THE EFFECT OF SOIL ZONE ON THE NUTRIENT CONTENTS OF VEGETABLES

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by

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PART I INTRODUCTION

Human beings have extensive nutritional requirements. They must receive an adequate supply of many different nutrients if they are to develop and maintain healthy bodies. These nutrients include several vitamins and minerals. A pronounced lack in the supply of any one of these may produce a deficiency disease in the individual. While the incidence of these is very rare in Canada, this does not mean that everyone is receiving the necessary supply of all required nutrients. Nutritionists believe that many people consume less than the optimum amounts, and point to the improved health of subjects whose nutritional status has been raised above minimum levels.

Foods vary appreciably in their contents of nutrients. Animal products are particularly good sources and constitute the majority of the so-called protective foods. However, animals rarely synthesize these nutrients themselves, but get them from their food in turn. So the essential food sources of vitamins and minerals are plant products. The latter foods when consumed directly provide a portion of the vitamin and mineral intake of the average person. This portion may be large since plant products are consumed in greater amounts than are animal ones.

Garden vegetables form a large share of the average diet. They vary a good deal in nutrient content. One kind of vegetable- indeed, even one variety of a vegetable- will show remarkable variations in the amounts of the different nutrients it contains. These variations have been attributed to differences in the soil, the moisture and temperature of the soil, light intensity, duration and quality, relative humidity and rainfall, and temperature,

and even to the maturity of the plant when harvested.

In Manitoba there is a variety of soil types, from the black earth of the Red River Valley to the podzol soils of the far north. They vary in acidity or alkalinity, in available mineral and organic matter, in texture and moisture. If this is really a factor affecting the nutrient content of vegetables we would expect to find differences in the nutrient content of the vegetables produced in these different soil zones. To test the validity of this the project reported herein was begun. It is a study of the nutritive value of vegetables grown in several areas of the province, these being chosen to represent the different soil zones. This was expected to give some indication of the variations which occur and to show whether these variations are due to the soil zone or to some other environmental effect, or both.

PART II REVIEW OF LITERATURE

FACTORS WHICH AFFECT THE VITAMIN AND MINERAL CONTENT OF VEGETABLES

Several investigators have studied the factors which are believed to affect the vitamin and mineral content of vegetables. Their work is discussed below for each factor investigated.

1. Locality.

Many attempts have been made to correlate the vitamin content of vegetables with locality or type of soil in which they are grown. Generally the investigators have not tried to control other factors of environment. In 1936, Tressler, Mack and King (90) found that twelve varieties of spinach grown on upland soil averaged 50%higher in ascorbic acid content than those same varieties grown on muck soil. They believed variety to be of secondary importance to locality. On the other hand, Lampitt, Baker, and Parkinson (49) found no differences in ascorbic acid concentration between potatoes of two varieties grown on two different, but well-defined, types of soil (black land and silt land). Also Hanson and Waldo (36) obtained close agreement with strawberries grown in several different types of soil, and Lyons and Fellers (58) decided that geographical source was not significant in the production of ascorbic acid in tomatoes.

Different varieties of tomatoes and cabbages were grown in several localities in Maine by Murphy (65). She found that plants from one locality might be consistently high in ascorbic acid during one season while another locality would produce plants with higher ascorbic acid content the next season. Her

results demonstrated that environmental agencies other than soil influence markedly the synthesis of ascorbic acid in tomatoes and cabbages, and that geographical location (longitude and latitude) is not a contributing factor, except insofar as environmental conditions are consistently characteristic of that situation. Other investigators, Sheets, et al. (80), Reder, Ascham and Eheart (77), Burkhart and Lineberry (16), and Hamner, Lyon and Hamner (35), agree with Murphy in her conclusions that conditions of the top environment tended to mask any effects of soil type on the vitamin content of vegetables.

Locality to some extent affects carotene. Magruder et al. (61) found that sandy soil produced better color, hence higher carotene values, in carrots. A marked deficiency of plant food materials resulted in small size and poor color.

The United States Plant, Soils and Nutrition Laboratory was founded in 1939 at Ithaca, N.Y., to investigate the factors affecting the nutritive value of foods. Their researches have been extensive. Their first studies dealt with soil fertility levels and cultural practices. In one of their earlier experiments, tomatoes were grown in Wyoming, California, Wisconson, and New York. Marked differences in ascorbic acid (93) and carotene (24) were noted. When these same soils were brought to Ithaca and tomato plants grown on them there, carotene and ascorbic acid values were similar for the different soils. This emphasized that environmental factors other than soil zones must be the important ones and that soil zone itself has no distinguishing effect on the ascorbic acid or carotene content. It was concluded that the

best proceedure in plant nutrition studies is to grow all plants in one place, possibly in nutrient watered sand. This ensures accurate control of the nutrients fed to the plant.

2. Specific Nutrients and Fertilizers, - Effect on Vitamins.

Hamner, Lyon and Hamner (35) of the United States Plant, Soils, and Nutrition Laboratory proved to their satisfaction that plants grown in sand cultures with a balanced nutrient solution were as high or higher in ascorbic acid as those grown in good soil. They initiated a series of pot studies on the effect of excess and deficiency of macro- and micronutrient elements on yield, marketability, and particularly on deposition of these elements in the plant.

a. Macronutrients: Hamner, Lyon and Hamner (35) showed that growth and fruitfulness of tomato plants, grown in sand cultures, could be correlated with minor variations in macronutrient composition. In general, variations in calcium and nitrate in the nutrient medium produced greater differences over wider ranges of concentrations than were obvious with the other elements. Ascorbic acid content was significantly higher for some sulfate deficient treatments, and significantly lower for potassium and phosphate deficiencies, than average values. With these exceptions no demonstrable effect of mineral nutrient supply on ascorbic acid was observed. Further studies were made by Bernstein, Hamner and Parks (10) on the effect of macronutrient elements using turnip greens. After comparing the ascorbic acid in plants grown in sand cultures and in soil, as affected by calcium, magnesium, potassium, nitrates, phosphates and sulfates, they concluded that neither variations in supply of macronutrients in sand, nor fertilizers in soil have very much effect on ascorbic acid content. In sand

cultures potassium deficient plants were low in ascorbic acid.

Other investigators have studied the effect of macronutrient elements on ascorbic acid. At the New York Agricultural Experimental Station, Karikka, Dudgeon, and Houck (44) found that neither soil reaction, nor amount of nitrogen, potassium and phosphorus in fertilizers, nor the addition of minor elements to soil to which a complete fertilizer had been added, had a consistent influence on the ascorbic acid content of potatoes. McCrory and Snyder (63) at the South Dakota Agricultural Experimental Station found that although fertilizers, natural or artificial, influenced the yield, they caused no consistent variations in the vitamin content of the crops. This agrees with the conclusions of Bernstein et al. (10) and of Karikka et al. (44).

This, however, is not a universally accepted opinion. Burrel, Brown and Ebright (17) stated that high nitrogen, or a complete fertilizer, gave rise to a higher ascorbic acid content in cabbage than did other fertilizers. On the other hand, Brown, Patton and Blythe (15), working with Swiss chard, found that significantly higher ascorbic acid values were obtained from plants receiving insufficient nitrogen, magnesium, manganese and potassium. They also found that ascorbic acid of Swiss chard plants which had been fertilized with double quantities of potassium and phosphorus was significantly lower. Complete fertilization tended to suppress the ascorbic acid of Irish Cobbler potatoes grown by Leischenring, Norris, Grambow and Donelson (53).

This obvious discrepancy in results might be due to the influence of locality on the effect of fertilization. Other

environmental factors associated with location at which the vegetables were produced could possibly be of greater importance in determining ascorbic acid than the fertilizer tested (53).

In further effort to find out the effect of place on different fertilizer treatments, Reder, Ascham and Eheart (77) conducted fertilization experiments at four different localities. Nitrogen, phosphorus, potassium, and calcium in all possible combinations were studied as they influenced the ascorbic acid content of turnip greens. Nitrogen fertilization gave increases in ascorbic acid at two places and significant decreases at two places. The overall statistical study for the four places gave a highly significant decrease in ascorbic acid for fertilization with nitrogen. Calcium fertilization seemed to have no significant effect. Considering the experiment as a whole the influence of place was 13.75 times as great as the most important average effect produced by any fertilizer treatment. These variations did not seem to be directly related to differences in soil composition or to differences in temperature.

It is possible that since fertilizing with nitrogen so greatly increases foliage of the plants, a deficit of nitrogen would result in decreased foliage and correspondingly more exposure of the vegetable to the sun. It has been shown that the more sunlight a vegetable receives the higher will be its ascorbic acid content. Conversely an increase in nitrogen supply would result in excess foliage and a consequent shading of the vegetable from the sun with lower ascorbic acid production.

There has been less work done on the effect of fertilization

on carotene. Whittemore (97), in 1934, found that magnesium, phosphorus and potassium fertilizers on different soils did not affect carotene values of spinach, though the yields were low where no fertilizer was applied. Holmes, Crawley and Kuzmeski (42) decided that neither magnesium sulfate nor limestone nor both produced any pronounced difference in carotene values of kale. Working at the United States Plant, Soils and Nutrition Laboratory, Ellis and Hamner (24) found that wide variations in the supply of macronutrients to tomato plants growing in sand cultures produced only slight variations in carotene content of the fruit even though the variations in nutrient supply greatly affected growth and fruitfulness. There were indications that increasing supplies of nitrates resulted in increasing carotene content but the magnitude of variations was not great.

There does not seem to be any information available on the effect of fertilizers on the thiamine and riboflavin content of vegetables. From various reports the amount of these in cereals varies with the location in which they are grown, but attempts to influence the content in crops have generally produced negative results. Most of the studies were not sufficiently comprehensive or controlled with respect to other factors to reveal any small differences due to fertilizers.

b. Micronutrients: Interest has been directed in the last ten years or more to the possible effects of deficiencies or excesses of micronutrient elements on the vitamin content of plants. Lyon, Beeson and Ellis (56), in 1943, studied the results of micronutrient deficiencies on the growth and the

vitamin content of the tomato. A deficiency of manganese, copper, zinc and iron resulted in considerably less growth and produced deficiency symptoms which were not found in control plants. The ascorbic acid content of fruits was not seriously affected by limiting manganese, zinc, copper, or molybdenum. Fruits from iron deficient cultures contained 30% more ascorbic acid than the controls.

Although Lyon, Beeson and Ellis (56), and Gum, Brown and Burrell (31) felt that a shortage of manganese had little effect on the ascorbic acid content of the tomato plant, Harmer, and Sherman (37), working with spinach, oats and Sudan grass, concluded that the application of manganese to a manganese deficient soil significantly increased the ascorbic acid of plants during the period of the year when such manganese application caused a significant plant growth response. Hester (40) also found that manganese greatly increased the ascorbic acid in tomatoes. An application of 1 g. of $Mn\ SO_4.4\ H_2O$ to 15,000 g. of Sassafras sandy loam increased the ascorbic acid content of tomato pulp from 142 to 243 mg. per liter. Over a few pounds of soluble manganese per acre in the soil is known to be toxic to tomato plants, thus excess fertilization with manganese would be detrimental.

All workers are apparently not agreed that manganese fertilization increases ascorbic acid in plants. Lyons and Fellers (58) stated that manganese fertilization had no effect on the ascorbic acid content of potatoes. Lyon and Beeson (55) decided that ascorbic acid contents were significantly less in turnips

and tomatoes as the concentration of manganese was increased in the nutrient medium.

Another microelement which has received some consideration is boron. There seems to be little agreement in reports from various investigators as to the effect of boron. Lyons and Fellers (58) reported that boron fertilization had no effect on ascorbic acid concentration of potatoes, and Lyon and Parks (57) reported the same results with tomatoes. Gum, Brown and Burrell (31) claimed that in boron deficiency ascorbic acid concentration of beets was lower than normal; while Lyon and Beeson (55), in 1948, found that as boron supply to turnip plants was increased, ascorbic acid values decreased 20%. This was also true for tomatoes.

Results of experiments with other microelements are also very contradictory. Iron deficiency was reported by Lyon, Beeson and Ellis (56), in 1943, as being associated with a 30% increase in ascorbic acid content of tomatoes. In 1948 these same workers (55) described an increase in iron as having no effect on the ascorbic acid content of turnips. A 60% increase in ascorbic acid was associated with relatively high copper concentrations, and a low value in tomatoes with increased molybdenum. According to the results of Lyon, Beeson and Ellis (56) a limited supply of molybdenum did not affect ascorbic acid in tomatoes nor did deficiencies of zinc or copper. Lyons and Fellers (58) reported no effect on potato tubers of added cobalt, mercury, zinc, magnesium or lead.

Less work has been done on carotene in plants than on

ascorbic acid. Lyon, Beeson and Ellis (56) decided that pro-vitamin A of tomato fruits was not significantly affected by a limited supply of micronutrients (manganese, copper, zinc, molybdenum and iron). Gum, Brown and Burrell (31) found that if leaves of tomato and beet plants showed manganese or boron deficiency the tomato fruit and beet roots would show lower carotene values.

Thiamine values can apparently be correlated with effects of micronutrient deficiencies in tomatoes (56). Boron and manganese deficient beets and tomatoes have slightly less thiamine than control plants (31). Lyon and Beeson (55) noted that as boron and manganese supply to turnips was increased, a large increase in both thiamine and niacin concentration occurred in the leaves.

There is so much disagreement in the literature that it is difficult to draw any conclusions as to the effect of nutrient supply on the vitamin content of vegetables. Possibly different vegetables react in different ways to varying concentrations of nutrients. Also it is possible that not enough consideration has been given to randomization of treatments and sampling, or to top environment as a whole.

3. Nutrient Composition of Soil -Effect on Minerals.

Minerals in vegetables seem to be more uniformly affected by nutrient composition of the soil than are vitamins. Coleman and Ruprecht (20) analysed tomatoes, celery, potatoes, oranges, grapefruit, string beans, cabbage and lettuce grown on different soils in Florida. Their data show clearly the influence of soils on the calcium content of the plants. The calcium content of

tomatoes grown in the Bladen soil, a strongly acid soil with a small amount of organic matter, was reported as 0.22%, while that of tomatoes grown in the Hernando soil, developed from a phosphatic limestone, was 0.45%. Similar variations were reported for cabbages and other vegetables.

A study of variations in calcium and phosphorus content of vegetables grown in Alabama soils was made by Bishop (12). Plants were grown in a greenhouse. Her analyses showed large variations in these minerals in the edible portions of vegetables. Cabbages varied in phosphorus from 0.208% in a Eutaw soil, to 0.086% in a Hartsell soil. In general the calcium contents of vegetables seemed to be high for those soils which produced vegetables with a low phosphorus content.

Peterson, Parmele and Fred (72) and Peterson (71) found that different varieties of cabbage were remarkably uniform in their contents of calcium, phosphorus, iron and nitrogen. It is possible that in some species one variety is a better feeder on certain nutrients than are other varieties of the same plant.

It seems to be agreed that if a soil is deficient in any particular mineral, that mineral will be correspondingly low in the vegetable grown in that soil (99)(42). Complete fertilizers containing nitrogen, phosphoric acid and potash when used in the usual amounts necessary for crop production exert very little influence on the mineral composition of the crops grown (20). It is generally agreed that heavy application will nullify any effects which soil types may have.

The concentration of any given element in plant tissue is, in many instances, also correlated with the supply of other elements. Calcium may be replaced by another base, possibly

potassium, supplied by the fertilizer (25). Fertilization with one element may increase the amount of that element taken up by a plant, but decrease the absorption of another element. According to the work of Leischenring and Donelson (52), phosphorus utilization by potatoes may be depressed when potassium or iron sulfate is added with phosphorus. Also, a significant decrease in calcium values of potatoes resulted from iron sulfate treatment. At the same time potatoes from iron sulfate treated plots contained a significantly smaller amount of iron than those to which no iron sulfate had been applied.

A similar relationship between minerals was found by Holmes, Crawley and Kuzmeski (42). Limestone fertilization increased the calcium and phosphorus of kale, and may have depressed the iron content, while magnesium sulfate fertilization definitely increased magnesium content of the kale, and may have slightly increased the calcium and phosphorus content. According to Sheets et al. (80), and Beeson, Lyon and Barrentyne (9), calcium fertilization increased the calcium utilization but decreased the phosphorus utilization of plants.

The problem of fertilization is a very complicated one. One fertilizer might increase the utilization of some ions and, at the same time, decrease the utilization of others, or perhaps decrease the synthesis of vitamins in a plant. Also, heavy fertilization with one particular element may raise the mineral and vitamin content of a plant, but have such a toxic effect on it that the yield would be very low. At the present time it would seem advisable to fertilize plants with elements known to be

deficient in the soil and to avoid over-fertilization.

