Lets Live Magazine, January, 1966

Self-protection by Plants Linked to Nutritional Values

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In the two preceding articles, the quality of food plants in terms of nutritional values was discussed. Crops classified as vegetable "greens" were considered, with spinach being singled out for detailed listings of varied chemical compositions in relation to some of the factors controlling different qualities.

The modifying factors are numerous enough to warrant their discussion in order to comprehend and appreciate the refined combinations in "natural balance" by which nature has developed healthy plants during their evolutionary ages for man to domesticate. More appreciation is demanded, now that our management of crops has made them sickly, allowed them to be taken by pests and diseases, and in view of our controversial views of qualities of a vegetable, like spinach, which has both friends and foes concerning its fitness as food.

Need to study nature

We need to study nature more, and books less, as Agassiz, one of our great scientists, suggested about a century ago. Nature was in the worldwide business of growing plants without treatments to pamper the soil or protect plant tops against pests many years before man's accumulated and recorded experience can cite claims for his successes in that productive activity. We are gradually returning to nature with confessions, as prodigals, that we are not able to duplicate her successes in climax crops. More of us are attempting to duplicate nature's methods, rather than continue in our efforts to fight pests and diseases with more and more powerful poisons.

Mentally stampeded by profit motives, we consider these seasonal damages to be caused by invading enemies. It would be more logical to view them as nature's elimination of plants in poor health, unable to survive because of our omission and disregard of factors which would keep them "well-fed and healthy" and able to exercise the same degree of self-protection that they possessed before man's arrival.

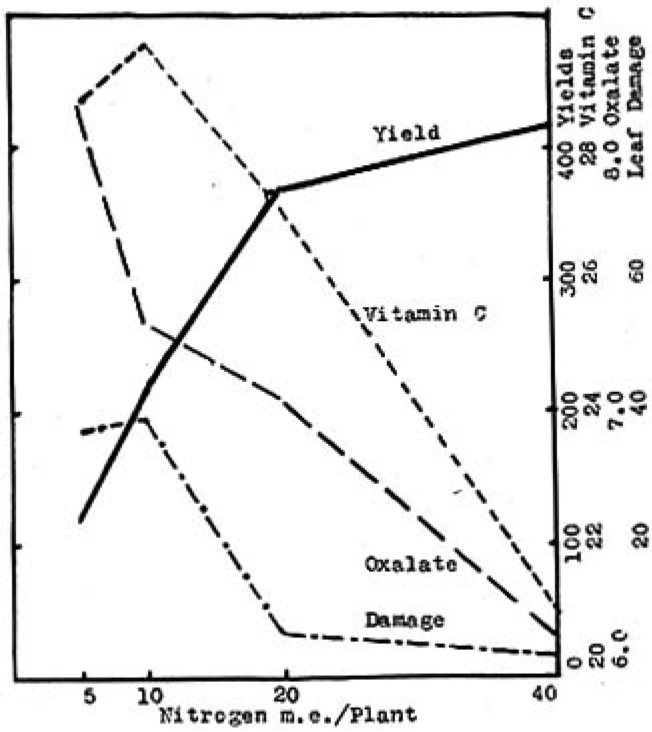
Dangerous compounds

When vegetable crops must be propped up by sprays of highly poisonous, polyphenolic and aliphatic compounds just to carry them near enough to maturity to be harvested, shall we not consider them of low nutritional quality simply because they were not healthy? Since plants take in many complex organic compounds via leaves and roots, shall we not consider the danger in the crop's absorption and retention of sprays which are highly lethal to humans as well as to insects?

Nature has been unique in balancing plant diets. She used no soluble salts. She grew crops on soils where reserve rock minerals were decomposing through microbial help from decayed organic matter. This growth accumulated to bring about inorgano-organic combinations of elements and compounds for balanced plant nutrition by selection and synthesis from the same kind of preceding crops. Now that we are testing soil to detect the first limiting element, which we then apply, then the second limiting one, and so on, we are bringing about an imbalance of salts, rather than a balance as achieved by the natural plan of plant nutrition through balance of elements and all other factors in the combination of weathering minerals and decaying organic matter from which solubles are leached out to sea.

