fertilizer application is in taking the plant out of a nutritionally stressed condition into an optimum growing system, thereby increasing yield and markedly influencing quality parameters, can partially explain the conflicting and inconsistent results found in the literature.

Finally, application rates of different nutrient sources need to be based on sound information, such as the chemical analysis of the products, an understanding of the material and specific crop requirements, and soil analyses. The utilization of different nutrient sources will be influenced by availability and quality, economic cost-benefit factors, political, social, and personal considerations. Through the judicious use of different nutrient sources maximum crop benefit can be realized with the least expenditure of material and energy and with minimal pollution.

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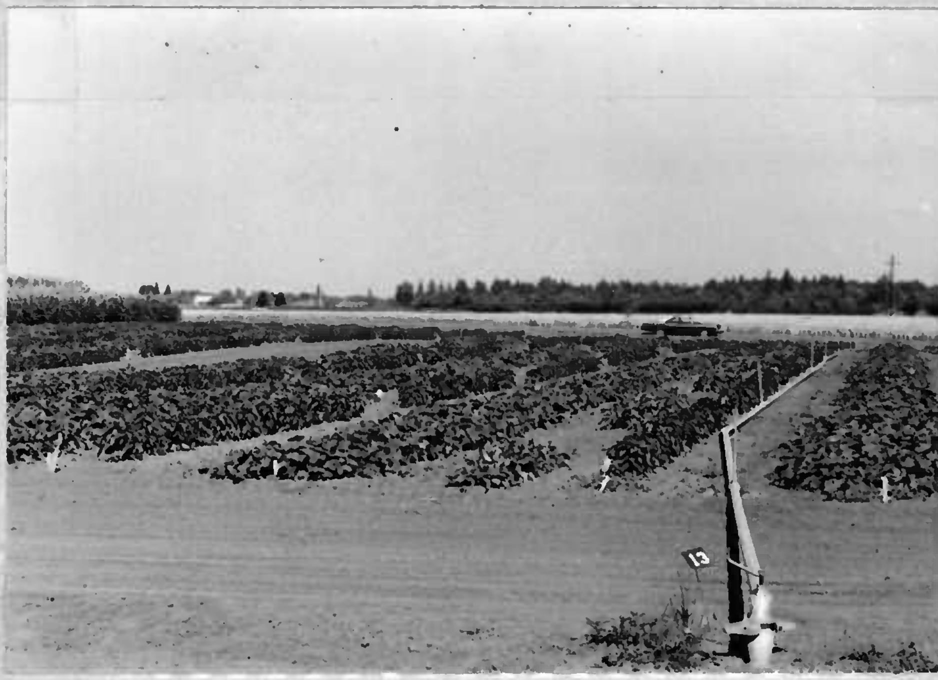
APPENDICES

Appendix A

Appendix Figure 1. Picture of the Main Area of the 1975 Experimental Site.