4. Light Quality and Intensity.

It is possible that the amount and quality of light that a plant receives is the greatest single factor other than heredity in determining the synthesis of ascorbic acid in plants. There is some evidence that it affects other vitamins as well.

A rapid loss of ascorbic acid was noticed by Kohman and Porter (46) when tomato plants were kept in the laboratory over night, and a rapid recovery when the plants were exposed to direct sunlight. They reasoned that the rapid loss of ascorbic acid in the growing plants suggested its use in some physiological process, with solar rays being essential to its production. Wokes, Barr, Brunskill and Shaw (100), in Great Britain, noted that low ascorbic acid content in tomatoes in one season was correlated with a smaller number of hours of sunshine during August, September and October.

Hamner, Bernstein and Maynard (34) described an experiment with tomatoes grown in temperature, humidity and light controlled chambers. The temperature was kept at 73° ± 2° F. with a relative humidity of 60 to 85%. One chamber was illuminated eight hours a day, another sixteen. Illumination was accomplished with white and daylight fluorescent lamps of 800 to 900 foot candles. Plants were grown in nutrient watered sand in two gallon crocks. Comparable plants were grown in a greenhouse. The vitamin content of those plants illuminated eight hours a day (16.7 ± .28 mg./100 g.) was significantly lower than those grown under sixteen hours illumination a day (19.5 ± 0.33).

Plants grown in the greenhouse were the highest in ascorbic acid (22.0 ± 0.37). Length of time of illumination, as well as light intensity, seems to be an important factor in the synthesis of ascorbic acid.

Further investigations by Hamner et al. (34) were carried out dealing with illumination during the growing period. Tomato plants were grown outside in pots in randomized positions. Comparison was made of the effects of shading the plants with cheese cloth (illumination reduced 75%) during various periods of growth and ripening. Controls grown in sunlight during the entire period to maturity gave fruits which averaged 25.8 mg./100 g., while negative controls grown completely in shade averaged 15.5 mg./100 g. Those tomatoes which were transferred from sunshine to shade during the growing period and matured in shade gave an average vitamin content not different from the shade controls regardless of the stage of transfer. Those plants transferred from shade to sunshine during the growing period were not different from the sunshine controls, regardless of the stage of transfer. The effect of shading seemed to be greatest just before the fruits ripen, and during the maturation period.

Other investigators agree with these conclusions. Kosti, Webster and Kirch (47) found low ascorbic acid values when tomato fruit was picked on rainy or cloudy days. High values were obtained at intervals where a high percentage of sunlight preceded the collection of samples. Several green vegetables were grown by McCrory and Snyder (63) under lath shade and in the open. Ascorbic acid was consistently lower under shade.

Ascorbic acid content of sunripe strawberries analysed by Burkhart and Lineberry (16) was greater than that of berries ripened in the shade. Hanson and Waldo (36), working with strawberries, found that shading of the berries by dense leaves did not lower the ascorbic acid content. Strawberries grown and ripened under reduced light intensity contained less ascorbic acid than those ripened on plants fully exposed to the light. Shading of the entire plants resulted in a much greater reduction in ascorbic acid than did shading of the berries only. They theorized that the larger amount of ascorbic acid is synthesized in the leaves and translocated to the fruit.

In 1950, Somers, Hamner and Kelly (85) conducted further studies on the relationship between illumination and the ascorbic acid content of tomato fruits. Experiments with tomato plants grown in sand culture showed that the amount of illumination of the fruits was of importance in determining their vitamin content; but, on the other hand, the amount of illumination received by the leaves for a few weeks prior to harvest apparently had much less effect or possibly no effect at all on the vitamin content. In view of this relationship, the authors expected that under field conditions, where large differences in foliation were obtained at different locations, there probably would be little or no correlation between the total amounts of sunlight and the ascorbic acid content of the tomatoes produced. This would possibly explain why tomato fruit from vines supported by poles have higher ascorbic acid than those lying on the ground, not receiving the full illumination from the sun as was found by Brown and

Moser (14). Great variations within similarly treated plants in one field as reported by Hamner, Lyon and Hamner (35) might also be attributed to differences in foliation.

Direct sunlight seems to have an effect on carotene in plants. Ripe tomato fruits grown in a greenhouse in summer or winter were reported by Ellis and Hamner (24) to average 26.4% lower in carotene than tomatoes obtained out of doors during the summer. Green vegetables have been reported by McCrory and Snyder (63) to have more carotene when grown under lath shade. Further work will have to be done to clear up discrepancies such as these.

There is some evidence that thiamine and riboflavin are also affected by strength of illumination. Tomatoes, cowpeas, beans, New Zealand spinach and potato plants were grown by Gustafson (33) in a greenhouse or a darkroom, and light intensity was varied by enclosing plants in large cages covered with unbleached muslin cloth of various thicknesses. The concentration of thiamine in these species was greater in plants exposed to high light intensity than in plants exposed to darkness, or low light intensity. In albino corn the opposite was true. Increased illumination increased riboflavin content, too, although the effect was less pronounced. Lyon, Beeson, and Ellis (56) noticed a pronounced effect on riboflavin content of variations in climatic, environmental conditions such as occur with definite positions in the greenhouse.

5. Temperature and Humidity.

Plants grown at low temperatures have more ascorbic acid

than those grown at higher temperatures. Reid (78) found that there was a lower accumulation of ascorbic acid occuring in plants grown in the light at 29° C (84.5° F) than at 24° C (75.5° F), probably the result of a more rapid rate of metabolic utilization rather than of less rapid synthesis of the vitamin.

Hamner, Bernstein and Maynard (34) described experiments with tomato plants grown in three temperature and humidity-controlled chambers; the first kept at about 78° F (24.4° C) and 90 ± 5% humidity, the second at 63° F (17.2° C) and 84 ± 5% humidity, and the third at 78° F (24.4° C) and 30-50% humidity. The chambers were illuminated for sixteen hours a day with white and daylight fluorescent lamps delivering 800 to 900 foot-candles of illumination. Plants were grown in sand in 2-gallon crocks watered with nutrient solution. Best growth was at high temperature and high relative humidity, and next best was at high temperature and low relative humidity. Growth was much slower at the lower temperature and fruits were much smaller and irregularly shaped. Fruits at the high temperature extreme (78° F) were also small but were regular in shape. The first chamber with high temperature and very high humidity produced the lowest ascorbic acid, 13.5 ± 0.30 mg./100 g.; the lowest temperature with moderately high humidity gave values of 15.6 ± 0.54; and the high temperature with average humidity gave the highest, 19.4 ± 0.39. Comparable plants grown in the greenhouses under different conditions of illumination contained 21.5 ± 0.35 mg./100 g.

It was reported by Magruder et al. (61) that environmental

conditions affect rate and percentage of germination of carrot seed, color and size of foliage, and size, shape, weight and color (indicative of carotene content) of the roots. Changing temperatures affected the amount and distribution of carotene in the root.

It is possible that these effects of variations in light intensities and temperatures may not show up to a great extent in field work. Platenius (73), after studying diurnal and seasonal changes in the ascorbic acid content of vegetables, came to the conclusion that under field conditions during summer, periods of low light intensities usually coincide with periods of relatively low temperature. Since these two factors have opposite effects on the ascorbic acid content of plants, the time of picking vegetables during the day is probably unimportant in field practice so far as ascorbic acid is concerned. He could detect no diurnal fluctuations in ascorbic acid content and found that single days of cloudy weather were without effect. Similar results were obtained by Currence (22).

6. Moisture.

The level of irrigation of plants is thought by some investigators to have an effect on ascorbic acid and carotene contents. Todhunter (86) in 1939 found that Winesap apples receiving 60 acre-inches of water seemed higher in ascorbic acid than those receiving only 30 acre-inches of water. Working with turnip greens, Reder, Ascham and Eheart (77) noticed that the highest ascorbic acid content of three spring crops was found in greens having the lowest average daily rainfall, and

where 49% of the days in the growing season were clear. Lowest ascorbic acid values were found where there was more rain and less sun. This latter result was due most possibly to the greater effect of sunshine on ascorbic acid.

Soil moisture, as it increased from low to high, decreased the total amount of color in carrot roots according to Magruder et al. (61). As mentioned above, color is an indication of carotene in carrots. Lantz (51) also noted a higher carotene content in conjunction with lowered irrigation of carrots.

7. Variations in Vitamin Content Within and Between Varieties of Vegetables.

The preceding reports have shown that the mineral and vitamin composition of vegetables is influenced to a greater or a lesser degree by soil, climate, rainfall, temperature and humidity. These factors of environment may be of sufficient magnitude to mask differences due to the variety of a plant; nevertheless, variety is of great importance in determining the deposition of nutrients. Several investigations have been undertaken to find the range of vitamins and minerals in different varieties of vegetables. These were determined on plants grown under as identical conditions of soil and environment as possible so that differences noted would be essentially those of variety.

The reports of a number of investigators on the variations found in numerous varieties and strains of vegetables are compiled in Table I. It is obvious that there is a wide range in values even though this table is essentially a table of

averages.

For thirty varieties and strains of cabbages tested, Burrell, Brown and Ebright (17) found variations in ascorbic acid of from 48 to 180 mg./100 g. The same variety did not have the same ascorbic acid content at different seasons or in different years, though in general the varieties that were higher in ascorbic acid tended to remain high, and lower to remain low. Warren, Hiltz and Robinson (96) reported variation from 39 to 46 mg./100 g. for three varieties of cabbage grown in Manitoba in the same season, soil, and at the same stage of maturity. Further investigations (67) made at the University of Manitoba gave a range of from 43 to 47 mg./100 g. for Danish Ballhead cabbage grown in one particular soil type, and a range of 27 to 66 mg. when this same variety was grown in seven districts in Manitoba.

It has been demonstrated by Walker and Foster (94) that ascorbic acid concentration in cabbages is an inherited factor. Quantity is therefore governed by combination of genes. It is possible to cross-breed well known cabbage varieties with varieties high in ascorbic acid, thus raising their content considerably, with retention of the major horticultural characteristics.

Carrots are a relatively poor source of ascorbic acid. Most investigators give a range of from 3 to 10 mg./100 g., with an average of about 6 mg. Pyke and Charkey (76) reported very little difference in ascorbic acid among varieties.

In studies of the ascorbic acid content of potatoes, Karikka,

TABLE I

VITAMIN CONTENT OF FRESH VEGETABLES
(Data reported in the literature)

Description		Ascorbic Acid (mg./100 g.)	Carotene (I.U./100 g.)	Riboflavin (mg./100 g.)	Thiamine (mg./100 g.)	Lit. Ref.
			CABBAGE			
*C.C.N. and	Min	38	60	0.04	0.05	18
**U.S.D.A.	Max	50	80	0.05	0.06	92
	Av.	44	70	0.045	0.056	
Sherman	Min	50	30	0.06	0.07	81
Tables	Max	90	80	0.135	0.14	
	Av.	70	55	0.098	0.105	
Adams-U.S.	Min	25	168			1
Agr. Expt.	Max	56	295			
Stations	Av.	40.5	232			
Other	Min	23	20		0.030	17;19;30; 50
Studies	Max	180	120		0.420	28
	Av.	16;89;130; 104;63	70		0.225	13;29;76
			CARROTS			
C.C.N. and	Min	5 A.P.	10,560 A.P.	0.05 A.P.	0.06 A.P.	18
U.S.D.A.	Max	6 E.P.	12,000 E.P.	0.06 E.P.	0.07 E.P.	92
Sherman	Min	3	2,200	0.06	0.06	81
Tables	Max	5	4,000	0.12	0.14	
	Av.	4	3,100	0.09	0.10	
Adams-U.S.	Min		1,730			1
Agr. Expt.	Max		47,000			
Stations	Av.		12,383;35,833			
Other	Min	5	1,700		0.038	30;50;51
Studies	Max	14	42,500		0.180	28;38
	Av.	14;8;5	12,916;33,417 8,127		0.109	13;29;76
			POTATOES			
C.C.N. and	Min	17 A.P.	20 A.P.	0.03 A.P.	0.06 A.P.	18
U.S.D.A.	Max	24 E.P.	20 E.P.	0.04 E.P.	0.11 E.P.	92
Sherman	Min	7	30	0.04	0.095	81
Tables	Max	15	50	0.08	0.165	
	Av.	11	40	0.06	0.130	
Adams-U.S.	Min	16				1
Agr. Expt.	Max	21				
Stations	Av.	18				
Other	Min				0.042	69
Studies	Max				0.188	28
	Av.	27.0	50		0.115	13;29;76

* Canadian Council on Nutrition

** United States Department of Agriculture

(Table I cont.)

Description		Ascorbic Acid (mg./100 g.)	Carotene (I.U./100 g.)	Riboflavin (mg./100 g.)	Thiamine (mg./100 g.)	Lit. Ref.
			TOMATOES			
C.C.N. and U.S.D.A.	Min	19	1,080			18
	Max	23	1,100			
	Av.	21	1,590	0.04	0.06	92
Sherman Tables	Min	21	550	0.037	0.07	81
	Max	24	1,150	0.063	0.115	
	Av.	22.5	850	0.050		
Adams-U.S. Agr. Expt. Stations	Min	9	1,270			1
	Max	35	1,347			
	Av.	22	1,309			
Other Studies	Min	5			0.024	14;30;50; 59;60
	Max	48			0.120	60;91
	Av.	27;30;22 20;16;26; 18			0.072	28 13;29;76
			TURNIPS			
C.C.N. and U.S.D.A.	Min	28	Trace	0.06	0.05	18
	Max	32		0.07	0.06	92
	Av.	30		0.065	0.055	
Sherman Tables	Min	20	10	0.050	0.065	81
	Max	30	20	0.100	0.095	
	Av.	25	15	0.075	0.080	
Adams-U.S. Agr. Expt. Stations	Min	51	3,323*			1
	Max	55	3,412			
	Av.	53	3,367			
Other Studies	Min		0		0.030	50
	Max		40		0.128	28
	Av.	30	20		0.079	13;29;76

* An unusual Tokyo variety grown in Colorado

Dudgeon and Houck (44) found that higher ascorbic acid varieties tended to remain high irrespective of the locality differences. They reported a range from 10.4 to 15.2 mg./100 g. for Irish Cobbler potatoes. Murphy, Dove and Akeley (66) agreed with Karikka et al. as to which varieties were most important sources of ascorbic acid, and reported Irish Cobbler potatoes grown in Maine as having a range of 21 to 20 mg. Olson, Warren, Hiltz and Robinson (68) gave a range of 15 to 23 mg. for Irish Cobbler potatoes grown in one soil zone and a range of 14 to 23 for the same variety grown in a different soil zone in Manitoba. A range from 20 to 41 mg. was found by Lampitt, Baker, and Parkinson (49) for potatoes grown in England.

Maclinn, Fellers and Buck (60) reviewed much of the literature up to 1938 on the ascorbic acid content of tomatoes and found reported variations ranging from 5 to 48 mg./100 g. fresh vegetable. Numerous other reports suggest a range in values from different sources, at different times of the year, of 10 to 50 mg. In a study of ninety-eight different varieties, all grown under similar conditions, Maclinn and Fellers (59) gave a range of 13 to 44 mg./100 g. Studies at the University of Manitoba (67) showed a range of 19 to 24 mg./100 g. for three varieties, with Early Chatham tomatoes ranging from 18 to 22mg.

Currence (22) noted that statistically significant differences between varieties of tomatoes were seldom found in field experiments. He emphasized the interrelationship of variety and prevailing environmental conditions. It is important to grow a variety which combines high vitamin content

vestigators. Thiamine in these vegetables is found in a concentration of 0.06 mg./100 g. for cabbages, carrots, turnips and tomatoes, while potatoes have about twice this much.

8. The Mineral Content of Vegetables.

The mineral content of vegetables seems to be little affected by variety. Differences noted by various investigators, as reported in Table II, may be attributed mainly to differences in growing conditions. Peterson, Parmele and Fred (72) and Peterson (71) found that different varieties of cabbage were remarkably uniform in their contents of calcium, phosphorus, iron and nitrogen. They deemed it possible that in some vegetables one variety might be a better feeder on certain nutrients than other varieties of the same vegetable, but this did not seem to be true for cabbages.

Turnips, cabbages and carrots, as reported in Table II, have about 0.03 g. of calcium per 100 g. while tomatoes and potatoes have about one third as much. On the other hand, all the vegetables listed contain approximately 0.02 to 0.03 g. of phosphorus per 100 g. The quantity of magnesium in the vegetables is relatively uniform and low at 0.01 mg./100 g. Potatoes contain about twice as much magnesium as the other vegetables listed.