Spinach highly responsive

Spinach, like almost any other crop, is highly responsive to nitrogen applied only to the soil--even if such treatment gives imbalances in the nutritional values of the crop as food. When researchers at the Missouri Experiment Station varied the nitrogen applied to the soil to study the effect of that factor on the concentration of the oxalate and vitamin C, the data revealed some interesting facts. (See accompanying illustration.)



INCREASE SHOWN . . . Graph indicates variance in spinach yield with increase of nitrogen in soil. Yields shown as gms./10 fresh plants; vitamin C as mgms./l00 gms.; oxalate as % of D.M.; and damages as % of leaf area.

Among these was the rapid increase of the crop yield with increments of applied nitrogen, starting at 5 milligram equivalents (m.e.) per plant and doubling to give the series 5, 10, 20 and 40 m.e. as the soil treatments. But more significant was the decrease in oxalate concentration (from a high of near 8.15% to 6.25%) with the increase in applied nitrogen from 5 to 40 m. e. per plant. When nitrogen was applied in these amounts, the first increment resulted in an increase of vitamin C concentration amounting to 0.5 milligrams per 100 grams. Then the vitamin C dropped from a high of 29 milligrams per 100 grams to a low of near 21.

Serves as catalyst

This suggests that vitamin C is a catalyst in the plant's life and is at high concentrations for stimulation of nutritional processes, but at lower concentration when more nearly balanced nutrition allows these processes to be more normal under less stimulation. It follows that it would be an error to try to grow a crop for high vitamin C if the content of this factor is high only when the plant process is abnormal. But, as seed and vitamin storage for starting life anew, fruit high in vitamin C would, we believe, be most healthy--quite the opposite of that for vegetative matter.

Fact about quality

The most interesting fact about quality revealed by the experiment was a result of accident: an attack on the spinach crop by the leaf-eating thrips insects (Heliothrips haemorrhoidalis). The leaf damage they created decreased from 40% at treatments of 5 and 10 m. e. of nitrogen to near 10% at 40 m. e. This suggests that with nitrogen as a factor in protein synthesis, there is not only an increase in nitrogen's support of growth of living tissue, but also a synthesis of compounds for self-protection. Also, there is less metabolic waste if the oxalate reduction is correctly interpreted when put into that category.

All this indicated that proper protein synthesis by plants given a balanced nutrition through balanced soil fertility results in "healthier" plants, more fit to survive attack by pests, and providing more healthful food for human consumption.

Lets Live Magazine, February, 1966

Variable Quality Production By Food Plants

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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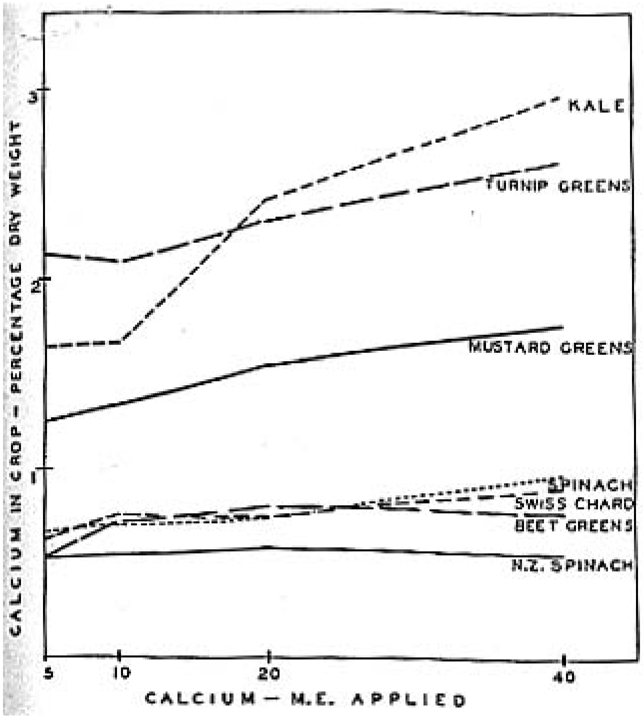
From the standpoint of economics, we emphasize the quantity of vegetables and other foods available on the market. From the health standpoint, we must look to their quality as nutrition for a biochemically complex, warm-blooded body. There are accurate measures of quantity, on which seller and buyer . are well agreed. However, the quality, much unknown to both, is seldom critically considered prior to purchase and consumption. Too often it is assumed that quality parallels plant pedigree. In view of these facts, it is fitting to consider just what factors in food crop production determine quality, and how these factors may take different orders of significance for different crops.