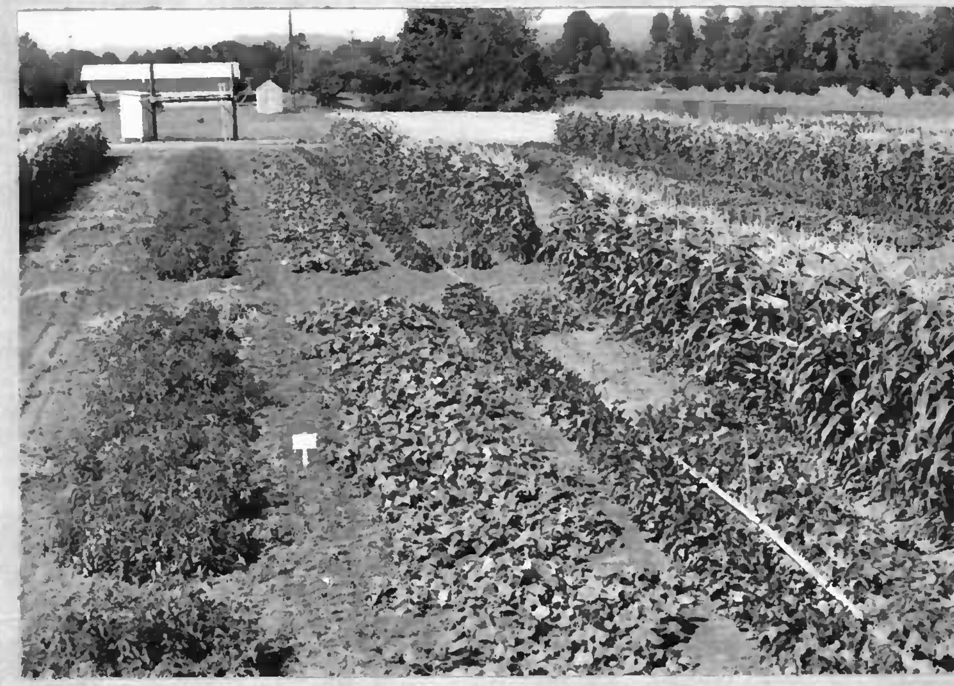


Appendix A (Continued)

Appendix Figure 2. Picture of the Tomato Area of the 1975 Experimental Site.

Appendix B

Appendix Figure 3. Picture of the 1976 Experimental Plots.



Appendix C

Cucumbers, 1976

On June 22, cucumbers, cv. 'Pioneer' were planted by a belt planter at about 15 cm. apart with seventy seeds/plot. Due to poor environmental conditions, germination and final stands were very poor, ranging from 25 percent to 44 percent. Two replications were entirely eliminated because of poor emergence. The other two replications were thinned to a plant spacing of 23 cm. apart where possible and averaged 20 to 25 plants in the two remaining replications. Every plant per plot from the two replications were harvested three times (8-26, 9-1, 9-7) and all fruit $\geq$ 3.8 cm. in length contributing to yield. Fruit were graded into the same sizes as used in 1975. Weights and number of fruit were recorded from every plot for each grade. Yield data were based upon 1.2 meter spacing between rows.

The means of only two replications per treatment are reported in Appendix Table 1 and 2.

There was NSD between any treatments in gross yield, but there appeared to be a trend for slight yield increases from applications of P and K and some of the organic materials.

Appendix C. Table 1. Effect of Fertilizer Treatments on Yield and Plant Stand of Cucumbers, 1976[1].

TRT No.	Treatment	Gross Yield	% of Gross Yield #1	#2	#3	Oversize	Misshapen	Total Yield H1	H2	H3	Total Marketable Fruit Yield[2]	Gross Number of Fruit Yield
1	Control	22.2	16.1	29.2	14.5	29.5	10.8	6.5	5.0	10.6	13.1	449873
2	15-20-15 L	22.0	19.6	41.6	15.9	10.3	12.6	5.4	10.9	5.7	16.5	532385
3	15-20-15 H	25.3	22.8	46.1	10.5	7.9	12.8	3.7	13.1	8.6	20.1	732568
4	18-24-6 L	29.2	15.9	32.3	11.0	28.8	12.1	7.7	8.8	12.7	17.5	701715
5	18-24-6 H	23.8	15.5	41.1	19.8	14.2	9.4	3.6	11.5	8.7	18.4	492923
6	OrgA.C.M. L	31.2	15.8	34.5	18.0	20.6	11.2	8.4	12.4	10.5	20.2	668710
7	OrgA.C.M. H	31.6	14.2	36.1	11.4	29.0	9.4	8.2	12.2	11.2	19.3	613463
8	N L	19.2	18.4	34.2	10.3	24.1	13.0	5.1	5.6	8.6	12.5	548888
9	N-P L	31.4	14.6	43.5	16.8	15.4	9.8	8.7	15.2	7.4	23.1	674450
10	N-P-K L	36.7	14.6	37.9	15.5	23.3	8.7	7.3	17.9	11.5	25.1	700998
11	P-K	35.8	12.5	34.9	16.9	25.9	9.9	10.6	13.3	11.9	22.9	674450
12	N-P-K H	28.8	17.7	34.6	15.1	19.5	13.1	3.9	13.1	11.8	19.2	731850
13	B.C.M. L	34.2	14.9	39.2	16.3	18.0	11.6	10.0	15.9	8.3	23.8	685213
14	B.C.M. H	39.7	12.3	34.6	10.5	30.0	12.7	11.5	11.9	16.4	22.7	708173
15	Sewage Sludge H	26.5	14.1	41.5	16.2	14.7	13.5	6.5	12.1	7.9	19.0	532385
16	Control	29.1	15.2	39.0	15.8	22.8	7.2	9.5	11.8	7.9	20.3	606288
	LSD .01	NSD	NSD	NSD	NSD	NSD	NSD	5.3	8.9	NSD	NSD	NSD