9. Maturity.

As vegetable tissues mature, great variations in ascorbic acid and carotene content are sometimes found. Some vegetables may increase in vitamin content as they go through the various stages of maturity, while others may decrease.

Table II

MINERAL CONTENT OF FRESH VEGETABLES
(Data reported in the literature)

Authority		Calcium (g/100 g.)	Phosphorus (g/100 g.)	Magnesium (g/100 g.)	Lit. Ref.
			CABBAGE		
*C.C.N. And **U.S.D.A.	Min Max Av.	0.034 0.046	0.023 0.031		18 92
Sherman Tables	Min Max Av.	 0.041	 0.028	 0.012	81
Beeson Tables	Min Max Av.	0.041 0.178 0.073	0.013 0.017 0.038	0.002 0.038 0.016	8
Other Studies	Min Max Avs	0.012 0.124 0.024;0.025	0.030 0.065 0.058;0.045		C. 23;79 P. 23;79
			CARROTS		
C.C.N. And U.S.D.A.	Min Max Av.	0.034 A.P. 0.039 E.P.	0.033 A.P. 0.037 E.P.		18 92
Sherman Tables	Min Max Av.	 0.042	 0.040	 0.017	81
Beeson Tables	Min Max Av.	0.024 0.056 0.040	0.014 0.065 0.033	0.012 0.025 0.017	8
Other Studies	Min Max Avs	0.027 0.044 0.035;0.041	0.018 0.054 0.039;0.018		C. 23;69 P. 23;69
			POTATOES		
C.C.N. And U.S.D.A.	Min Max Av	0.007 A.P. 0.011 E.P.	0.041 A.P. 0.056 E.P.		18 92
Sherman Tables	Min Max Av.	 0.013	 0.053	 0.027	81
Beeson Tables	Min Max Av.	0.0017 0.014 0.0049	0.011 0.049 0.025	0.005 0.023 0.013	8
Other Studies	Min Max Avs	0.003 0.012 0.006;0.008 0.0084	0.037 0.077 0.057;0.054 0.047		C. 23;69 P. 23;69

* Canadian Council on Nutrition
** United States Department of Agriculture.

TABLE II (Continued)

Authority		Calcium (g/100 g.)	Phosphorus (g/100 g.)	Magnesium (g/100 g.)	Lit. Ref.
			TOMATOES		
C.C.N. And U.S.D.A.	Min	0.011 A.P.	0.026 A.P.		18
	Max				92
	Av.				
Sherman Studies	Min				81
	Max				
	Av.	0.017	0.027	0.012	
Beeson Tables	Min	0.008	0.029	0.017	8
	Max	0.048	0.084	0.028	
	Av.	0.024	0.035	0.022	
			TURNIPS		
C.C.N. And U.S.D.A.	Min	0.032 E.P.	0.034 E.P.		18
	Max	0.040 E.P.	0.045 E.P.		92
	Av.	0.036 E.P.	0.039 E.P.		
Sherman Tables	Min				81
	Max				
	Av.	0.051	0.032	0.016	
Beeson Tables	Min	0.008	0.029	0.013	8
	Max	0.048	0.084	0.059	
	Av.	0.024	0.035	0.030	
Other Studies	Min	0.030	0.045		C. 23
	Max	0.032	0.045		P.23
	Av.	0.031	0.045		

Murphy (65) noted, paralleling maturation of the tissues, a definite decline in the ascorbic acid concentration of cabbages. These results were confirmed by Warren, Hiltz and Robinson (96) working with vegetables grown at the University of Manitoba. They found that ascorbic acid content of cabbages was high as they first reached optimum maturity. Then it decreased towards the end of the "mature" period. In one month ascorbic acid of Golden Acre variety decreased 20%, while that of the Jersey Wakefield decreased 15% in three weeks, and the Copenhagen Market 20% in two weeks.

The ascorbic acid content of carrots, as reported by Lantz (51) varied considerably, but in all tests the highest values were found in the very young carrots. With Red Core Chantenay carrots she noted a value of 10.5 mg/100 g. 87 days after planting. There was a rise to 14.1 mg. at 96 days, and then a sharp decrease to 7.8 at 103 days, and to 5.6 at 108 days. At 122 days the ascorbic acid reached 9.7 mg., similar to the value at 87 days. On the other hand, Pyke and Charkey (76) found that from bunching size onward, stage of maturity did not seem to influence the ascorbic acid content of carrots.

The concentration of ascorbic acid in new potato tubers tends to increase with the time of growth and to reach a maximum shortly before the normal harvesting time. After about three months growth the percentage of ascorbic acid is fairly constant and the weight of the vitamin, of course, increases in the tuber. These results were found by Lyons and Fellers (58) and Lampitt, Baker and Parkinson (49). Kelly and Somers (45) found that upon

death of the tops, the ascorbic acid content of the tubers begins to decline.

Some reports (34;47;59;60;67) have indicated that the ascorbic acid content of "mature-green" tomato fruits is essentially the same as for fully ripened ones; and others (14;43;87) indicate that ascorbic acid content increases during ripening. It appears that partially grown seed tomatoes are poorer in ascorbic acid than the ripe ones, but that after a fruit has reached its full size and is in the so-called "mature-green" stage, the increase in ascorbic acid during subsequent ripening is relatively slight.

The carotene in carrots also increases during growth. Lantz (51) noted that all carrots studied increased greatly in carotene content during growth. There was a faster increase in faster growing carrots (spring varieties). Following are her results with Imperator carrots and Red Core Chantenay.

	Imperator		Red Core Chantenay	
Planting date + no. of days	H_2O %	Carotene mg./100 g.	H_2O %	Carotene mg./100 g.
March 31, 1944				
87	88.5	3.5	89.2	2.9
96	89.2	4.5	89.1	3.7
108	87.8	7.6	89.7	7.1
122	90.2	4.6	89.3	10.5

Pyke and Charkey (76) found that six varieties of carrots grown in Colorado increased rapidly in carotene value during the growing season. Harvested as baby carrots, these varieties planted early in the season averaged 7.4 mg. carotene per 100 g., while corresponding samples harvested as mature carrots of at least two

inches crown diameter averaged 18.0 mg/100 g. Planted later in the season the young carrots averaged 8.4 mg. and mature carrots 21.5 mg. carotene per 100 g. Pepkowitz, Larson, Gardner and Owens (70) also noted that carrots increased in carotene content during maturity, reaching a maximum approximately 90 days from seeding, and then decreased again.

Degree of maturation has a marked effect in most vegetable crops (70), especially peppers which increase in ascorbic acid and greatly increase in carotene when ripe. As an average for all varieties of peas studied, overmature peas decreased 39% according to Pepkowitz et al. (70), but there was no significant change in carotene content. He could find no effect on beets of maturity.

10. Distribution of Vitamins in the Vegetable Tissues.

Not only are there differences in vitamin and mineral content of vegetables because of variety; there are differences in the distribution of these nutrients within the vegetable itself. Sheets, Leonard and Gieger (79) found that the outer green leaves of cabbages contained 50% more ascorbic acid than the inner bleached ones. In twelve different leafy vegetables analysed, the leaf blades furnished 96.3 to 99% of the total carotene and 76 to 86.6% of the total ascorbic acid. Green leaves of cabbages contained 21 times more carotene than the bleached inner leaves. Smith, Hiltz and Robinson (82) found the greatest concentration of ascorbic acid in the core, the next greatest in the inner leaves of cabbage.

Carotene was found by Harper and Zscheile (38) to be unevenly distributed through the carrot root. Different varieties differed

in their percentage content of the various carotenes. Many varieties contained approximately equal percentages of carotene in the phloem and xylem portions of the root, but in a few varieties the differences were considerable. Cross-sectional slices from the tip, center and top regions revealed that the tip and center were essentially identical but the top was 50% higher in total carotenoids.

Lampitt, Baker and Parkinson (48) studied the distribution of ascorbic acid in potato plants. The leaves and the new tubers contributed the bulk of the ascorbic acid present in the plants. The potato was separated into (a) peel about one-eighth of an inch thick and (b) residual tissue. No significant differences were found between the peel and tissue unless conditions of storage induced sprouting, when the concentration of ascorbic acid in the sprouts and surrounding eyes was greater than that in the remainder of the tissue.

Maclinn and Fellers (59) found that the Comet variety of field tomatoes had the largest amount of ascorbic acid in the locule section, 19 mg./100 g. The outside skin and flesh averaged 11 mg./100 g. as did the center core. Analyses of tomato fruit by Ellis and Hamner (24) showed a greater carotene concentration at the stem end than at the blossom end. Gustafson (32), in an analysis of tomato plants for thiamine and riboflavin, found that the mature leaves contain more of these vitamins than do the ripe fruits. Immature leaves and stems have the highest concentration of these vitamins.

Sheets, Leonard and Gieger (79) analysed different parts of

leafy vegetables for calcium and phosphorus. The green leaves of cabbages contained about three times as much calcium, and somewhat less phosphorus than the bleached leaves. Seven-Top turnips from the same seed grown in five plots located in different areas and different soil types, were analysed for calcium and phosphorus. Calcium content was approximately the same for all parts of the leaf, while the phosphorus from leaf blades was from 25 to 75% greater than from the petioles or midribs.

Calcium content was found by Donelson, Leischenring, Grambou and Norris (23) to be consistently lower for pared carrots, potatoes and turnips than for unpared samples. No such losses were apparent for phosphorus. Leischenring and Donelson (52) found that calcium and iron were concentrated in the skin and cortical layer of potatoes while phosphorus was concentrated in the medulla.

Variations in vitamin and mineral contents of vegetables have been reported as caused by many environmental factors, alone or in combination. Geographical location in which a vegetable is grown seems to have an effect when the top environment is consistently characteristic of that location. Deficiencies of particular mineral elements in the soil may be expected to produce corresponding mineral deficiencies in the vegetable, and may cause a change in the vitamin content. A combination of several elements may have a different effect from that produced by any element alone. Increased intensity of illumination appears to increase the ascorbic acid, thiamine and riboflavin contents of vegetables, and decrease the carotene. Low temperatures tend to increase ascorbic acid and carotene; too much precipitation to depress ascorbic acid and carotene in vegetables. Great differences are found between varieties of vegetables through the stages of growth to maturity.

PART III ORGANIZATION OF THE PROJECT

The aim of the project was to study the nutritive value of vegetables grown in different soil zones of the province with reference to ascorbic acid, carotene (for one year only), riboflavin, thiamine, calcium, phosphorus and magnesium, in an attempt to discover the variations which might occur throughout the province, and, if possible, to determine the cause of these variations. The project was carried out over two growing seasons, 1949 and 1950, using the same locations wherever possible. It was thought that by continuing the project this long, climatic effects might be separated from soil effects.

In the 1949 season vegetables were grown in six different soil areas of the province with a varying number of plants in each area. The areas were as follows, differentiated by the prevailing type of soil:

Soil Zone	Area
Brown Black	Boissevain
Black (clay loam)	Darlingford; University
Northern black	Hamiota
Grey black	Swan River
Rendzina	Ericksdale
Podzol	Regions north of The Pas

Outside the province, vegetables were grown at Swift Current, Saskatchewan (Brown steppe) to note any differences caused by dry conditions prevailing in that soil zone, and at Norman Wells, North West Territories (Podzol) to see if the long daylight hours of the far north had any effect. No plots

were obtained in the Black soil zone in 1950 because of flood conditions.

Cooperators were selected with the help of the Extension Service. The aim was to obtain three cooperators, or three plots in each soil zone. Wherever possible a farmer's garden plot was used for growing the vegetables; otherwise they were grown in good summerfallow land. An outline plan of planting (see appendix- Table I) was sent to the cooperators. A list of the cooperators is given in the appendix, Table II, and Table III. Each is given a "key" number by which his sample is indicated in the later tables. These numbers, and cooperators differ for the two seasons.

Vegetables Studied:

The vegetables selected for study in the two seasons, and their varieties, were:

Cabbage	Danish Ballhead
Carrots	Chantenay
Potatoes	Irish Cobbler
Tomatoes	Early Chatham
Turnips	Laurentian

To ensure that similar material was grown at all stations, carrot and turnip seed, potato tubers, and cabbage and tomato plants were sent out from the University to the selected cooperators. The agricultural representatives supervised planting, checked the plants during the summer and suggested weed or insect control measures. They also checked on developments at harvest time and supervised harvesting, packaging and

shipping of the vegetables.

The time of seeding or planting was as follows:

Carrots and turnips---	May 15 to May 20
Potatoes and cabbages-	May 15 to May 20
Tomatoes----------	June 8 (approximately)

Planting was somewhat later in 1950 because flood conditions at the University delayed the distribution of seed and plants.

Harvesting:

With the exception of a portion of the carrot samples all vegetables were harvested when mature (unless harvested early because of frost danger).

Cabbages: Cabbages were harvested about the middle of September. Four average size marketable heads were selected, wrapped in brown paper, packed and shipped immediately to the University for analysis.

Carrots: Carrots were picked at both the bunching stage (one half to three quarters of an inch crown diameter) and at the mature stage. Twenty such roots were to be selected for each shipment. The tops were removed to within an inch of the root. The roots were packed in moist moss or paper with a waxed paper wrapping, and shipped immediately.

Potatoes: Potatoes were harvested about the middle of September. The sample consisted of eighteen average sized tubers made up by selecting three tubers from each of six hills. An attempt was made to take tubers only from plants which produced well and appeared healthy. The tubers were packed in

paper cartons or bags.

Tomatoes: Tomatoes were harvested as soon as the majority of the plants had each ripened three or more firm, full-sized fruits. Fifteen such fruits were selected (if possible), three from each of five different plants. All fruits were picked at the same time. They were wrapped individually in soft paper and packed close together into a wooden container.

Turnips: Turnips were harvested about the second week in October. Six average size marketable roots were packaged and shipped immediately.

SAMPLING METHODS

In the 1949 season, the following analyses were done on the vegetables received: ascorbic acid, thiamine, riboflavin, calcium, phosphorus and magnesium. Carotene analyses were made in addition to these of the 1950 samples.

In the 1949 season, vitamin analysis was done, if possible, as soon as the vegetables arrived. Those vegetables which could not be analysed immediately were stored at 63° to 68° F. in the root cellar of the Plant Science building. Samples for all the analyses were taken at one time. Vitamin analyses and moisture determinations were done as soon as the vegetables were sampled. Mineral samples were stored in 25 ml. of concentrated sulphuric acid until they were analysed later in the winter.

In the 1950 season the vitamin samples were stored in a freezer at -10° ± 5° F (3). Ascorbic acid samples were first blended in metaphosphoric acid by means of a Waring Blendor, (standard method of analysis as described later), filtered, and the extract frozen in tightly stoppered bottles. Carotene samples were stored in the freezer in 1% alcoholic potassium hydroxide. Thiamine and riboflavin samples were weighed into bottles and frozen (tightly stoppered) in their extracting acids.

Sampling for ascorbic acid, thiamine and riboflavin was the same. Due to the speedy oxidation of ascorbic acid to dehydro-ascorbic acid in air the samples for this vitamin were placed in 1% metaphosphoric acid as soon as possible after the

vegetables were cut. The problem of obtaining a representative sample was much greater because excess handling or mixing in a meat grinder would hasten destruction of ascorbic acid. Carotene sampling was similar to that for ascorbic acid. Samples for carotene analysis were placed in bottles and covered with alcoholic potassium hydroxide shortly after the vegetables were cut. Vegetables for thiamine and riboflavin and mineral analysis were put through a meat grinder and mixed thoroughly. Tomatoes were mixed by means of a Waring Blendor.

Preparation of the vegetables for sampling was as follows: outer, torn leaves of cabbages were removed, any dirt was rinsed off and the cabbage dried. Carrots, potatoes and turnips were washed, dried, and peeled with a double edged vegetable peeler so that the thickness of the peel was uniform, about one-eighth of an inch; tomatoes were washed and the stems removed.

Size of sample varied with the type of analysis. Fifty g. samples were used for ascorbic acid, 5 g. samples for riboflavin, and 3 g. samples for thiamine in both seasons. In the 1949 season 7 g. samples of tomatoes and 6 g. samples of the other vegetables were used for minerals (calcium, phosphorus and magnesium determinations were made on a single sample). In the 1950 season it was thought better to increase the sample size for minerals to 100 g. for all vegetables wherever possible. For carotene analysis in 1950, 25 g. samples were used. Two g. samples were used for moisture determinations in both years.

Sampling in all cases was as representative as possible. Methods for each of the vegetables were as follows:

1) Cabbages: Cabbages were sampled with a cylindrical saw-tooth edged borer by the method of Smith, Hiltz and Robinson (82). The cabbages were divided into three horizontal planes. Six cylindrical samples were taken from each cabbage, two from each plane, rotating from left to right around the cabbage. Three cabbages were sampled from each lot received. From this stage the sample was treated differently for different analyses.