In the discussion last month, eight crops of vegetable "greens" were classified according to how they synthesized the metabolic by-product oxalic acid, in the presence of which calcium and magnesium react to form calcium and magnesium oxalates. These are highly insoluble, hence indigestible.

Calcium content

It is significant to note that Swiss chard, Savoy spinach, beet greens and New Zealand spinach--the "greens" of the Goosefoot family which produce the oxalic acid--are also low in calcium (less than one percent of the dry weight); while those of the mustard family, which do not produce oxalic acid, are twice as high in calcium. They are also higher in their concentration of that element when the soil is richer in calcium fertility. But this was not the response to soil fertility which was shown by the "greens" of the Goosefoot family. (See accompanying graph.)



Comparative calcium contents of green leafy vegetables
according to calcium additions to the soil
(as Milligram-Equivalents per plant)

You should be familiar with the nutritional quality innate to the Goosefoot species and to its response to soil treatment if you intend to feed children these "greens" to furnish ample calcium for building bones and preventing rickets.

Catalogued incorrectly

Some crops are catalogued by characteristics emphasized in common garden conversation, such as, "Oh, that is an easy crop to grow. One can raise it most anywhere." This is a statement commonly made about spinach, either the Bloomsdale Savoy or New Zealand. These are grown in spring and autumn. Savoy is higher in oxalate when grown in the spring. Both kinds respond markedly to applications of nitrogen fertilization, but tolerate wide variations in contents of minerals and protein. They are, consequently, grown most anywhere. But their nutritional values also classify almost anywhere "on the up and the down," with the latter prevailing in the case of "crude" protein as the total of all the forms of its nitrogen contents multiplied by 6.25 and labeled "protein."

Measure of values

Protein, characterized as a specific array of the essential amino acids, is a very good measure of nutritional values, or of what is often called the "Biological' Index." Schuphan (1) reports fresh spinach varying from 1.38% to 5.38% in crude protein; from 0.31% to 1.46% in oxalic acid; from 0.10% to 2.75% in total sugars; from 0.05% to 0.25% in total calcium; and from 0.02% to 0.12% in total phosphorus. All of these are variations from the low to a high of five times the former, or 500%.

When the composition of a plant can play over such a wide range of its synthesized contents and of essential nutrient elements, the soil fertility, does not appear to be a serious limiting factor. In that respect, we can understand why spinach can be grown on almost soil; as a field crop in spring, or in autumn; and as an over-wintering vegetable in cold frames or in hothouse Such range in possibilities for growing its bulk ought to raise the question "What is that bulk in terms of qualitiy as protein which goes as low as percent in 'crude' protein?"

Vitamin C content

Nevertheless, before we condemn "greens" vegetable, it is significant to note that it is not completely devoid of any of the 10 essential amino acid which make up complete protein. This was determined by extensive sampling in the studies by Dr. Schuphan. Also using vitamin C (ascorbic acid) as another criterion of nutritional value along with the mineral elements the complete proteins--this vegetable does not grade at such a low level. In nearly 300 samples of spinach, Schuphan reports the variation in vitamin C from 2.4 milligrams per 100 grams (24 ppm) to 157 milligrams per 100 grams (1570 ppm), or from the low to a high of 65 times greater. In carotene, the precursor of the fat-soluble vitamin A, spinach varies from 0.7 milligrams per 100 grams (7 ppm) to 6.3 milligrams per 100 grams (63 ppm) or from a low to a high of nine times greater. When spinach can reach those two high values in ascorbic acid and in carotene, while red, not quite ripe, tomatoes carry respectively 41.7 and 0.59 milligrams per 100 grams (417 and 5.9 ppm), the spinach does not take a low rank in these essentials in quality as food.