1. Results are means of the two replicates per treatment in m. tonnes/ha or number of fruit/ha.

2. Excludes misshapen and oversize fruit.

Appendix C. Table 2. Effect of Fertilizer Treatments on the Number of Cucumber Fruit Harvested, 1976.

TRT No.	Treatment	% of Gross Number of Fruit #1	#2	#3	Oversize	Misshapen	Total Number of Fruit H1	H2	H3	Total Marketable Number of Fruit Yield[2]	Plant Stand[3]
1	Control	52.7	24.8	5.4	5.5	11.7	130585	98298	220990	371665	19.5
2	15-20-15 L	51.3	26.7	5.0	1.8	15.2	99733	213098	219555	435523	20
3	15-20-15 H	54.8	27.8	2.9	1.2	13.3	114083	299915	318570	625660	25
4	18-24-6 L	53.5	22.9	3.6	5.4	14.6	170048	180093	351575	561085	25
5	18-24-6 H	41.6	33.6	7.5	3.0	14.4	86818	175070	231035	416150	19
6	Org A.C.M. L	49.2	26.9	6.4	4.2	13.3	167178	223143	278390	540278	25
7	Org A.C.M. H	45.5	29.4	4.4	6.7	14.0	142065	244668	226730	489335	23.5
8	N L	58.3	22.5	3.5	4.0	11.7	122693	110495	315700	473550	22.5
9	N-P L	46.4	30.9	5.8	3.3	13.6	143500	247538	283413	558933	25
10	N-P-K L	47.6	30.3	6.2	5.7	10.3	104755	249690	346553	586915	25
11	P-K	44.1	29.6	6.4	5.8	14.0	148523	210945	314983	540995	25
12	N-P-K H	54.3	21.5	4.6	3.5	16.1	100450	212380	419020	579023	25
13	B.C.M. L	45.9	31.4	6.3	3.9	12.5	130585	300633	253995	573283	20
14	B.C.M. H	43.5	30.8	4.3	6.7	14.7	187268	230318	290588	557498	25
15	Sewage Sludge H	44.9	31.5	5.9	3.2	14.5	83230	218120	231035	439110	20.5
16	Control	47.7	29.1	5.8	4.4	13.0	126280	217403	262605	500815	23.5
	L.S.D. .01	NSD	NSD	NSD	NSD	NSD	NSD	138831	NSD	NSD	NSD

3. Germination percentage was also recorded but NSD between any treatments, Range 4-76%, caused by adverse climatic and pathological problems.

Appendix D

Tomato Toxicity Trial, 1976

Two cultivars of tomatoes were grown in the trial (cvs. Willamette and New York) to determine possible phytotoxic effects from excess fertilization. Appendix Table 3 indicates the fertilizer treatments, sources of materials and the rate of application. Appendix Figure 4 illustrates the tomato field.

This was a limited study with little replication and no statistical analysis. Yet, it would appear that these fertilizers can be applied in higher than normal amounts and not cause any phytotoxicity problems on clay loam soils similar to the one used in this experiment (Appendix Tables 6 and 7). No phytotoxicities were observed in any of the treatments with either cultivar. Generally, there were reductions in gross and green fruit yield, and average plant weight, with slight increases in marketable yield, when comparing to both low and high application rates in the main 1976 experiment.

There are many factors to consider before predictions can be made on phytotoxicities with very high rates of these fertilizers.