(a) Ascorbic Acid:

The six cylinders from three cabbages were mixed and three 50 g. samples were taken from this for separate ascorbic acid determinations.

(b) Carotene:

Sampling was the same as for ascorbic acid. Two 25 g. samples were taken for analysis.

(c) Thiamine, Riboflavin, Minerals and Moisture:

Samples were taken from three or more cabbages as for ascorbic acid. These were mixed thoroughly and put through a meat grinder, mixed again, and samples in duplicate weighed out for the respective analyses.

2) Carrots:

(a) Ascorbic Acid and Carotene:

Pie shaped segments were taken from top to bottom of the carrots, from the outer edge to the center of the core in depth. Two wedges were taken from each of two carrots, these being from opposite sides. This made up a sample for one analysis. Analyses were done in triplicate for ascorbic acid and in duplicate for carotene.

(b) Thiamine, Riboflavin, Minerals and Moisture:

At least six whole carrots were ground in a meat grinder and samples in duplicate weighed out from these for the respective analyses.

3) Potatoes:

(a) Ascorbic Acid and Carotene:

Two wedge shaped samples were taken from opposite sides of two potatoes, cut along the longitudinal axis. Three such samples were analysed for ascorbic acid and two for carotene.

(b) Thiamine, Riboflavin, Minerals and Moisture:

Not less than six potatoes were ground in a meat grinder, mixed thoroughly and duplicate samples weighed out for each analysis.

4) Tomatoes:

(a) Ascorbic Acid and Carotene:

Two pie-shaped segments of about one-eighth of a tomato each were taken from each of two tomatoes to make up one sample. Three such

samples were used for separate ascorbic acid analyses and two for carotene analyses.

(b) Thiamine, Riboflavin, Minerals and Moisture:

At least six whole tomatoes were blended to pulp in a Waring Blendor cup and samples in duplicate taken from this for each analysis.

5) Turnips:

(a) Ascorbic Acid and Carotene:

Two wedge shaped samples were taken longitudinally from opposite sides of each turnip. Three such samples were used for separate ascorbic acid determinations and two for carotene.

(b) Thiamine, Riboflavin, Minerals and Moisture:

Two, large, wedge-shaped pieces were taken from opposite sides of at least three turnips, ground up, and mixed thoroughly. Samples in duplicate were taken from this.

METHOD OF CHEMICAL ANALYSIS

1. Ascorbic Acid:

Ascorbic acid was determined by the rapid method of Loeffler and Ponting (54). Wherever possible 50 g. of vegetable were used. This was blended with seven times as much 1% metaphosphoric acid (350 ml.) by means of a Waring Blendor, filtered, and about 100 ml. of filtrate collected. In the analysis of the 1950 samples the extract was frozen at this stage. When the extract was to be analysed later in the year, it was allowed to come to room temperature and aliquots taken. The ascorbic acid concentration was determined by measuring the amount of reduction of an aliquot of standardized 2,6-dichlorophenol indophenol dye caused by the sample and comparing it with the reduction by various known concentrations of ascorbic acid. Determinations were made with the use of a Coleman Model 11 spectrophotometer with wave length set at 520 mμ.

A standard curve was made as suggested by Morell (64). The calculations for the standard curve are given in the appendix in Table IV, and the standard curve used is given in the appendix as Figure I.

2. Carotene Analysis:

Carotene was determined by the method of Wall and Kelley (95), 25 g. samples being used for all analyses. The sample was extracted with a foaming mixture of 95% ethyl alcohol and Skellysolve B in a Waring Blendor. The extract was filtered and the vegetable pulp washed clear of color

by means of alcohol and Skellysolve B. The alcohol and extracted water were removed from the Skellysolve in separatory funnels. The Skellysolve extract of carotene was evaporated to 25 ml. in a warm water bath under suction. The 25 ml. was chromatographed on a column composed of one part of Micron Brand Magnesium oxide to three parts of Johns-Manville Celite 503. Carotene bands were eluted with 5% acetone in Skellysolve B and then made up to a convenient volume. Transmission of light through the solution was measured in a Cenco photelometer with light at 44 mμ (approximately). Transmission was compared with that of 90% β and 10% α carotene. Carotene was estimated as β-carotene. A standard curve was made by plotting μg/ml. of carotene against the % transmission. Methods of calculation and the calibration curve are given in the appendix in Table V and Figure II.

3. Thiamine Analysis:

Thiamine was determined by the method of Hennessy (39). Five gram samples were used in all determinations. The sample was extracted in a boiling water bath with 0.1 N sulfuric acid. Then it was cooled, takadiastase in sodium acetate solution added, and incubated at 45° to 50° C. The cooled mixture was made up to volume and filtered.

A 25 ml. aliquot of the filtrate was passed through columns of activated Decalso, which adsorbed the thiamine. Thiamine was eluted from the column by 25% potassium chloride in 0.1 N hydrochloric acid. The eluate was collected, made up to volume, and aliquots placed in two reaction

vessels. One was used as a blank and thiamine was not oxidized in this. In the other the thiamine was oxidized to thiachrome with potassium ferricyanide. This was extracted with isobutanol and the fluorescence of the sample extract and a similar extract of the blank was measured with a Coleman Model 12 photofluorometer. The fluorescence of the unknown was compared with fluorescence of a known quantity of thiamine treated similarly and the thiamine concentration was calculated in μg./g.

4. Riboflavin Analysis:

Riboflavin was determined according to the method of Andrews (2). "Life-time Red" glassware was used throughout. A 3 g. sample was used in all analyses. The sample was extracted with 0.1 N sulfuric acid in a 100 ml. volumetric flask kept in a boiling water bath for one hour. It was then cooled, and sodium phosphate solution, glacial acetic acid, and takadiastase added in turn. The extracts were incubated at 45° to 50° C., cooled, made up to volume and filtered.

A 50 ml. aliquot was oxidized with potassium permanganate, and then decolorized with hydrogen peroxide. The decolorized extract was allowed to drip through a Florisil column which adsorbed the riboflavin. The riboflavin was eluted with pyridine containing acetic acid.

The fluorescence of the unknown and of a riboflavin standard was measured with a Coleman Model 12 photoflurometer. The concentration of riboflavin in the vegetable was determined from these measurements.

5. Preparation of the Extract for Mineral Analysis:

The mineral samples were transferred from the bottles in which they had been stored to Kjeldahl flasks. The samples were digested in sulfuric acid for one-half hour after the water had evaporated. The contents were cooled, 5 ml. concentrated nitric acid added, and digested again until the extract was colorless.

The contents were transferred to Erlenmeyer flasks, neutralized with concentrated ammonium hydroxide and evaporated to dryness. The residue was cooled and to it about 3 ml. of concentrated hydrochloric acid added. After 10 minutes 100 ml. of distilled water were added and the mixture boiled to coagulate the silica. This was filtered. The filtrate was collected in a 250 ml. volumetric flask, cooled, and made up to volume. This extract was used for mineral determinations.

6. Phosphorus Analysis:

Phosphorus was determined by the method of Fiske and Subbarow (27). A 40 ml. portion of the extract was placed in a 100 ml. volumetric flask and approximately 20 ml. of water added, and mixed. Ten ml. of ammonium molybdate solution and 4 ml. of reducing agent (1-amino-2-naphthol-4-sulphonic acid) were added. The solution was made up to volume and mixed. The solutions were allowed to stand for 30 minutes to bring out the maximum blue color. Then intensity of color was read in a Cenco photelometer and the concentration was calculated by reference to a standard curve.

The standard curve was prepared using 0.4389 g. KH_2PO_4 per

liter of distilled water (0.025 mg. P/ml.). Calculations are shown in the appendix in Table VI and the calibration curve in the appendix as Figure III.

7. Calcium Determination:

Calcium and magnesium determinations were made according to the methods of the First International Congress of Soil Science, (A.O.A.C; 4). A 200 ml. portion of the extract prepared for mineral determination was used. A small amount of ammonium chloride was added to prevent the precipitation of magnesium. Ammonium hydroxide (1:9) was used to neutralize the solution. It was then heated almost to boiling, hot ammonium oxalate added slowly, and brought to the boil. The solution was allowed to stand over night to precipitate the calcium which was filtered out by quantitative ashless filter paper. The filtrate was saved for magnesium determination. The filter paper and its contents were dried, then ashed at 700° C. to convert the precipitate to calcium oxide. The cooled residue was weighed as calcium oxide.

8. Magnesium Determination (4).

To the filtrate from the calcium determinations sodium ammonium phosphate and then concentrated ammonium hydroxide were added. The solution was allowed to stand over night to precipitate magnesium. The magnesium was filtered on quantitative ashless filter paper, and washed with ammonium hydroxide. The precipitate was dried and then ignited at 900° C. The residue was cooled and weighed as magnesium pyrophosphate ($Mg_2P_2O_7$).

9. Moisture Determinations.

In the 1949 season 2 g. samples were air dried over night in aluminum moisture dishes, then dried in an oven at 130° C. to constant weight. In the 1950 season the samples were dried in air, then in a vacuum oven at 100° C. to constant weight.

Each vitamin or mineral analysis was calculated using the particular moisture content of the vegetable used. Then, since moisture varied to some degree in the samples, all analyses were calculated to a common moisture basis for each kind of vegetable. Those levels used as standards were those selected from the Winton and Winton (98) tables, stated as being the usual average for each vegetable. These standards are:

Cabbages	87%
Carrots	89%
Potatoes	79%
Tomatoes	94%
Turnips	90%

PART IV RESULTS AND DISCUSSION

The average vitamin and mineral contents of the vegetables analysed in the 1949 and 1950 seasons are given in Tables III and IV. For comparison values given in the Canadian Council on Nutrition food tables (18) are included. Each figure for our experimental work represents the mean of all analyses on a particular vegetable for that season. While carrots were analysed in two stages of maturity, "early" and "late", for the purpose of Tables III and IV the two means were averaged.

Ascorbic acid is expressed as mg./100 g. in all tables. Cabbages, potatoes and tomatoes in both seasons had averages higher than the values given in the Canada food tables (18), while carrots and turnips had lower ones. Manitoba-grown Danish Ballhead cabbages are an excellent source of ascorbic acid, containing over twice as much as reported to be average values for Canada. This may be due to a combination of a normally high ascorbic acid producing variety, and favorable conditions of growth. Carrots are not important sources of this nutrient. The variety grown in the two seasons contained slightly less than is found to be the Canadian average. Tomatoes and turnips contain about equal amounts of ascorbic acid. The tomatoes grown here were much better sources than the average while turnips were poorer. Conditions of growth in the 1950 season were not good for tomatoes. Many had to be picked green for fear of frost. Irish Cobbler potatoes seem to be slightly better than average as sources of ascorbic acid.

TABLE III

NUTRIENT CONTENT OF MANITOBA VEGETABLES

AS COMPARED WITH AVERAGES FOR ALL CANADA

VITAMINS - 1949 and 1950

Vegetable	Ascorbic Acid (mg./100 g.)			Vitamin A (I.U./100 g.) (0.6 μg. carotene = 1 I.U.)	
	Canadian* Average	Determined in this project 1949	1950	Canadian Average	Determined in this project 1950
Cabbages	38	90.7	78.96	60	trace
Carrots	6	4.7**	5.60**	12,000	12,437
Potatoes	14	16.1	16.74	20	trace
Tomatoes	19	26.5	24.62	1,080	598
Turnips	32	19.9	25.05	trace	trace

Vegetable	Riboflavin μg./g.			Thiamine μg./g.		
	Canadian Average	Determined in this project 1949	1950	Canadian Average	Determined in this project 1949	1950
Cabbages	0.4	0.62	0.47	0.5	1.12	0.77
Carrots	0.6	0.47**	0.35**	0.7	0.54**	0.54**
Potatoes	0.4	0.29	0.24	1.1	1.27	1.01
Tomatoes	0.4	0.42	0.32	0.6	0.80	0.72
Turnips	0.6	0.24	0.21	0.6	0.68	0.56

* Canadian Council on Nutrition - food tables (18)

** Averages for early and late carrots.

Since the 1950 season was much more cloudy and wet than the 1949 one, it was expected that ascorbic acid contents for all vegetables grown in 1950 would be lower than for the previous year. However, it appears that those vegetables grown above the ground and exposed more to the effects of sunlight showed a decrease, while all the root vegetables showed an increase in 1950. Several investigators (100, 34, 47, 85, 77) found lower amounts of ascorbic acid values when the season was cloudy and wet. These results were with vegetables, the edible parts of which were grown above the ground. Our results for tomatoes and cabbages confirm their findings.

Carotene analyses were done for the 1950 crop only. In Table III the carotene values are expressed as I.U. of vitamin A (0.6 μg. carotene = 1 I.U.). The vitamin A contents of carrots were much higher than the Canadian average, proving them to be an excellent source of this nutrient. Tomatoes, on the other hand, were low in vitamin A. The value for tomatoes compares with the Sherman average (Table I). It is unfortunate that carotene results are not available for the 1949 crop, since these low values for 1950 may have been due to seasonal effect. The literature (24) confirms lowered carotene contents in tomatoes exposed to less sunlight. Some analyses were done on cabbages, potatoes and turnips, but only very small traces of the vitamin were found in any of these.

Riboflavin values are expressed in μg./g. The averages for cabbages and tomatoes compare favorably with the Canadian ones, but those for the other vegetables are consistently lower.

TABLE IV

NUTRIENT CONTENT OF MANITOBA VEGETABLES

AS COMPARED WITH AVERAGES FOR ALL CANADA

MINERALS 1949

Vegetable	Calcium g./100 g.		Magnesium g./100 g.		Phosphorus g./100 g.	
	Canadian* Averages	Determined in this project	Sherman** Averages	Determined in this project	Canadian Averages	Determined in this project
Cabbage	0.034	0.087	0.012	0.045	0.023	0.050
Carrots	0.039	0.052***	0.017	0.040***	0.037***	0.031
Potatoes	0.011	0.027	0.027	0.049	0.056	0.053
Tomatoes	0.011	0.046	0.012	0.063	0.026	0.031
Turnips	0.036	0.039	0.016	0.025	0.039	0.033

* Canadian Council on Nutrition - Food tables (18).
** Sherman, Chemistry of Foods and Nutrition (81).
*** Averages for early and late carrots.

Riboflavin values for the 1950 season were all lower than those for the same vegetable for 1949. Less favorable growing conditions may have been responsible for this (56). Vegetables are not considered important sources of riboflavin, but, of the vegetables studied, cabbages, carrots and tomatoes seem to be better than the others.

Thiamine contents for all vegetables except carrots are much higher than those values for the whole of Canada. There is a decrease in the 1950 season. The explanation for this might be similar to that for riboflavin (33). Carrots and turnips had thiamine contents about half those of cabbages and potatoes, while tomatoes had two-thirds as much.

Mineral analyses of vegetables are available for only the 1949 crop. The calcium and magnesium contents of vegetables were considerably higher than the values reported in the literature. The 6 and 7 g. samples used for analysis were too small to ensure a high degree of accuracy in analysis. The results may be interpreted as showing trends in calcium and magnesium contents, rather than absolute values. Cabbages and carrots are better sources of calcium than the other vegetables. Tomatoes and potatoes rank highest as sources of magnesium, while turnips were lowest in this mineral.

Phosphorus contents of the vegetables agree quite closely with those in the literature. Cabbages and potatoes have the greatest amounts of phosphorus. Tomatoes, carrots and turnips contain about three-fifths as much.

Odd-numbered Tables V to XXIII are more complete tables of

the vitamin and mineral contents of vegetables. Each figure is an arithmetic average of two determinations made on a random sample of a vegetable grown at the location indicated. Values are grouped according to soil zone, and an average value is given for each soil zone. At the bottom of each table overall averages are shown for each vegetable. These are the averages used in Tables III and IV. It is possible to compare the vitamin or mineral content of a vegetable grown in one soil zone with that grown in another or with the average content for that vegetable. The numbers in the first column refer to the collaborators. The names of the collaborators and the locations where the vegetables were grown are indicated by the same numbers in Tables II and III in the Appendix.

Following each table of nutritive values, there is a table of the analysis of variance for that nutrient as found in the different vegetables grown in the seven soil zones. These were calculated by the method of Snedecor (84) for unequal and disproportionate subclass numbers. Interaction was calculated by the method of Snedecor, solving equations by the method of Crout (21), and was found to be quite near the value for error. Due to the difficulty involved in finding interaction, the value for error was used to test significance. It was thought that this might bias upwards, to some extent, the F values, but not so much as to cause any great differences in significance. The variance represented by error arises from differences of results for the duplicate determinations, and thus is a measure of discrepancies due to laboratory technique.