Constituents vary

It is important to realize that food constituents vary with the respective psysiological stages during the growth. of the vegetable plants; with the conditions at the time of the harvest; and with the time elapsed between harvest and the moment of consumption, since when the living plant is uprooted or cut its supporting rootstalk, it undergoes modified and disturbed respiratory processes and other changes in a kind of "pre-death" struggle of a living body. This effects changes in quality according to handling conditions, temperature and time.

The eye examining the food crop at the market is not a fit measuring instrument for quality; nor can it determine internal changes in chemical composions. It is essential that the market gardener and the customers understand what some of the problems of quality production are, and which factors serve to raise quality and hold it at a high level for the consumer.

(1) Werner Schuphan, Nutritional Values in Crops and Plants, Faber and Faber, London, 1965.

Lets Live Magazine: March, 1966

Nutritional Values of Vegetables Change Rapidly

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In these current reports on the quality of food crops (vegetables and fruits), the Bloomsdale Savoy spinach was the first one considered. This is sometimes eaten as a fresh vegetable (plant tops only) in a green salad, but is more commonly taken cooked as a pot-herb. It may serve here in considering the quality of plant tops; carrots will serve for quality of plant roots; and apples for quality of tree fruit. These three a long history of widespread acceptance as food. By means of these, through chemical and biochemical measure--if not through biological assays where quality as nutrition can be measured accurately by the growth-response of microbes, animals and man.

Quality varies

The fact that spinach is grown almost all year around creates varied quality, particularly from the biochemical standpoint. Plants are living substance, anchored to the soil in place and fed according to the soil's biodynamic processes which furnish nutrition to the plants. Simultaneously, the soil microbes may be collaborators or competitors eating at the first sitting.

Different soils and different weather conditions (acting on both soil and quality may become more quantitative plant) at various times of the year must be expected to bring about changes in the quantity and quality of the constituents created within the vegetable crop. Spinach gives opportunity to consider changes in nutritional values during the growth, or life, of the plant, and then after the harvest, or death, while enroute from the garden to market and the consumer's table.

Five stages or crops

Some experiments with spinach* report these chemically-measured changes from the time of seeding through growth, divided into five stages or crops. Seeding was done in mid-January, in forcing frames, and a light fertilization was given at the beginning of March. In the middle of that month, the first plant sampling was made. This consisted of plantlets which had developed rounded and transitional leaves in addition to the cotyledons. The second sampling, at the end of March, included additional small, successive leaves. By the third sampling, these leaves were better developed for harvesting as young spinach. The fourth sampling, or crop, gave plants for customary early harvesting, while the fifth sampling, April 20, 95 days from seeding, consisted of fully-grown plants like those one finds on the market in spring.

Report of studies

From the chemical studies of five crops, or samplings, during the plant's life, the following information was reported:

1. The undesirable oxalic acid content diminished with progressive development of the plants.
2. The total amount of sugar (including both monosaccharides and di-saccharides) is seemingly adapted to the metabolic state of the plant It was highest at the third sampling.
3. Ascorbic acid concentration (vitamin C) rose to its maximum in the second and third samplings, and then fell to its lowest at the time of full growth, when the plants are commonly marketed.
4. The concentration of carotene was highest in the youngest plants sampled. It was lowest in the last sampling, being about half of the initial high. The increase in leaf-stalk and in the mid-rib of the leaves, both of which contain no carotene, makes the increase in plant bulk serve to dilute the concentration in the plant as a whole.
5. Of the essential amino acids, some were high during the second sampling, and most of them declined from then on, or from the first sampling. Accordingly, the eight essential amino acids, commonly called "the index of biological value," were at a maximum during the second of these samplings, and declined from that early degree of plant development to their lowest level at the time of harvest for market.
6. The nitrate nitrogen increased significantly in the last two samplings. With an earlier dressing of nitrogen, phosphorus and potassium on the soil at the beginning of March and another one of nitrogen only, the time period from then until late April should permit enough nitrate production in the soil to account for the high nitrate content the crop at harvest.
7. The inorganic elements in the crop excluding sodium) did not show changes for the different stages of plant growth. Sodium and chlorine increased in concentration toward maturity of the spinach plants.
8. Sulfur behaved much the same, with but a slight increase toward maturity, as was also true for calcium. But the latter was more pronouncedly so, in a kind of inverse effect to the concentration of the oxalate. While the shift for oxalate was from a high to low in a ratio of 4.7 to 1, the shift by calcium, as inverse from low to high, was in a ratio of 1 to 4:7. The harmful effects by the oxalic acid are reduced through its precipitation by calcium, but the beneficial effects of the calcium are thereby eliminated, especially in the spring. The crop in autumn was lower in the oxalate.