Appendix D. Table 3. Fertilizer Treatments in the Tomato Toxicity Trial, 1976.

TRT No.	Treatment[1]	Rate kgN/ha	Actual Elemental Application: Preplant kgN/ha N - P - K	Preplant lbs/acres N - P - K
17	15-20-15[2]	439	439-258-366	392-230-327
18	18-24-6	439	439-259-122	392-231-109
19	Org A.C.M.[3]	439	448-211-202	400-189-180
20	Sewage Sludge[4]	439	722-150-40	644-134-36
21	B.C.M.	439	984-506-428	879-452-382

1. Treatments, T17 - T19 were replicated, T20 and T21 single plots. Materials for treatments, T-17 - T19 were supplied by O. M. Scott and Sons Company.
2. Code name F-7817
3. Org. A.C.M. = dehydrated chicken manure
4. Sewage sludge from Biogro, Willow Lake Wastewater Treatment Plant, City of Salem, OR. NH_3-N= 187 kg/ha.

Appendix D. Table 4. Effect of Fertilizer Treatments on the Soil Analysis of the Tomato Toxicity Trial 1976

TRT No.	Treatment[2]	pH	P (ppm)	Extractable Cations: K (ppm)	Ca (meq/100g)	Mg (meq/100g)	Na (meq/100g)	B ppm	Total N	Zn (ppm)	Fe (ppm)	Cu (ppm)
	Prior to Planting & Fertilizing[1]	6.2	28	156	13.3	6.3	-	-	-	-	-	-
17	15-20-15	5.4	61	256	11.0	5.9	-	-	.11	-	-	-
18	18-24-6	5.4	67	216	10.4	5.5	-	-	.11	-	-	-
19	Org A.C.M.	6.2	42	228	12.4	6.2	-	.56	.11	2.4	90.8	2.58
20	Sewage Sludge	6.1	37	198	12.5	6.3	.17	.36	.12	7.0	114.8	4.18
21	B.C.M.	5.7	40	222	11.8	6.1	-	.45	.08	1.8	114.8	2.66

1. Sampled March, 1976, others 8-18-76. Soil sample depth 15 cm.
2. T17 - T19, 5 probes/plot= 10 probes/trt. T20 - T21, 10 probes/plot.

B.C.M.= Bulk Chicken Manure.

Appendix D. Table 5. Effect of Fertilizer Treatments on the Mineral Content of Tomato Leaves of the Tomato Toxicity Trial, 1976[1].

TRT No.	Treatment	Cultivar	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
17	15-20-15	New Yorker	4.96	3.31	.64	3.30	.82	312	328	16	22	43	246
17	15-20-15	Willamette	4.00	2.99	.65	2.93	.81	232	249	15	26	34	107
18	18-24-6	New Yorker	4.35	2.86	.58	3.37	.94	289	384	13	20	38	323
18	18-24-6	Willamette	4.41	3.72	.54	3.21	1.01	183	195	12	27	34	113
19	OrgA.C.M.	New Yorker	4.64	3.13	.55	3.69	1.19	72	346	12	27	48	256
19	OrgA.C.M.	Willamette	4.60	2.68	.52	3.35	.86	58	224	14	31	35	135
20	S. Sludge	New Yorker	4.92	3.43	.44	3.57	1.03	96	581	17	33	70	537
20	S. Sludge	Willamette	4.11	3.77	.42	3.11	.93	66	181	18	39	51	110
21	B.C.M.	New Yorker	4.88	4.05	.47	3.55	.93	212	243	13	29	59	149
21	B.C.M.	Willamette	4.60	4.07	.51	3.27	1.00	176	229	16	37	51	146

1. Sampling date: 8-19
N, K, P, Cu, Mg as % dry wt.
Mn, Fe, Cu, B, Zn, Al as ppm, dry wt.

Appendix D. Table 6. Effect of Fertilizer Treatments on the Yield and other Characteristics of the Tomato Toxicity Trial, cv. Willamette, 1976.[1]