TABLE V

ASCORBIC ACID CONTENTS OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in milligrams per 100 grams)
1949 Season

Vegetable		Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbage	Potatoes
Moisture level %		89	89	90	94	87	79
Key No.	Soil Zone						
2.	Brown	4.60	1.91	30.56	28.03	---	26.40
3.	black	1.62	1.44	20.50	23.91	96.56	24.77
4.		4.76	1.24	23.71	29.91	65.29	17.01
Av.		3.66	1.53	24.92	27.28	80.93	22.73
6.	Black	6.15	2.77	11.08	23.86	106.43	22.55
7.		4.97	3.70	31.90	27.74	105.59	30.11
8.		5.99	4.02	15.29	32.89	100.60	21.07
18.		6.79	2.67	10.76	28.83	109.63	22.57
20.		---	5.43	5.55	28.81	116.44	19.56
Av.		5.98	3.72	14.92	28.43	107.74	23.17
1.	Northern	10.01	2.13	32.41	11.49	96.50	4.18
9.	black	5.91	2.68	---	22.60	90.85	16.23
25.		6.14	4.76	---	25.36	106.40	2.53
27.		---	2.45	14.78	14.95	72.10	15.14
Av.		7.35	3.01	23.60	18.60	91.45	9.52
13.	Grey	6.38	---	---	---	---	---
17.	black	5.55	3.51	17.41	27.79	102.42	24.97
19.		5.47	4.38	34.73	16.28	100.11	27.15
21.		7.47	2.71	26.25	27.37	90.22	11.81
24.		---	2.34	---	27.77	109.02	8.11
26.		---	8.05	24.08	26.64	64.15	47.59
Av.		6.22	4.20	25.62	29.17	93.18	23.93
5.	Rendzina	10.20	5.72	13.27	21.62	109.53	14.85
10.		4.62	6.68	24.04	25.16	104.60	18.60
14.		5.41	2.20	13.80	21.42	90.90	14.07
Av.		6.74	4.87	17.04	22.73	101.68	15.84
22.	Brown steppe	3.54	5.19	12.56	---	109.02	20.25
15.	Podzol	6.36	4.74	16.28	28.83	85.61	8.21
28.		---	4.51	26.93	---	---	1.79
30.		---	2.51	---	---	107.87	5.87
31.		---	3.54	17.62	---	68.16	7.74
33.		---	4.25	---	33.99	---	---
Av.		6.36	3.91	20.28	31.41	87.21	5.90
*11.	Azonal	6.24	2.38	---	26.58	54.35	7.45
Average		5.76	3.71	19.85	26.48	90.70	16.10

* Not included in the analysis of variance

TABLE VI

ANALYSIS OF VARIANCE

FOR

ASCORBIC ACID CONTENT OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1949 SEASON

Sources of variation	D.F.	Mean Square	F	1% Point
Total	135	33,609.48		
Subclasses	41	45,831.91		
Within Subclasses (error)	94	28,278.42		
Vegetables	5	2,704,509.64**	95.64	3.20
Soils	6	22,003.02**	4.67	2.99

** Two stars indicates significance at the 1% point, one star, at the 5% point.

Table V shows the ascorbic acid contents of vegetables grown in the 1949 season. Observation of these data reveals a range in the soil zone averages from 3.54 to 7.35 mg./100 g. for early carrots, 1.53 to 4.87 for late carrots, 14.92 to 24.92 for turnips, 18.60 to 30.29 for tomatoes, 54.34 to 149.85 for cabbages and 5.90 to 23.93 for potatoes. Early carrots are better sources of this nutrient than late carrots. These large ranges have been encountered by other workers.

The analysis of variance was applied to Table V, and the F values for vegetables, as reported in Table VI, was found to be 95.64. This was highly significant and indicates that some vegetables are better sources of ascorbic acid than others. This is to be expected. The F value for soil zones was found to be significant at the 1% level. This indicates a decided difference in the ascorbic acid content of a vegetable, depending upon the soil zone in which it is grown.

Averages for the ascorbic acid contents of all the vegetables in each of the zones were:

Black	31.5
Grey-black	31.4
Brown steppe	30.1
Rendzina	28.2
Northern black	26.6
Podzol	24.2
Brown-black	23.6

The question arises as to whether it was the type of soil that caused these variations, or the climatic factors associated with the different locations of these soils.

These soils are quite different in physical appearance and chemical content. The Brown, Brown-black and Black zones are

found on the prairie. The Brown earth zone in this experiment was represented by Swift Current, Sask., the Brown-black by Boissevain and the Black by the Red River Valley. These three zones are alkaline and contain a high amount of calcium in the form of carbonates and sulfates. Greatest amounts are found in the Brown earth, least in the Black earth. Brown earth is high in soluble salts such as chlorides and sulfates of sodium, potassium and magnesium, calcium chloride and sodium and potassium carbonates. These soils are high in nitrogen.

The Northern black earth and Grey-black earth zones are in the transition belt characterized by prairie and aspen grove. Samples came from McConnel, Hamiota and Basswood for the Northern black earth zone, and from Swan River, Erickson, Kenville, Benito, Rosa, Tolstoi and Durban for the Grey-black soil zone. These two zones have some calcium in the form of calcium carbonate. They are highest of all the zones in organic matter, and therefore have much phosphorus.

The other three zones are the Grey-wooded zone and the two Podzol zones found farther north in the forest regions. The Grey-wooded zone has deciduous trees and the Podzol mixed forest and coniferous trees depending on the location. The soils are acid clays and are high in iron and aluminum, low in nitrogen and calcium. The organic matter accumulates on the soil but does not extend to any great depth. The Pas and Sprague are in the Grey-wooded zones, and Norman Wells, N.W.T., Island Lake, South Indian Lake and Wabowden have Podzol soils. The soil zones which are more heavily forested are high in moisture content.

TABLE VII

ASCORBIC ACID CONTENT OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in milligrams per 100 grams)
1950 Season

Vegetable	Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbage	Potatoes
Moisture level %	89	89	90	94	87	79
Key Soil No. Zone						
3. Brown	4.14	5.90	37.02	17.44	51.76	15.94
4. black	5.61	3.17	11.50	16.14	88.05	24.81
5.	4.73	2.92	26.69	16.04	86.25	7.14
Av.	4.83	4.00	25.07	16.54	75.35	15.96
9. Northern	6.12	---	---	25.74	70.96	21.25
10. black	3.78	---	24.95	---	75.42	21.07
Av.	4.95	---	24.95	25.74	73.19	21.16
6. Grey	2.22	---	21.29	36.89	77.01	14.96
7. black	---	---	---	27.42	64.57	14.53
8.	---	---	---	33.05	77.52	20.87
15.	---	---	---	---	66.41	9.25
20.	0.00	---	13.87	---	102.50	4.63
22.	5.49	---	27.07	---	---	18.50
Av.	2.57	---	20.74	32.45	77.60	13.79
2. Rendzina	3.95	11.61	30.12	13.59	97.61	14.22
13.	---	---	26.80	19.41	84.38	15.75
17.	4.15	---	25.19	---	---	16.11
Av.	4.05	11.61	27.37	16.50	91.00	15.36
12. Brown steppe	---	---	---	---	91.00	22.43
1. Podzol	5.67	4.57	19.29	21.71	72.81	11.29
11.	5.53	---	33.94	42.07	---	15.24
14.	5.00	---	---	---	---	9.58
18.	6.41	---	26.52	---	---	15.26
19.	1.15	---	13.54	---	88.23	15.18
Av.	4.75	4.57	23.32	31.89	80.52	13.31
*16. Azonal	5.63	---	28.85	---	64.03	15.18
Average	4.46	6.73	25.05	24.62	78.96	16.74

* Not included in the analysis of variance.

TABLE VIII

ANALYSIS OF VARIANCE

ASCORBIC ACID CONTENT OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1950 SEASON

Sources of Variation	D.F.	Mean Square	F.	1% Point
Total	79	749.40		
Subclasses	35	1,596.88		
Within Subclasses (error)	44	75.26		
Vegetables	5	10,881.41**	144.68	3.46
Soils	5	621.11**	8.25	3.46

Those locations which are farther north have longer hours of sunshine, and Norman Wells has 24 hours of sunlight a day during the summer.

When the ascorbic acid contents of these vegetables are considered with respect to the type of soils on which they are grown, one finds that the Black soil zone which produced the highest contents of this nutrient in the vegetables, and the Brown-black soil zone which produced the lowest are very similar in chemical and physical properties. The Black earth does not contain as high a percentage of calcium carbonate and calcium sulfate as the Brown-black earth, nor as much soluble salts. It is also less alkaline than the Brown-black earth. The differences in ascorbic acid contents of these vegetables do not seem to be explained by the lack or excess of any particular nutrient in the soil, nor to alkalinity or acidity. Temperature, rainfall and sunlight may vary for the different soil zones, and are possible sources of the ascorbic acid variations, alone or in combination with the soils.

The ascorbic acid contents of vegetables for the 1950 season are reported in Table VII. The soil zone averages range from 2.57 to 4.95 for early carrots, 4.00 to 11.61 for late carrots, 20.74 to 27.37 for turnips, 16.50 to 32.45 for tomatoes, 73.19 to 91.00 for cabbages and 13.31 to 22.43 for potatoes. It may be noted that late carrots appear to be better sources of ascorbic acid than early carrots. This is because of a single value, 11.61, from the Rendzina soil zone, which is quite out of line with the others. If this were omitted from the averages,

early carrots would appear better sources than late carrots.

Analysis of variance was applied to the table and the results are reported in Table VIII. The F value calculated for vegetables was 144.68, which was highly significant at the 1% level. This emphasizes the great difference in ascorbic acid contents between these vegetables. The F value for soil zones was 8.25. This also was significant at the 1% level. This shows that, as in 1949, there were differences in the vitamin contents of the vegetables which could be attributed to the soil zones.

The averages for all the vegetables by soil zone are:

Grey-black	31.9
Northern black	31.2
Rendzina	27.9
Brown-black	23.6
Podzol	21.8

The average for the Brown steppe soil zone is not included because only the values for cabbages and potatoes go to make up this average. As explained before, no vegetables were grown in the Black soil zone in 1949, and in 1950 it produced vegetables with the highest average ascorbic acid contents. Those grown on the Northern black and Rendzina soils had ascorbic acid contents which were in the middle range in both years, while vegetables grown on the Podzol and Brown-black soils had the least in both years. This agreement over the two years indicates a definite trend for one soil zone to produce vegetables with consistantly more of this nutrient than another soil zone.

The Grey-black and Northern black soils, which produced vegetables with high ascorbic acid contents, are neutral in pH, having a moderate amount of calcium and potassium and high

TABLE IX

CAROTENE CONTENT OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in micrograms per gram)

1950 Season

Vegetable		Early Carrots	Late Carrots	Tomatoes
Moisture level %		89	89	94
Key No.	Soil Zone			
3.	Brown	46.48	72.54	4.13
4.	Black	53.11	68.62	3.26
5.		51.89	49.97	5.71
Av.		50.49	63.71	4.37
9.	Northern	72.04	---	3.80
10.	black	52.77	---	---
Av.		62.41	---	3.80
6.	Grey	39.03	---	3.89
7.	black	---	---	4.22
8.		---	---	3.16
15.		---	---	---
22.		96.74	---	---
Av.		65.91	---	3.76
2.	Rendzina	39.57	142.16	1.59
13.		---	---	2.10
17.		68.75	---	---
Av.		54.16	142.16	1.85
1.	Podzol	---	41.78	1.18
11.		122.10	---	7.16
14.		93.31	---	---
18.		67.85	---	---
19.		51.53	---	---
Av.		83.70	41.78	4.17
*16.	Azonal	83.46	---	---
Average		66.69	82.55	3.59

* Not included in the analysis of variance.

TABLE X

ANALYSIS OF VARIANCE

FOR

CAROTENE CONTENT OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1950 SEASON

Sources of Variation	D.F.	Mean Square	F.	5% Point	1% Point
Total	29	1,482.04			
Subclasses	14	2,676.34			
Within Subclasses (error)	15	367.37			
Vegetables	2	14,584.31**	39.70		6.36
Soils	4	190.44	0.52	3.06	

phosphorus. Hamner, Lyon and Hamner (35) found that potassium and phosphate deficiencies caused vegetables to be low in ascorbic acid. Since the above soils contained adequate amounts of the above macro-nutrient elements, the vegetables grown in them would be expected not to have low ascorbic acid contents. This is obviously the case.

The top soil of the Podzol zones has a high amount of organic matter, and the soil is quite acidic. Iron oxide is found in these regions in larger quantities than in other soils. According to the literature (56), iron deficiencies are associated with high ascorbic acid in vegetables. No reports could be found on the effects of high iron soils, but we found them to give vegetables with below normal amounts of all the vitamins studied.

Carotene contents of carrots and tomatoes are reported in Table IX. Results are available for the 1950 season only, so comparisons cannot be made over the two years. It is apparent that the more mature carrots are better sources than the young carrots. This agrees with the results of Lantz (51), Pyke and Charkey (76) and Pepkowitz, Larson, Gardner and Owens (70), all of whom found that carrots increased in carotene as they reached maturity, the carotene being at a maximum when the carrots were at the best marketable stage.

The analysis of variance, summarized in Table X, shows a highly significant difference between vegetables as sources of carotene. However, the analysis for soil zones shows that there is no significant difference between soil zones. The F value

TABLE XI

RIBOFLAVIN CONTENTS OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in μg./g.)
1949 Season

Vegetable		Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbage	Potatoes
Moisture level %		89	89	90	94	87	79
Key No.	Soil Zone						
2.	Brown	0.45	0.19	0.25	0.48	---	0.27
3.	black	0.53	0.50	0.24	1.11	0.72	0.28
4.		0.51	0.31	0.24	0.39	0.68	0.25
Av.		0.50	0.33	0.24	0.66	0.70	0.27
6.	Black	0.55	0.43	0.31	0.37	0.52	0.32
7.		0.51	0.44	0.25	0.46	0.54	0.33
8.		0.44	0.32	0.23	0.50	0.49	0.34
18.		0.58	0.39	0.16	0.43	0.76	0.34
20.		---	0.59	0.19	0.35	0.69	0.42
Av.		0.52	0.43	0.23	0.42	0.60	0.35
1.	Northern	0.76	0.31	0.23	0.26	0.60	0.24
9.	black	0.60	0.36	---	0.35	0.72	0.27
25.		0.58	0.33	---	0.32	1.05	0.20
27.		---	0.32	0.24	0.28	0.69	0.19
Av.		0.65	0.33	0.24	0.30	0.77	0.23
13.	Grey	0.49	---	---	---	---	---
17.	black	0.57	0.37	0.22	0.44	0.68	0.30
19.		0.50	0.38	0.25	0.38	0.61	0.32
21.		0.58	0.37	0.23	0.39	0.57	0.32
24.		---	0.30	---	0.52	0.64	0.26
26.		---	0.51	0.25	0.48	0.36	0.30
Av.		0.54	0.39	0.24	0.44	0.57	0.30
5.	Rendzina	0.50	0.34	0.22	0.39	0.50	0.32
10.		0.50	0.31	0.27	0.48	0.80	0.24
14.		0.50	0.33	0.25	0.50	0.69	0.25
Av.		0.50	0.33	0.25	0.46	0.66	0.27
22.	Brown steppe	0.48	0.40	0.21	---	0.62	0.33
15.	Podzol	0.66	0.43	0.32	0.29	0.72	0.28
28.		---	0.33	0.24	---	---	0.19
30.		---	0.33	---	---	0.48	0.43
31.		---	0.52	0.23	---	0.61	0.18
23.		---	0.49	---	0.36	---	---
Av.		0.66	0.42	0.26	0.33	0.60	0.27
*11.	Azonal	0.60	0.38	---	0.36	0.45	0.29
Average		0.56	0.38	0.24	0.42	0.62	0.29

* Not included in the analysis of variance

TABLE XII

ANALYSIS OF VARIANCE

FOR

RIBOFLAVIN CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1949 SEASON

Sources of Variation	D.F.	Mean Square	F.	5% Point	1% Point
Total	135	0.0297			
Subclasses	41	0.0752			
Within Subclasses (error)	94	0.0098			
Vegetables	5	5.2356**	534.24		3.20
Soil Zones	6	0.0063	0.64	2.19	

for between soil zones was 0.52, while the 5% level of significance was 3.06. According to the literature, carotene in vegetables is not significantly affected by limitations of macro-nutrients (97, 42, 24). Lyon, Beeson and Ellis (56) found no effect for macro-nutrients, including manganese. Gum, Brown and Burrell (31) found that extreme deficiencies in iron or manganese might have an effect. In this event the plant itself would show the effects of the deficiency of the element. The soils included in this study did not show these acute deficiencies, so our results confirm the lack of effect of normal amounts of macro- or micro-nutrients.