Processes stimulated

After harvest, with the plant top cut from the rootstalk and sustenance from there eliminated, the metabolic processes will be under decided stimulation of the enzymatic actions. This reaction doubles its rate for about every 18° F. rise in temperature at which the harvested crop is held. Consequently, if cold storage is not used, storage loss at 65° F. for 40 hours may amount to nearly 20% by weight, according to Schuphan's data. The protein nitrogen, as a percent of the total nitrogen, may diminish by nearly 12%.

This latter change alone, when the living tissue is consuming itself, stands out as a loss which is not measured by the same scales as those used to measure moisture and plant bulk. The former loss is of interest to the nutritional scientist; the latter to the dealer and the economist, both of whom are far removed from consideration of the plant's waste of its own proteins, sugars and other quality factors for better health and taste.

Unfortunately, the changes in quality of vegetable plants during life and after harvest are recognized mainly in terms of their "filling" power, rather than in terms of nutritional value. There is much yet to be learned concerning the nutritional qualities of food plants.

**Werner Schuphan, Nutritional Values in Crops and Plants, Faber and Faber, 24 Russell Square, London WC1, 1965.*

Lets Live Magazine: April, 1966

Variable Nutritive Values in Carrots

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In the quality of a vegetable crop like spinach, one is considering the plant's potential for maintaining the species via the production of quality seeds. In the case of the carrot, a biennial plant, we are considering the root from the standpoint of quality for over-winter dormancy, after the first year; and the storage of essentials for growth, in the second year, of a seed crop vital for the species' survival.

This root vegetable's values as nutritious food for man are the same as those which spell quality for healthy survival of the plant species. These are built and stored during the first season in order to grow seed during the second. The roots of the second-year crop are not edible. It is the plant's struggle to multiply its own kind that means health-giving nourishment for animals and man.

Important for Children

The carrot is an important vegetable in the nourishment of children. "Of all the vegetables," says Dr. Schuphan, it is the best source of the important provitamin A, carotene. But this statement, so generally accepted, undoubtedly needs qualification. There are cultivars, i.e., accepted plant selections in wide use which contain little, and others which contain a great deal of carotene." For high quality of even this common vegetable, one must be cautious and not assume, through blind faith in the name, that quality is present. Carrots are available almost all the year round. Whether carrots are raw or preserved by canning makes little difference in the provitamin content grown into the root.

Vary widely

But in this one criterion, emphasized so widely as an indicator of nutritional value of this yellow, oil-bearing vegetable, the carrot roots may vary widely. In detailed chemical analyses of more than 300 samples, during more than 20 years, the data for carotene ranged from the lowest of 0.50 to the highest of 31.00 to give the mean value of 8.53 milligrams per 100 grams of the fresh material. For the sugar contents, also a factor in quality, there was a range between 1.9 and 10.3 with a mean of about 5.0%.

Studies were also made of various kinds of carrots on the market and in wide use to determine the carotene content of the root as a whole and in its separated core. This division is made since the core is the stem-like portion for continued growth, while the surrounding part is for the nutrition of the core, much as in the case of the apple, in which the core is the portion for reproduction, while the edible part is reserve nutrition for that activity. Of five common market varieties of carrots of higher choice, the range in carotene was from near 7 milligrams to 12 milligrams per 100 grams of fresh material. But when arranged in the order of that increase for the entire carrot, there was the inverse, or decrease, of this provitamin from near four to near three in the core. Also, the relation of the size of the core to the entire carrot decreased. Accordingly, then, one can select and grow carrots with higher carotene content by observing the core in relation to the rest of the root.