TRT No.	Treatment	# of Reps	Gross or Potential[2] Yield	Marketable[3] Yield	Green Fruit Yield[4]	# Fruit/ha Gross	# Fruit/ha Marketable	# Fruit/ha Green Fruit	Mean Plant Weight (Ind. Plt)	Mean Fruit Wt. of Marketable Yield (Grams)
17	15-20-15	2	96.6	53.7	43.0	956800	409630	547170	1.9	131
18	18-24-6	2	90.2	58.1	32.1	882050	444314	437736	1.6	131
19	Org A.C.M.	2	90.1	60.6	29.5	1072214	553748	518466	2.3	109
20	S. Sludge	1	95.5	61.8	33.6	857532	404248	453284	1.6	153
21	B.C.M.	1	97.6	51.8	45.7	956800	337272	619528	1.9	154

Willamette, Continued

TRT			% of Gross Yield at				% Gross Fruit No. at				Average Fruit Wt. by Harvest (grams)				% of H1 of Fruit Wt.			
No.	Treatment	# of Reps	H1	H2	H3	Green Fruit	H1	H2	H3	Green Fruit	H1	H2	H3	Green Fruit	Cull	<3.8 cm	3.8-7.6	>7.6 cm
17	15-20-15	2	1.9	21.3	32.3	44.5	1.3	16.0	25.6	57.1	151	135	128	79	0	0	65	35
18	18-24-6	2	2.3	30.7	31.4	35.6	1.6	22.0	26.7	49.7	146	143	120	73	0	0	70	30
19	Org A.C.M.	2	2.5	33.7	31.1	32.8	2.0	24.5	24.6	49.0	107	113	106	57	4.4	0.9	78	16.8
20	S. Sludge	1	2.4	32.0	30.4	35.2	1.7	22.3	23.2	52.9	160	160	146	74	0	0	67	33
21	B.C.M.	1	1.1	27.2	24.9	46.9	0.9	16.5	17.9	64.8	131	168	142	74	0	0	80	20

Willamette, Continued

TRT		% Fruit number - H1			
No.	Treatment	Cull	<3.8 cm	3.8-7.6	>7.6cm
17	15-20-15	0	0	72.9	27.1
18	18-24-6	0	0	80	20
19	Org A.C.M.	5.6	1.9	84.7	7.9
20	S. Sludge	0	0	75	25
21	B.C.M.	0	0	85.7	14.3

1. Results are either the means of treatment replications or the value obtained with the plots not replicated, in m. tonnes/ha and number of fruit/ha.
2. Includes both marketable and green fruit.
3. All fruit harvested at H1= ripe stage; H2= pink stage; H3= any physiologically mature. Includes cracked fruit.
4. All fruit >2.54 cm. at final harvest not physiologically mature.

Appendix D. Table 7. Effect of Fertilizer Treatments on the Yield and Other Characteristics of the Tomato Toxicity Trial, cv. New Yorker, 1976.

TRT No.	Treatment	# of Reps	Gross or Potential Yield[2]	Marketable[3] Yield	Green Fruit Yield[4]	# Fruit/ha Gross	# Fruit/ha Marketable	# Fruit/ha Green Fruit	Mean Plant Weight (Ind. Plt)	Mean Fruit Wt. of Marketable Yield (Grams)
17	15-20-15	2	52.6	42.6	10.0	541788	391092	150696	0.8	109
18	18-24-6	2	57.9	47.3	10.6	577668	420992	156676	0.7	112
19	Org A.C.M.	2	47.1	35.7	11.4	477802	292422	185380	0.8	122
20	S. Sludge	1	41.3	38.3	3.0	426972	368368	58604	0.5	104
21	B.C.M.	1	56.1	40.6	15.5	603980	367172	236808	0.8	111