In Table XI the riboflavin contents of the 1949 vegetables are tabulated. Examination of these data reveals that some vegetables are better sources of this nutrient than others. This is emphasized when the analysis of variance for riboflavin is examined in Table XII. The F value for vegetables is 534.24, which is highly significant at the 1% level of F = 3.20. The actual differences between vegetables are shown in Tables III and XI. Late carrots are found to contain only two-thirds as much riboflavin as early carrots. This indicates that the amount of riboflavin in carrots decreases as the vegetable reaches maturity. No reports could be found in the literature dealing with the effect of maturity on the riboflavin contents of vegetables.

The analysis of variance applied to soil zones shows that there is no significant difference in the riboflavin contents of vegetables grown in different soils. The F value for soil zones

TABLE XIII

RIBOFLAVIN CONTENTS OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in micrograms per gram)
1950 Season

Vegetable	Early Carrot	Late Carrot	Turnips	Tomatoes	Cabbages	Potatoes
Moisture level %	89	89	90	94	87	79
Key No. Soil Zone						
3. Brown	0.38	0.24	0.22	0.33	0.47	0.13
4. black	0.33	0.46	0.31	0.17	0.45	0.46
5.	0.33	0.36	0.33	0.14	0.53	0.21
Av.	0.35	0.35	0.29	0.21	0.48	0.27
9. Northern	0.37	---	---	0.26	0.35	0.32
10. black	0.61	---	0.10	---	0.41	0.12
Av.	0.49	---	0.10	0.26	0.38	0.22
6. Grey	0.25	---	0.26	0.48	0.17	0.21
7. black	---	---	---	0.24	0.39	0.15
8.	---	---	---	0.34	0.31	0.30
15.	---	---	---	---	0.62	0.22
20.	0.27	---	0.15	---	0.50	0.29
22.	0.45	---	0.21	---	---	0.29
Av.	0.32	---	0.21	0.35	0.40	0.24
2. Rendzina	0.19	0.27	0.30	0.18	0.60	0.21
13.	0.38	---	0.25	0.34	0.53	0.30
17.	0.43	---	0.24	---	---	0.21
Av.	0.33	0.27	0.26	0.26	0.57	0.24
12. Brown steppe	---	---	---	---	0.64	0.32
1. Podzol	0.29	0.33	0.22	0.41	0.22	0.17
11.	0.47	---	0.19	0.45	---	0.19
14.	0.54	---	---	---	---	0.25
18.	0.52	---	0.19	---	---	0.24
19.	0.34	---	0.16	---	0.49	0.15
Av.	0.43	0.33	0.19	0.43	0.36	0.20
*16. Azonal	0.37	---	0.23	---	---	0.20
Average	0.38	0.32	0.21	0.32	0.47	0.24

* Not included in the analysis of variance.

TABLE XIV

ANALYSIS OF VARIANCE

FOR

RIBOFLAVIN CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1950 SEASON

Sources of Variation	D.F.	Mean Square	F.	5% Point	1% Point
Total	80	0.0174			
Subclasses	35	0.0249			
Within subclasses (error)	45	0.0116			
Vegetables	5	0.1120**	9.66		3.44
Soils	5	0.0120	1.03	2.42	

is 0.64, while the 5% level of significance is 2.19. There does not seem to be any information available in the literature on the effect of soils on the riboflavin contents of vegetables. This is likely because they are not considered good sources of this vitamin.

A study of riboflavin contents of vegetables grown in similar soils in 1950, leads to the same conclusions. Riboflavin values for 1950 are reported in Table XIII. Early carrots again prove to be better sources of this nutrient than the late carrots. Analysis of variance of vegetables for riboflavin, summarized in Table XIV, shows again that there are highly significant differences between vegetables, but that the differences between soil zones are not significant even at the 5% level.

Averages of all vegetables for each soil zone are given below for 1949 and 1950. The averages are almost identical within each year, so that no statistical significance could be expected.

	1949	1950
Brown-black	0.44	0.32
Black	0.42	(no samples)
Northern black	0.42	0.32
Grey-black	0.41	0.31
Rendzina	0.41	0.32
Brown steppe	0.41	(too few samples)
Podzol	0.44	0.31

There is a distinct difference between years, and this has already been discussed on page 50.

Thiamine content of vegetables was studied during two seasons. The results of the 1949 analyses for thiamine are

TABLE XV

THIAMINE CONTENT OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in µg./g.)
1949 Season

Vegetable		Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbage	Potatoes
Moisture level %		89	89	90	94	87	79
Key No.	Soil Zone						
2.	Brown	0.43	0.38	0.78	0.73	---	0.90
3.	black	0.55	0.48	0.59	0.90	1.36	1.29
4.		0.52	0.35	0.80	0.75	0.97	0.95
Av.		0.50	0.40	0.72	0.79	1.17	1.05
6.	Black	0.58	0.55	0.75	0.68	1.00	1.31
7.		0.44	0.56	0.96	0.61	0.99	1.23
8.		0.55	0.40	0.71	0.80	1.04	1.39
18.		0.64	0.45	0.66	0.65	1.15	1.66
20.		---	0.66	0.59	0.79	1.08	1.30
Av.		0.55	0.52	0.73	0.71	1.05	1.38
1.	Northern	0.86	0.64	0.94	0.82	0.88	1.01
9.	black	0.66	0.49	---	0.44	1.05	1.25
25.		0.56	0.66	---	0.74	1.19	1.08
27.		---	0.60	0.76	0.82	1.02	0.92
Av.		0.69	0.60	0.85	0.71	1.04	1.07
13.	Grey	0.60	---	---	---	---	---
17.	black	0.57	0.48	0.59	0.78	1.06	1.02
19.		0.36	0.52	0.81	0.78	1.06	1.46
21.		0.55	0.55	0.74	0.72	1.12	1.16
24.		---	0.44	---	1.16	1.22	1.06
26.		---	0.50	0.74	0.77	0.64	1.00
Av.		0.52	0.50	0.72	0.84	1.02	1.14
5.	Rendzina	0.50	0.46	0.77	0.59	1.34	1.61
10.		0.50	0.39	0.84	0.69	1.11	1.24
14.		0.46	0.40	0.66	0.86	1.13	1.31
Av.		0.49	0.42	0.76	0.71	1.19	1.39
22.	Brown steppe	0.41	0.46	0.55	---	1.75	1.93
15.	Podzol	0.62	0.52	0.37	0.98	1.04	1.00
28.		---	0.56	0.55	---	---	0.80
30.		---	0.49	---	---	1.35	1.47
31.		---	0.80	0.40	---	0.68	0.87
23.		---	0.55	---	0.80	---	---
Av.		0.62	0.58	0.44	0.89	1.02	1.04
*11.	Azonal	0.73	0.61	---	0.86	0.74	1.17
Average		0.56	0.51	0.68	0.80	1.12	1.27

* Not included in the analysis of variance

Table XVI

ANALYSIS OF VARIANCE

FOR

THIAMINE CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1949 SEASON

Source of Variation	D.F.	Mean Square	F.	1% Point
Total	135	0.062		
Subclasses	41	0.167		
Within subclasses (error)	94	0.016		
Vegetables	5	1.993**	125.35	3.20
Soil Zones	6	0.158**	9.96	2.99

reported in Table XV. This table shows that there is a wide range in values for the different vegetables. The averages for early carrots from the different soil zones are from 0.41 to 0.73, late carrots from 0.40 to 0.60, showing early carrots to contain more of this nutrient. The averages for turnips ranged from 0.44 to 0.85, tomatoes from 0.71 to 0.98, cabbages from 0.72 to 1.70, potatoes from 1.07 to 1.93. Some vegetables are obviously better sources than others. This is proven by the analysis of variance in Table XVI. The F value for vegetables is 125.25 which is highly significant at the 1% level of 3.20. When the difference between soil zones was tested, it was found to be significant at the 1% level of 2.997, the F value for soil zones being 9.96. This means that the thiamine content of the vegetables is affected by the soil zones in which they are grown. These differences might be attributed to the soils or to the differences in sunlight and other climatic factors which are found. The soil zone averages for all the vegetables were:

Brown steppe	1.02
Northern black	1.00
Black	0.83
Rendzina	0.83
Grey-black	0.80
Podzol	0.77
Brown-black	0.75

The two soils which produced vegetables with the highest thiamine values are quite different in composition. The Brown steppe is a prairie soil, alkaline in nature, with a high content of calcium, and of soluble salts of sodium, potassium and magnesium. The land in the Northern black soil zone is bushy. The soil is neutral in pH, and consequently contains much less calcium and

TABLE XVII

THIAMINE CONTENTS OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures in micrograms per gram)
1950 Season

Vegetable		Early Carrot	Late Carrot	Turnips	Tomatoes	Cabbages	Potatoes
Moisture level %		89	89	90	94	87	79
Key No.	Soil Zone						
3.	Brown	0.60	0.48	0.70	0.59	0.59	0.88
4.	black	0.43	0.57	0.50	0.71	0.76	2.08
5.		0.46	0.49	0.81	0.58	0.90	1.08
Av.		0.50	0.51	0.67	0.63	0.75	1.35
9.	Northern	0.59	---	---	0.75	0.65	0.89
10.	black	0.41	---	0.51	---	0.70	0.87
Av.		0.50	---	0.51	0.75	0.68	0.88
6.	Grey	0.46	---	0.47	0.56	0.86	0.86
7.	black	---	---	---	1.11	0.75	1.11
8.		---	---	---	0.80	0.61	0.89
15.		---	---	---	---	0.90	0.81
20.		0.41	---	0.45	---	0.96	1.00
22.		0.47	---	0.35	---	---	0.83
Av.		0.45	---	0.42	0.82	0.82	0.92
2.	Rendzina	0.35	0.75	0.63	0.64	0.90	0.99
13.		0.50	---	0.72	0.54	0.56	1.09
17.		0.45	---	0.42	---	---	0.73
Av.		0.43	0.75	0.59	0.59	0.73	0.94
12.	Brown steppe	---	---	---	---	0.84	0.96
1.	Podzol	0.43	0.47	0.42	0.41	0.67	0.88
11.		0.70	---	0.57	1.19	---	0.82
14.		---	---	---	---	---	0.87
18.		0.55	---	0.43	---	---	0.78
19.		0.37	---	0.55	---	0.90	0.83
Av.		0.51	0.47	0.49	0.80	0.79	0.84
*16.	Azonal	0.53	---	0.68	---	0.80	1.21
Average		0.49	0.58	0.56	0.72	0.77	1.01

* Not included in the analysis of variance.

TABLE XVIII

ANALYSIS OF VARIANCE

FOR

THIAMINE CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1950 SEASON

Source of Variation	D.F.	Mean Square	F.	5% Point	1% Point
Total	79	0.0687			
Subclasses	35	0.1151			
Within Subclasses (error)	44	0.0318			
Vegetables	5	0.5340**	16.79		3.46
Soils	5	0.0380	1.19	2.43	

other salts. The Brown-black soil zone, which produced vegetables with the lowest thiamine, is, on the other hand, very similar to the Brown steppe soil. It is consequently difficult to discover why these soils produce vegetables whose thiamine contents differ as much as these. It is reported (55) that thiamine increases in turnips as boron and manganese increase in the soils. No studies of the effect of macro-nutrient elements on the thiamine contents of vegetables have been reported. The best explanation for our results is that climatic effects differing in these zones have caused the variations which occur. Gustafson (33) reported increases in thiamine of potatoes and tomatoes as the percentage of illumination increased. Other vegetables might be affected similarly.

Thiamine contents of vegetables grown in 1950 are given in Table XVII. The analysis of variance of these data, in Table XVIII, shows a significant difference between vegetables as sources of the nutrient. In this year more mature carrots appear to be better sources of thiamine than young carrots. The F test for the differences between soil zones is not significant. This does not agree with the results in 1949 which showed a significant F value, and which we interpreted as being caused by climatic environmental factors.

Data of mineral analyses are available only for the 1949 crop. Calcium percentages are reported in Table XIX. The averages for each vegetable grown in different soil zones vary considerably. Averages for early carrots range from 0.041 to 0.084, for late carrots from 0.021 to 0.058, turnips from

TABLE XIX

CALCIUM CONTENT OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in grams per 100 grams.)
1949 Season

Vegetable	Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbages	Potatoes
Moisture level %	89	89	90	94	87	79
Key No. Soil Zone						
2. Brown	0.053	0.021	0.040	0.012	---	0.018
3. black	0.028	---	0.048	0.019	0.064	0.022
4.	0.041	---	0.034	0.033	0.088	0.012
Av.	0.041	0.021	0.041	0.021	0.076	0.017
6. Black	0.046	0.061	0.082	0.030	0.067	0.050
7.	0.056	0.022	0.054	0.153	0.129	0.031
8.	0.044	0.044	0.046	---	0.111	0.022
18.	0.086	0.027	0.029	0.061	0.093	0.053
20.	---	0.049	0.013	0.007	0.045	0.023
Av.	0.058	0.041	0.045	0.033	0.089	0.036
1. Northern	0.066	0.041	0.020	0.035	0.086	0.006
9. black	0.039	0.051	---	0.088	0.194	0.052
25.	0.057	0.057	---	0.018	0.161	0.042
27.	---	0.064	0.046	0.007	0.038	0.047
Av.	0.054	0.053	0.033	0.037	0.120	0.037
13. Grey	0.058	---	---	---	---	---
17. black	0.095	0.043	0.042	0.002	0.061	0.021
19.	0.089	0.057	0.020	0.010	0.150	0.029
21.	0.006	0.047	0.029	0.000	0.072	0.037
24.	---	0.045	---	0.003	0.120	0.003
26.	---	0.053	0.046	0.013	0.046	0.021
Av.	0.062	0.049	0.034	0.006	0.090	0.022
5. Rendzina	0.064	0.036	0.015	0.020	0.084	0.028
10.	0.036	0.073	0.054	0.159	0.107	0.016
14.	0.072	0.064	0.054	0.138	0.078	0.021
Av.	0.057	0.058	0.041	0.106	0.090	0.022
22. Brown steppe	0.045	0.061	0.036	---	0.078	0.026
Av.	0.045	0.057	0.038	---	0.078	0.026
15. Podzol	0.089	0.057	0.055	0.055	0.089	---
28.	---	0.045	0.046	---	---	0.028
30.	---	0.047	---	---	0.053	0.045
31.	---	0.041	0.032	---	0.094	0.037
23.	---	0.040	---	0.018	---	---
Av.	0.089	0.046	0.044	0.037	0.079	0.037
*11. Azonal	0.042	0.031	---	0.080	0.071	0.022
Average	0.056	0.045	0.039	0.046	0.087	0.027

* Not included in the analysis of variance.

TABLE XX

ANALYSIS OF VARIANCE

FOR

CALCIUM CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1949 SEASON

Source of Variation	D.F.	Mean Square	F.	1% Point
Total	131	0.00100		
Subclasses	41	0.00266		
Within Subclasses (error)	90	0.00025		
Vegetables	5	0.01014**	40.56	3.23
Soils	6	0.00217**	8.68	3.12

0.033 to 0.045, tomatoes from 0.006 to 0.106, cabbages from 0.071 to 0.120, potatoes from 0.017 to 0.037. The averages at the bottom of the Table are for each vegetable over all the soil zones. These are discussed on page 52. Early carrots are shown to be better sources of calcium than late carrots. The significant F value for between vegetables, as shown in Table XX, proves that some vegetables are better sources of this nutrient. The F value for between soil zones, 8.68, is highly significant at the 1% point of 3.12. The type of soil, therefore, has an effect on the calcium content of the vegetables grown on it.

The average percentages of calcium for all the vegetables in each soil zone are:

Rendzina (alkaline)	0.066
Podzol (acid)	0.065
Northern black (neutral)	0.058
Black (alkaline)	0.053
Brown steppe (alkaline)	0.049
Grey-black (neutral)	0.044
Brown-black (alkaline)	0.036

It was expected that alkaline soils, being high in calcium salts, would produce vegetables which contain a great deal of this mineral, since the literature shows that if a soil has a high content of a particular mineral, the plants grown in that soil will have correspondingly large amounts of it. However, in our study, this does not seem to be the case. Rendzina soil, which is highly alkaline, produced vegetables with the greatest amount of calcium, but Podzol soil, strongly acid with some organic matter, grew vegetables whose average calcium content was almost the same as for those grown in the Rendzina soil.