Sugar Content

In considering the nutritive values of the sugar content of the carrot, it its helpful to note that the core is higher in monosaccharide sugar than is the carrot as a whole. The latter is higher in the disaccharide form. Consequently, the core is not as sweet to the taste as the surrounding parts where the sweeter of the two sugars is more concentrated. Extending the winter storage moves the sugar from the disaccharide supply to maintain the life of the core. Consequently, carrots become lower in disaccharide and other factors used to maintain the life of the root. The good flavor lessens, accordingly, after about February, in carrots stored since autumn harvest.

One does not usually consider carrots for their protein values, but even if these are as low as near one-half per cent of the carrot's fresh weight, than half of that is really pure protein. Similarly, the ascorbic acid (vitamin C) content is not significant for emphasis when the highest value found is about one-tenth of the highest content found in spinach.

Spring crop superior

Like spinach, the carrots grown in the spring are superior in quality to those grown in autumn. Sunlight is a factor in producing carotene in the carrot root, as it is for producing more ascorbic acid in spinach, tomatoes and other vegetables. Therefore, the lengthening days of the spring season, in contrast to the shortening days of autumn, call forth a response known as "photoperiodism." Accordingly, with more carotene comes more yellow color, so even the eye can help in selecting carrots for their nutritional value.

In the carrot, improvement in carotene content can be obtained by systematic choice and multiplication of nutritional values, too long neglected when economic rather than health interests dominate the vegetable marketing. We need more emphasis on "nutritional gardening." The housewife needs to realize that since she does the buying, she must speak out and create the demand for vegetables grown by those suppliers who are truly nutritional gardeners.

Lets Live Magazine: May, 1966

Values of Apples

According to Chemical Analysis

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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The apple has enjoyed great popularity, despite Biblical reports concerning it. Recently, however, it seems to have lost first place to the citrus fruits which are limited to more tropical climates and to areas of greater sunlight. We have learned that sunshine is a requisite when the vitamin C, even in vegetables, is synthesized more highly in relation to light than to the fertility marked by either the soil's organic compounds or any of its inorganic nutrient elements. Hence, variations in exposure to sunlight due to the shading of the fruit by leaves result in corresponding variations in the concentration of vitamin C.