TRT No.	Treatment	# of Reps	% of Gross Yield at				% Gross Fruit No. at				Average Fruit Wt. by Harvest (grams)				% of H1 of Fruit Wt.			
			H1	H2	H3	Green Fruit	H1	H2	H3	Green Fruit	H1	H2	H3	Green Fruit	Cull	<3.8 cm	3.8-7.6	>7.6 cm
17	15-20-15	2	6.3	40.0	34.8	18.9	4.7	31.4	36.3	27.6	128	125	93	66	0	0	77.6	22.4
18	18-24-6	2	4.4	46.8	30.4	18.4	3.8	39.0	30.2	27.1	116	120	101	68	0	0	81.7	18.3
19	Org A.C.M.	2	3.9	38.5	33.4	24.3	3.6	33.7	23.2	39.5	108	114	136	62	0	1.4	75.7	22.9
20	S. Sludge	1	9.9	57.1	25.6	7.3	7.0	49.6	29.7	13.7	137	112	84	51	0	0	75.0	25.0
21	B.C.M.	1	2.5	37.5	32.4	27.7	1.6	29.3	29.9	39.2	146	119	100	66	0	0	61.5	38.5

TRT No.	Treatment	% of Fruit No. H1 as			
		Cull	3.8cm	3.8-7.6	>7.6 cm
17	15-20-15	0	0	86.3	13.7
18	18-24-6	0	0	89.6	10.4
19	Org A.C.M.	0	3.3	85.6	11.0
20	S. Sludge	0	0	84.0	16.0
21	B.C.M.	0	0	75.0	25.0

1. Results are either the means of treatment replications or the valve obtained from unreplicated plots in m. tonnes/ha or number in fruit/ha.
2. Includes both marketable and green fruit.
3. All fruit harvested at H1= ripe stage; H2= pink stage; H3= any physiologically mature.
4. All fruit >2.54 cm. at final harvest not physiologically mature.

Appendix D

Figure 4. Picture of the Tomato Toxicity Field Trial, 1976.

Appendix E

Micro-Contamination of Vegetables

A major concern with the utilization of sewage sludge on vegetables is the possibility of microbial contamination. The New York State Department of Health (96) reports that sludge can contain water-borne disease organisms which may cause typhoid fever, para-typhoid fever, amebic dysentery, infectious jaundice, and other intestinal infections (i.e. gastro enteritis or diarrhea). Fungi and nematodes can also be present. The monitoring of sewage sludge becomes very important since these organisms can be found both on the adhering soil and inside the edible portion of the crop. For fresh market crops that are consumed raw there could be a potential problem. Two indicator groups of organisms (fecal coliforms and fecal streptococci), themselves rarely pathogenic yet always present in sludge, are used to detect sludge contamination. The samonella group of pathogenic bacteria represent the greatest potential health hazard.

When the number of fecal coliforms are >1,000, there is 96% probability that pathogens are present. If the coliform:streptococci ratio is > 2.5, the pollution source is probably human. When the ratio is < 1, the pollution source is probably livestock.[1]

Although this study was not designed to monitor microbial contamination, measurements were made on two separate dates with radish roots from sewage sludge, fresh bulk chicken manure, and the control. The results (Table 8) indicate that most treatments are

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[1] Personal communication by Dr. C. Hagerdon, Dept. of Microbiology, OSU.

Appendix E. Table 8. Micro-Contamination Counts on Radish Roots[1], 1976

No.	Treatment	Plot	Fecal Coliforms	Fecal Streps	Salmonella
1.	Control	12	0	>24,000[2]	0
2.	Control	26	100	>24,000	0
3.	Control	38	78	>24,000	0
4.	Control	49	---	---	--
5.	Sewage sludge	13	170	>24,000	0
6.	Sewage sludge	19	170	>24,000	0
7.	Sewage sludge	36	1,700	>24,000	36
8.	Sewage sludge	53	130	>24,000	18
9.	B.C.M.	3	>24,000	>24,000	18
10.	B.C.M.	31	700	>24,000	37
11.	B.C.M.	37	4,300	>24,000	0
12.	B.C.M.	57	>24,000	>24,000	110

1. Summary of MPN results, MPN given as number of bacterial/1 gram of unwashed radish root material.
2. Above instrument sensitivity.
3. Tests were conducted and analyzed by Dr. C. Hagedorn, Dept. of Microbiology, O.S.U.
4. Sampling of roots performed after radish harvest.
5. The following were sampled from radish roots contributing to yield data, harvested 7-28, 7-30-76.