TABLE XXI

MAGNESIUM CONTENT OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in grams per 100 grams)
1949 Season

Key No.	Soil Zone	Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbage	Potatoes
Moisture level %		89	89	90	94	87	79
2.	Brown	0.043	0.016	0.029	0.089	---	0.045
3.	black	0.029	---	0.025	0.058	0.041	0.087
4.		0.044	---	0.025	0.040	0.039	0.043
Av.		0.039	0.016	0.026	0.062	0.040	0.058
6.	Black	0.034	0.034	0.030	0.068	0.056	0.049
7.		0.044	0.031	0.024	0.097	0.038	0.053
8.		0.022	0.014	0.017	0.047	0.032	0.038
18.		0.118	0.019	0.030	0.044	0.038	0.049
20.		---	0.062	0.025	0.038	0.054	0.094
Av.		0.055	0.032	0.025	0.059	0.044	0.057
1.	Northern	0.041	0.034	0.023	0.100	0.053	0.054
9.	black	0.043	0.015	---	0.087	0.059	0.041
25.		0.053	0.007	---	0.032	0.053	0.038
27.		---	0.048	0.007	0.036	0.053	0.040
Av.		0.046	0.026	0.015	0.064	0.055	0.043
13.	Grey	0.056	---	---	---	---	---
17.	black	0.073	0.021	0.019	0.076	0.046	0.038
19.		0.060	0.040	0.019	0.036	0.046	0.042
21.		0.039	0.015	0.016	0.050	0.064	0.052
24.		---	0.040	---	0.027	0.072	0.049
26.		---	0.045	0.012	0.033	0.040	0.052
Av.		0.057	0.032	0.017	0.044	0.054	0.047
5.	Rendzina	0.048	0.030	0.061	0.037	0.059	0.070
10.		0.031	0.034	0.026	0.077	0.061	0.038
14.		0.077	0.023	0.032	0.082	0.052	0.039
Av.		0.052	0.029	0.040	0.065	0.057	0.049
22.	Brown steppe	0.029	0.020	0.026	---	0.045	0.037
15.	Podzol	0.087	0.075	0.031	0.106	0.043	---
28.		---	0.022	0.019	---	---	0.045
30.		---	0.023	---	---	0.072	0.050
31.		---	0.034	0.022	---	0.030	0.066
23.		---	0.037	---	0.058	---	---
Av.		0.087	0.038	0.024	0.082	0.048	0.054
*11.	Azonal	0.040	0.029	---	0.066	0.015	0.044
Average		0.051	0.028	0.025	0.063	0.045	0.049

* Not included in the analysis of variance.

TABLE XXII

ANALYSIS OF VARIANCE

FOR

MAGNESIUM CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1949 SEASON

Source of Variation	D.F.	Mean Square	F.	5% Point	1% Point
Total	132	0.00049			
Subclasses	41	0.00072			
Within Subclasses (error)	91	0.00038			
Vegetables	5	0.00395**	10.39		3.23
Soils	6	0.00030	0.79	2.20	

Vegetables grown in Brown-black soil, which is highly alkaline, were lowest in calcium content. These results are contrary to those of Coleman and Ruprecht (20).

The magnesium contents of the vegetables are given in Table XXI. The analysis of variance, detailed in Table XXII, applied to these data, shows a highly significant difference between vegetables as sources of magnesium. The differences are discussed on page 52. Late carrots have only three-fifths as much magnesium as early carrots.

The type of soil does not seem to have any effect on the magnesium contents of the vegetables grown in it. This is shown by the analysis of variance. The F value for between soil zones is 0.79, while the 5% level of significance for F is 2.30. Since magnesium is a mineral always found in adequate quantities in the diet when other mineral supplies are adequate, very little experimental work has been done concerning this nutrient. No reports could be found in the literature dealing with the effect of soil zone on the magnesium contents of vegetables. One might expect that the vegetables would have a content of magnesium proportional to the amount found in the soil. This is not the case for these results.

Table XXIII is a summary of the percentage of phosphorus in vegetables according to the soil zones in which they are grown. There is a good deal of variation for any one vegetable. More mature carrots are better sources of phosphorus than early ones. Averages for early carrots range from 0.019 to 0.040, late carrots from 0.025 to 0.053, turnips from 0.029 to 0.040,

TABLE XXIII

PHOSPHORUS CONTENTS OF VEGETABLES GROUPED ACCORDING TO SOIL ZONE

(All figures are in grams per 100 grams)
1949 Season

Vegetable		Early Carrots	Late Carrots	Turnips	Tomatoes	Cabbage	Potatoes
Moisture level %		89	89	90	94	87	79
Key No.	Soil Zone						
2.	Brown	0.037	0.031	0.038	0.033	---	0.059
3.	black	0.036	---	0.023	0.025	0.063	0.051
4.		0.035	---	0.026	0.023	0.054	0.039
Av.		0.036	0.031	0.029	0.027	0.059	0.050
6.	Black	0.042	0.034	0.038	0.036	0.052	0.059
7.		0.038	0.039	0.033	0.033	0.050	0.075
8.		0.019	0.030	0.020	0.021	0.050	0.041
18.		0.029	0.032	0.044	0.032	0.048	0.050
20.		---	0.027	0.020	0.019	0.031	0.074
Av.		0.032	0.032	0.031	0.028	0.046	0.060
1.	Northern	0.054	0.047	0.049	0.022	0.045	0.043
9.	black	0.034	0.024	---	0.028	0.051	0.047
25.		0.032	0.049	---	0.025	0.050	0.044
27.		---	0.091	0.030	0.046	0.050	0.044
Av.		0.040	0.053	0.040	0.030	0.049	0.045
13.	Grey	0.043	---	---	---	---	---
17.	black	0.017	0.024	0.025	0.023	0.029	0.038
19.		0.019	0.024	0.029	0.017	0.039	0.034
21.		0.025	0.029	0.033	0.024	0.043	0.047
24.		---	0.021	---	0.040	0.055	0.040
26.		---	0.027	0.029	0.034	0.036	0.040
Av.		0.026	0.025	0.029	0.028	0.040	0.040
5.	Rendzina	0.041	0.040	0.034	0.030	0.059	0.067
10.		0.024	0.031	0.037	0.026	0.063	0.030
14.		0.019	0.027	0.037	0.035	0.050	0.046
Av.		0.028	0.033	0.036	0.030	0.057	0.054
22.	Brown steppe	0.021	0.025	0.032	---	0.058	0.075
15.	Podzol	0.021	0.030	0.033	0.043	0.059	---
28.		---	0.031	0.040	---	---	0.066
30.		---	0.039	---	---	0.067	0.084
31.		---	0.049	0.037	---	0.050	0.058
23.		---	0.024	---	0.039	---	---
Av.		0.021	0.035	0.037	0.041	0.059	0.069
*11.	Azonal	0.025	0.031	---	0.032	0.030	0.032
Average		0.029	0.033	0.033	0.031	0.050	0.053

* Not included in the analysis of variance.

TABLE XXIV

ANALYSIS OF VARIANCE

FOR

PHOSPHORUS CONTENTS OF VEGETABLES

GROWN IN DIFFERENT SOIL ZONES

1949 SEASON

Source of Variation	D.F.	Mean Square	F.	1% Point
Total	132	0.00021		
Subclasses	41	0.00045		
Within Subclasses (error)	91	0.00010		
Vegetables	5	0.00229**	22.9	3.23
Soil Zones	6	0.00044**	4.4	3.02

tomatoes from 0.027 to 0.043, cabbages from 0.030 to 0.071, potatoes from 0.032 to 0.075%.

When the analysis of variance was applied to these data, it was found that the vegetables varied significantly as sources of this mineral. This is shown in Table XXIV. The type of soil or the location of the soil affects the phosphorus contents of the vegetables grown in it. The F value for between soils was significant at the 1% level.

The soil zone averages for all the vegetables are:

Podzol*	0.045
Northern black*	0.043
Brown steppe	0.042
Rendzina	0.039
Brown-black	0.038
Black*	0.038
Grey-black*	0.032

* high phosphorus soils

Podzol and Northern black soils are high in phosphorus. Vegetables from these soils averaged highest in this nutrient. However, Grey-black soils are also high in phosphorus, and vegetables grown on these averaged lowest. These results do not confirm reports in the literature. Wittwer, Albrecht and Schroeder (99) found that if a soil is deficient in any particular mineral, that mineral will be correspondingly low in the vegetable grown in that soil, and vice versa. Bishop (12) found that high calcium contents of vegetables are associated with low phosphorus contents. Our results show high calcium and high phosphorus contents from the same soil zone. Low calcium and low phosphorus were also found together. Leischenring and Donelson (52) found that iron treatments in

soil depressed phosphorus utilization by plants. In our study Podzol soil was highest in iron. However, the concentration of iron may not have been great enough to depress phosphorus contents, since no such depressing is apparent.

PART V. SUMMARY

1) A two year study has been made of the effect of soil zone on the nutrient content of cabbages, carrots, potatoes, tomatoes and turnips grown in different soil zones in Manitoba. Nutrients studied in 1949 were ascorbic acid, riboflavin, thiamine, calcium, magnesium and phosphorus. The experiment was repeated in 1950, for which season ascorbic acid, carotene, riboflavin and thiamine contents were investigated.

2) Average nutrient contents of vegetables compared favorably with those reported in the Canadian Council on Nutrition food tables. Different vegetables varied significantly as sources of the particular nutrients.

3) Young carrots were found to be better than more mature carrots as sources of ascorbic acid, riboflavin, calcium and magnesium. Mature carrots are better sources of carotene and phosphorus. Thiamine was highest in early carrots from the 1949 crop, but highest in late carrots from the 1950 one.

4) Ascorbic acid contents of vegetables grown in different soil zones varied significantly in both seasons.

5) Carotene and riboflavin contents did not vary significantly between vegetables grown at the various points selected in the soil zones.

6) Thiamine contents of vegetables varied significantly in different soil zones for the 1949 crop. These variations could not be attributed to any particular soil constituent and

it is postulated that they might be caused by climatic environmental agencies. Soil zone variations were not significant in the 1950 crop.

7) Highly significant differences were found between calcium contents of vegetables grown in different soil zones.

8) Magnesium contents of the vegetables did not seem to be affected by the variations in the soil zones.

9) There were significant differences in the phosphorus contents of the vegetables grown within the different soil zones. High calcium contents were generally associated with high phosphorus contents.

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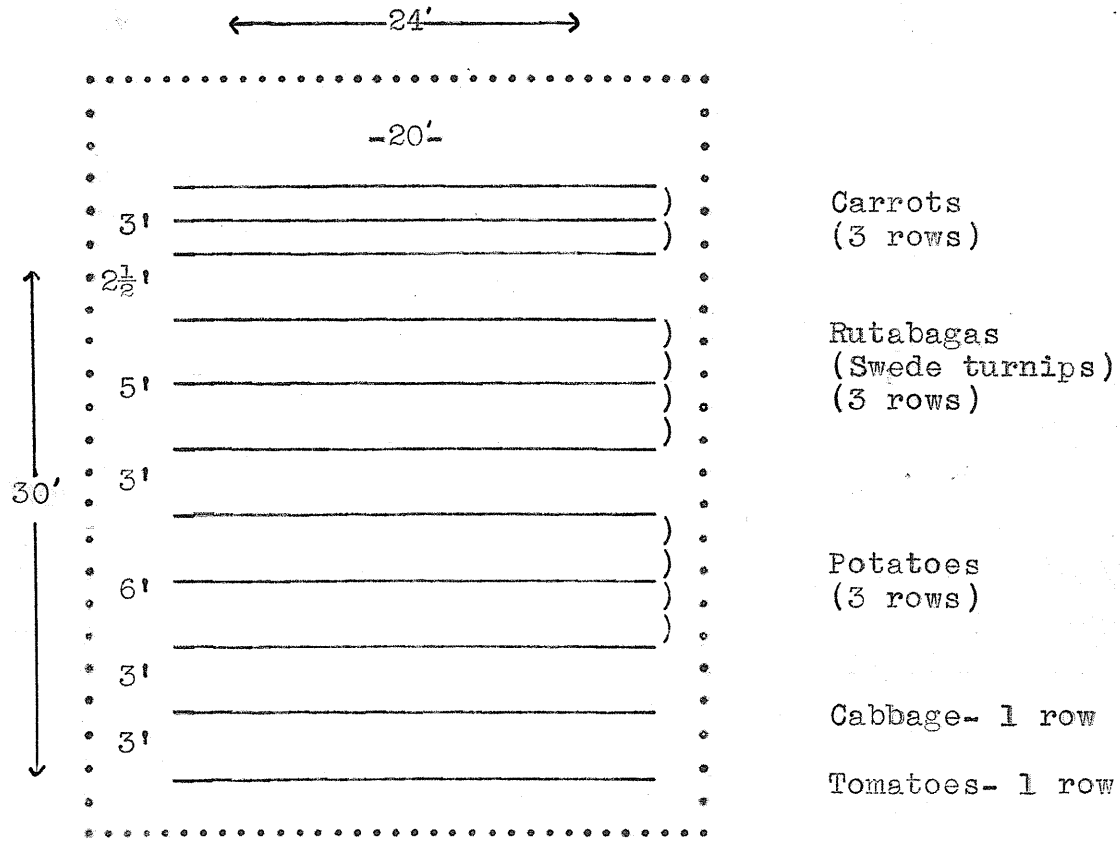
APPENDIX TABLE I

Plan for Cooperative Study of Vitamin Content of Vegetables Grown in Different Soil Zones of Manitoba

Area of plot and surrounding paths 24 ft. x 30 ft.
Length of rows 20 ft.
Width of path space around plot at least 2 feet.
Plot to consist of:

1. three rows of Chantenay carrots
2. three rows of Laurnetian Swede turnips
3. three rows of Irish Cobbler potatoes
4. one row of Danish Ballhead cabbage
5. one row of Early Chatham tomato

Suggested Plan



Space between rows:

Carrots 18 inches
Turnips 30 inches
Potatoes 3 ft.
Cabbage 3 ft.
Tomatoes 3 ft.

Seeding and Planting Instructions.

Space between plants in the rows:

Carrots - thin to stand 2 inches apart when young plants are 2 - 3 inches high.
Turnips - thin to 12 inches apart when young plants are 2 - 3 inches high.
Potatoes - plant 18 inches apart.
Cabbage - plant 2 feet apart.
Tomatoes - plant 3 feet apart.

Time of Seeding or Planting.

Carrots and Turnips - May 15 - 20.
Potatoes and cabbage - May 15 - 20 or as soon as delivered.
Tomatoes - June 8 or as soon as delivered.

Seed of carrots and turnips, seed pieces of potatoes, and transplants of cabbages and tomatoes will be supplied by the University.

Depth of Seeding.

Carrots and turnips - $\frac{3}{4}$ inch or into soil moisture.
Potatoes - 3 - 4 inches.
Cabbage and tomatoes - slightly deeper than level at which they grew in the greenhouse flats.

A pint of water applied to each transplant at planting time will aid in obtaining quick growth and good stands.

APPENDIX TABLE II

COOPERATORS IN VEGETABLE PROJECT

1949

Key Number	Name	Address	Soil Zone
1.	D. McConnell	McConnell	Northern Black
2.	C.C. Musgrove	Boissevain	Brown black
3.	Wm. Buck	Boissevain	Brown black
4.	E.H. McCausland	Boissevain	Brown black
5.	J.K. Lamb	Ericksdale	Rendzina
6.	Mrs. T. Ching	Darlingford	Black
7.	Mrs. Harry Wood	Darlingford	Black
8.	Mr. Duncan	Darlingford	Black
9.	T.J. Strachan	Hamiota	Northern black
10.	D. Lawrence	Ericksdale	Rendzina
11.	J.E. Jaegar	The Pas	Azonal
13.		Swan River	Grey black
14.	A. Lindell	Ericksdale	Rendzina
15.	K.M. McKenzie	Norman Wells,N.W.T.	Podzol *
17.	Beryl Thoren	Erickson	Grey black
18.	Plant Science Div.	University	Black
19.	Mrs. E.C. Sims	Kenville	Grey black
20.	Soils Dept.	University	Black
21.	C. Shadbolt	Benito	Grey black
22.	R.M. Blakesly, Expt. Station	Swift Current, Sask.	Brown Steppe
23.	A. Listmeyer	Sprague	Podzol
24.	E.W. Driscoll	Erickson	Grey black
25.	A. Dixon	Hamiota	Northern black
26.	A. Harvey	Durban	Grey black
27.	Sophie Waksymchuk	Basswood	Northern black
28.	T. Wass	Island Lake	Podzol *
30.	R.E. Dysart	South Indian Lake	Podzol
31.	R.D. Davidson	Wabowden	Podzol *

* Not definitely Podzolic. Podzolic soil is found in patches.

APPENDIX TABLE III

COOPERATORS IN VEGETABLE PROJECT

1950

Key Number	Name	Address	Soil Zone
1.	K.M. McKenzie	Norman Wells, N.W.T.	Podzol *
2.	J.K. Lamb	Ericksdale	Rendzina
3.	C.C. Musgrove	Boissevain	Brown black
4.	Wm. Buck	Boissevain	Brown black
5.	W.O. Lee	Boissevain	Brown black
6.	Beryl Thoren	Erickson	Grey black
7.	Mrs. E.C. Sims	Kenville	Grey black
8.	C. Shadbolt	Benito	Grey black
9.	C.T.G. Bailey	Hamiota	Northern black
10.	C.T.G. Bailey	Hamiota	Northern black
11.	T. Wass	Island Lake	Podzol *
12.	R.M. Blakesly	Swift Current, Sask.	Brown steppe
13.	D. Lawrence	Ericksdale	Rendzina
14.	R.E. Dysart	South Indian Lake	Podzol
15.	W.A. McKay	Kenville	Grey black
16.	Mrs. J.E. Jaeger	The Pas	Azonal
17.	A. Lindell	Ericksdale	Rendzina
18.	R.D. Davidson	Wabowden	Podzol *
20.	Mrs. W. Bodnarchuk	Rosa	Grey black
21.	Mrs. R. Gray	Sprague	Podzol *
22.	Mrs. A. Skolny	Tolstoi	Grey black

* Not definitely Podzolic. Podzolic soil is found in patches.

APPENDIX TABLE IV

CALIBRATION DATA FOR SPECTROPHOTOMETRIC DETERMINATION OF ASCORBIC ACID

μg./ml. Ascorbic Acid	Galvanometer Reading (a) G_s	Log G_s	Observed (b) Log G_s Log G_{sd}	Calculated (c)
5	43.4	1.6375	0.0247	0.0250
10	47.1	1.6730	0.0602	0.0595
15	50.8	1.7059	0.0931	0.0940
20	55.6	1.7451	0.1323	0.1285
25	59.5	1.7745	0.1617	0.1630
30	64.4	1.8089	0.1961	0.1975
35	69.6	1.8426	0.2298	0.2320
40	75.5	1.8780	0.2652	0.2665
45	82.1	1.9143	0.3105	0.3010
50	87.5	1.9420	0.3292	0.3355

(a) Mean of two, 15- second readings.

(b) Galvanometer reading for the dye standardization was 41.0. Log G_{sd} = 1.6128

(c) Calculated from line of best fit by the method of least squares. Log Y_c = 0.0069X - 0.0095

Standard Error was 0.11045

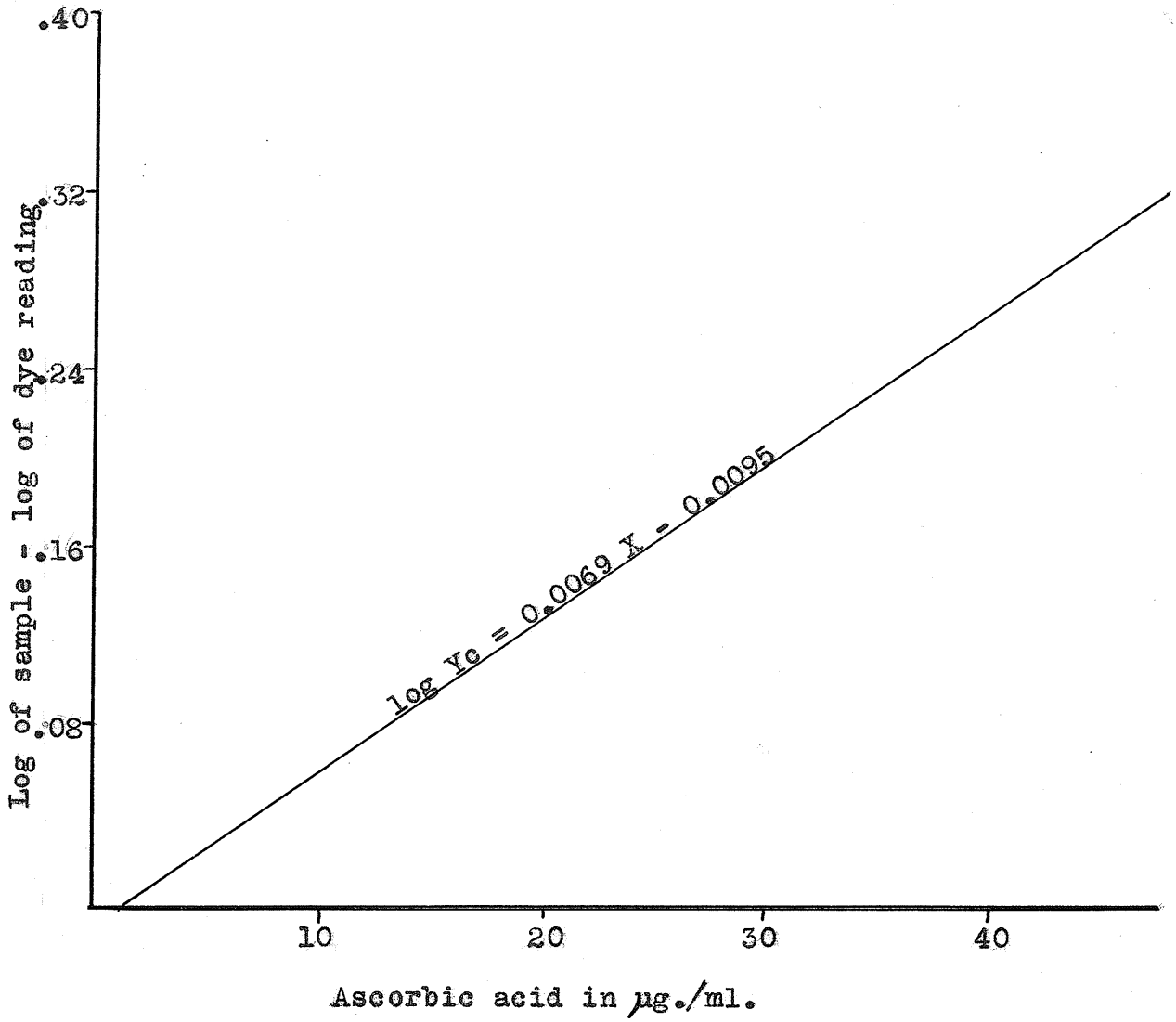


FIGURE I - CALIBRATION CURVE FOR PHOTOMETRIC DETERMINATION OF ASCORBIC ACID

APPENDIX TABLE V

CALIBRATION DATA FOR SPECTROPHOTOMETRIC

DETERMINATION OF CAROTENE

µg./ml. Carotene	Galvanometer Reading G_s	Log G_s	Calculated Value (a)	Antilog
.1	94.0	1.9731	1.9690	93.1
.2	86.5	1.9370	1.9355	86.2
.3	79.0	1.8976	1.9019	79.8
.4	73.0	1.8633	1.8684	73.9
.5	68.0	1.8325	1.8349	68.3
.6	63.8	1.8048	1.8014	63.3
.7	58.7	1.7686	1.7679	58.6
.8	54.8	1.7388	1.7343	54.2
.9	50.0	1.6990	1.7008	50.2
1.0	46.4	1.6665	1.6673	46.5

(a) Calculated from line of best fit by the method of least squares. Log $Y_c = -0.3352X + 2.0025$

Standard Error of Estimate in % of the mean was 0.18.

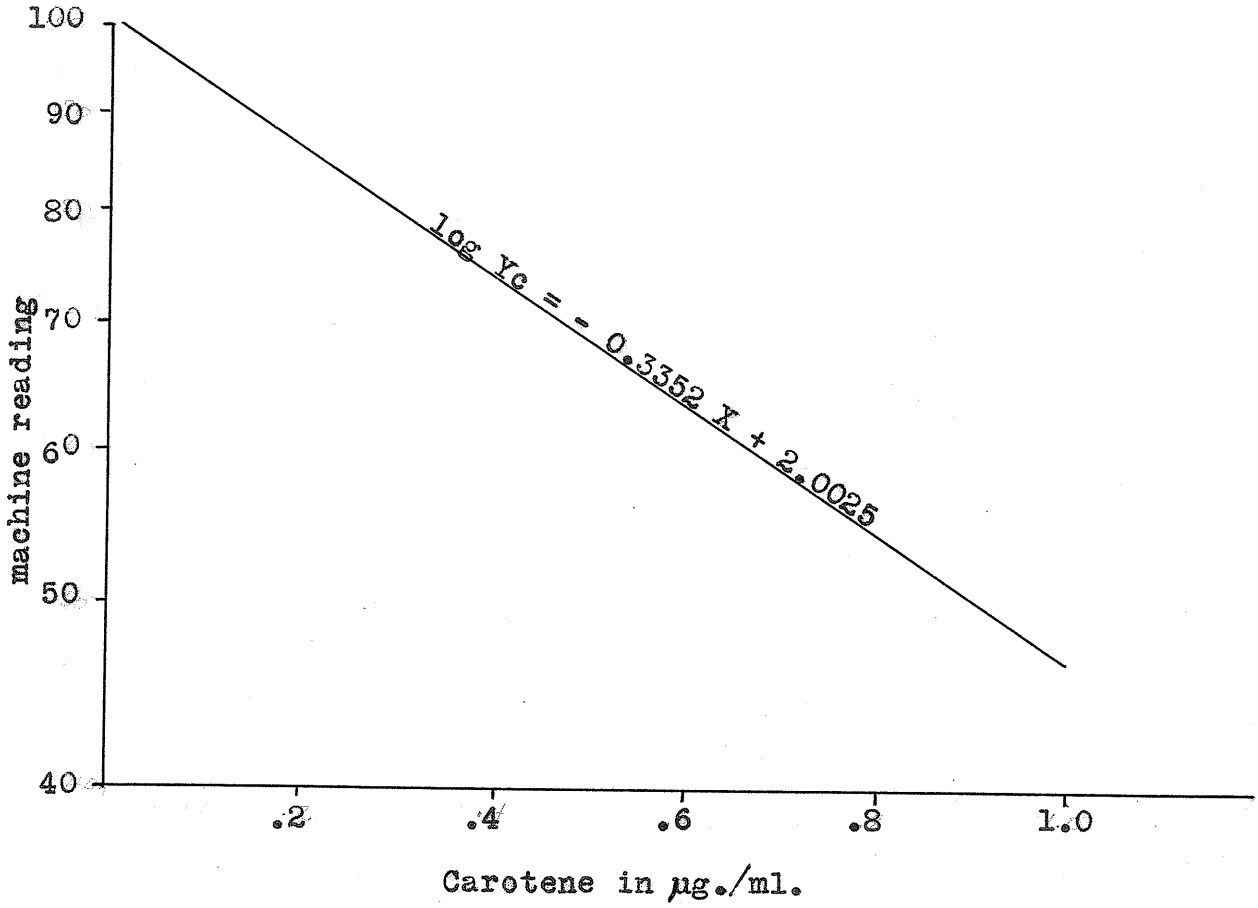


FIGURE II - CALIBRATION CURVE FOR PHOTOMETRIC DETERMINATION OF CAROTENE

APPENDIX TABLE VI

CALIBRATION DATA FOR SPECTROPHOTOMETRIC DETERMINATION OF PHOSPHORUS

Phosphorus mg./ml.	Galvanometer Reading- Gs	Log Gs	Calculated Y Value (a)	Antilog Yc
.01	95	1.9777	1.9791	95.3
.02	91	1.9590	1.9677	92.8
.03	89	1.9494	1.9562	90.4
.04	87	1.9395	1.9448	88.1
.05	85	1.9294	1.9333	85.8
.06	84	1.9243	1.9218	83.5
.07	82	1.9138	1.9104	81.4
.09	78	1.8921	1.8875	77.2
.10	75	1.8751	1.8761	75.2
.125	70	1.8451	1.8474	70.4
.150	66	1.8195	1.8188	65.9
.175	63	1.7993	1.7902	61.7
.200	59	1.7709	1.7615	57.8
.225	55	1.7404	1.7328	54.1
.250	52	1.7160	1.7014	50.3
.275	48	1.6812	1.6755	47.4
.300	45	1.6532	1.6468	44.3
.325	41	1.6128	1.6182	41.5
.350	38	1.5798	1.5895	38.9
.375	35	1.5441	1.5609	36.4

(a) Calculated from line of best fit by the method of least squares. $\log Yc = -1.1459X + 1.9906$

(b) Standard error of estimate in % of the mean was 7.75.

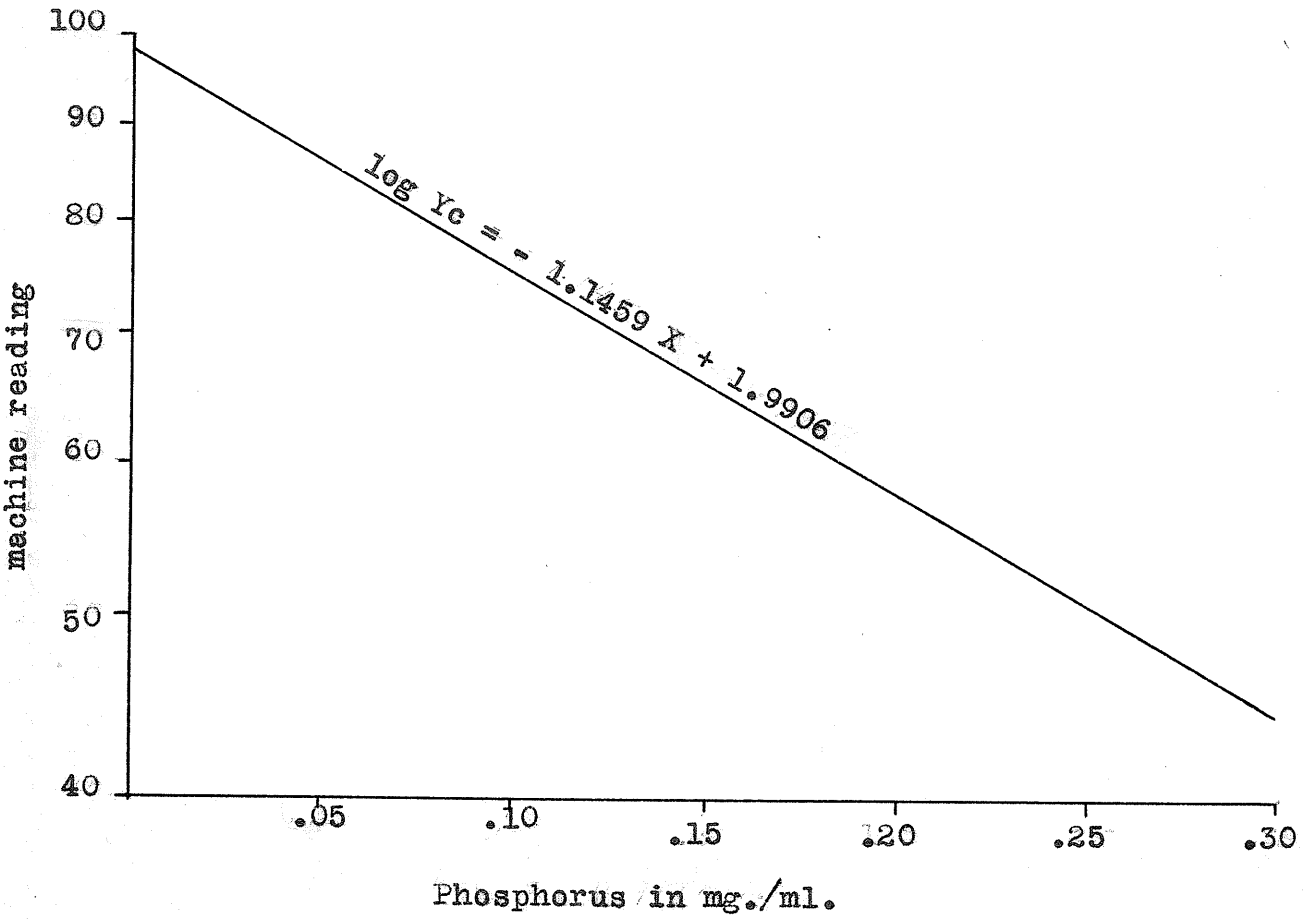


FIGURE III - CALIBRATION CURVE FOR PHOTOMETRIC DETERMINATION OF PHOSPHORUS