   Two washed radish root samples, B.C.M. (T14) and Sewage sludge (T15) were found negative for Salmonella sp. on bacteriological cultures as analyzed by Dr. B. Coles, School of Veterinary Medicine, O.S.U. The same treatment samples were also found to be negative for Salmonella sp. as analyzed by Dr. C. Hagedorn, Dept of Microbiology, O.S.U.

probably contaminated from livestock.

The results need to be interpreted with caution as the soil, irrigation water, and organic materials were not monitored separately.

Contamination from field plot to plot could easily have occurred from tractor tires, or simply walking from plot to plot. The results do indicate that greater research is necessary before the utilization of sewage sludge can safely be recommended for vegetable production, especially when applied just prior to planting or during the current growing season.

Appendix F. Sample Ballots Used in the Flavor Evaluation of Bell Peppers and Tomatoes, 1975.

Dept. of Food Science & Technology
Oregon State University

Product______________ NAME__________________

Date__________________

1. Compare the flavor of the coded samples in direct comparison to the reference sample.
2. Score the desirability of the coded samples.

Flavor	Desirability
____ Same as Reference	____ Very Desirable
____ Slightly Different	____ Moderately Desirable
____ Moderately Different	____ Slightly Desirable
____ Quite Different	____ Neutral
____ Very Different	____ Slightly Undesirable
____ Extremely Different	____ Moderately Undesirable
____ Very Extremely Different	____ Very Undesirable

If different, please describe the difference.

Appendix G. Method of Analysis of Sewage Sludge

Ten grams of sewage sludge and 10 ml. nitric acid were added together in a volumeteric flask and placed on a hot plate and gradually evaporated down. This was repeated with 10 ml. of nitric acid and again gradually heated and evaporated down. Five ml. of percholoric acid ($HClO_4$) was then added and heated. It was evaporated down until a recognizable white fume was released. This was correlated with a near colorless solution. The solution was diluted into two 100 ml. volumetric flasks. Many elements could be read directly by atomic absorption, others (i.e. Na, K, Mg, Zn) were diluted again (10 to 100) and directly read.

These analyses were performed by Don Miller, Soil Science Department, O.S.U.

Appendix H

Method of Analysis of Lead, Cadmium, and Mercury in Sweet Corn kernels as analyzed by Agricultural Chemistry, 1976.

1. All the samples were ground in a mortor. A portion of the samples were dry ashed at 500^{o}C for the lead and cadmium determination. Another portion of the sample was digested with HNO_2-H_2O_2 for the mercury determination.
2. The lead and cadmium were determined by flame AA at 283.3 nm. and 228.8 nm., respectively, while mercury was determined by cold vapor AA at 253.7 nm.

Appendix I. Method of Analysis of pH, Soluble Solids, and Specific Gravity of Radish - 75

1. Topping both ends of radishes.
2. Slicing radishes by a modified carrot slicing machine. Each slice 3.2 nm.
3. Blending in Waring blender for two minutes.
4. Pouring slurry in labelled pint jar.
5. For pH: Read directly from pH meter after adjusting pH meter.
6. For soluble solids (S.S.) and specific gravity: Slurry placed in double layered cheese cloth and sample obtained placed on the Bausch and Lome refractometer. Values read directly.
7. All utensils and equipment cleaned between samples.
8. Temperature correction for S. S. accounted for when necessary.
9. Radishes held at cold storage (0.6° C. - 1.7° C).

THOU SHALT HAVE A PLACE
ALSO WITHOUT THE CAMP, WHITHER
THOU SHALT GO FORTH ABROAD. AND
THOU SHALT HAVE A PADDLE AMONG
THY WEAPONS; AND IT SHALL BE,
WHEN THOU SITTEST DOWN ABROAD,
THOU SHALT DIG THERE WITH, AND
SHALT TURN BACK AND COVER THAT
WHICH COMETH FROM THEE.

DEUTERONOMY 23,
VERSES 13 - 14.

*MOSAIC LAW.