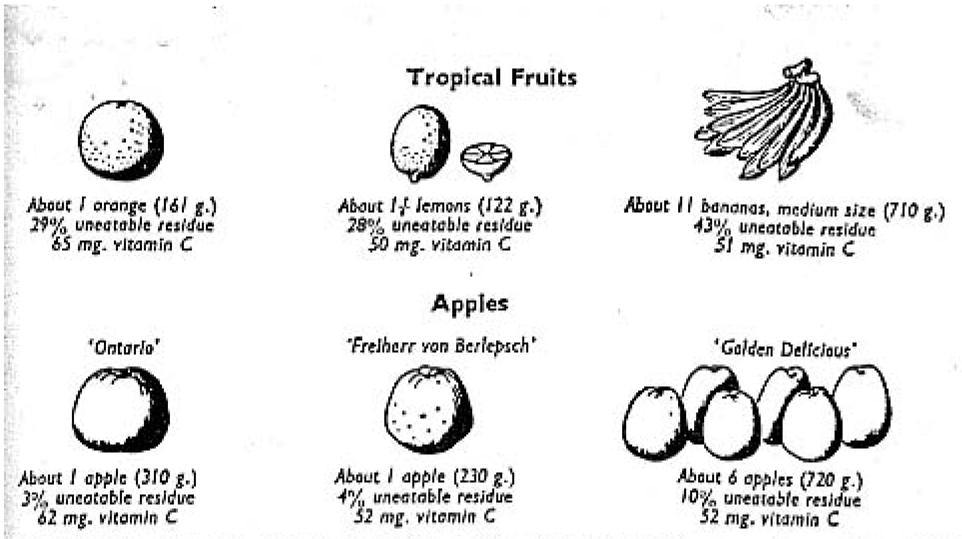
Color not a criterion

Judging by this fact, it would seem that in the normally red apple, the higher degree of color development should indicate a higher vitamin C concentration. However, these two qualities are not linked, and there are plenty of red apples of "mouth-watering" appearance which are low in acid taste and in distinct and pleasing flavors. Also, there may have been so many apples grown with concern for no more than the red color and large yields that the choice apples which might have held their markets on quality have disappeared.

Considering vitamin C, let us remind ourselves that apples can produce this factor in the temperate zones and over enormous land areas from which the citrus fruits are excluded by shorter seasons of growth, lower temperatures, and less intense solar radiation. Accordingly, the apple needs to be maintained as a vitamin C source which lies within closer range of most persons than the tropics or non-frost areas.

Comparison of values

The daily requirement of ascorbic acid (vitamin C) for adults in the United States is 50 milligrams. Using this as a basis, let us consider the nutritional value of three varieties of apples and three tropical fruits as shown on the accompanying chart. This shows that of two varieties a single large apple (larger than the citrus) will supply the daily adult need. However, of one variety of apples of smaller size, a half-dozen would be required to provide the minimum requirement of vitamin C. That requirement would demand consumption of 11 bananas. In terms of these facts, the apple must be considered a good source of ascorbic acid, especially in view of its availability over long seasons, its extended storage life with slow loss of vitamin quality, its small amount of inedible waste, plus other properties surpassing those of citrus fruits.



The daily requirement of vitamin C for adults—about 50 milligrams of ascorbic acid—is contained in each of the above.

In Dr. Werner Schuphan's studies 134 different kinds of apples were used for vitamin C content, even though this factor is not considered in judging market value. The amounts of Vitamin C range from a high of 31.8 milligrams in 100 grams of fresh matter to a of 2.3 milligrams. Apples of 16 kinds recommended widely in Germany include those above 14 milligrams. Since the inedible portion of the apple is small it requires not more than three or four medium or small apples per day to supply the adult needs of vitamin C. If we were to take 30 milligrams of C, which is considered the adult requirement in England, one or two apples a day would suffice. The 16 different kinds (with some periods of storage) provide apples most of the year around, excepting the four months of summer.

Familiar varieties listed

Included in 134 different kinds of apples tested, and listed (without reference to locality of growth) in their ofder of decreasing contents of vitamin C are 10 familiar American and English varieties having more than 15 milligrams of vitamin C per 100 grams. In the order of decreasing amounts of C, and the numbered order of rank, they are as follows: 2--Pippin (Ribston); 6--Golden Noble; 4--Ontario; 16--Yellow Belleflower (Linneous Pippin); 17--King of the Pippins; 20--Lady Hollendale; 22--Northern Spy; 24-- Norfolk Pippin; 28--Bramley's Seedling; and 32--White Transparent.

Without the numbers of still lower rank (from 33 to 84), the list included 10 additional familiar names of American and English apples. Accordingly, the apples of both these countries must be expected to vary in vitamin C from a high of 30 milligrams per 100 grams of edible fresh substance to a low of near zero. One must, therefore, learn about apple quality since some of this fruit can deliver such high amounts of this one nutritional factor of which we require less than a 50th of an ounce per day.

Contain less minerals

In contrast to citrus fruits, apples do not contain harmful oxalic acid. We cannot boast about either the apple or the citrus as sources of quantities of mineral substances, including the trace elements. "Apples contain potassium, magnesium, iron chloride and phoshate in much smaller quantities than are present in many vegetables which are considered low in these elements. Also, the sulfur and sodium content is higher than in the vegetables having the smallest contents.

Vegetables contain, for the most part, multiples of the values of apples for these eight mineral substances, as well as for trace elements. Here are a few examples: Calcium--Kohlrabi contains over 50 times as much as apples; Phosphate--Cucumbers contain more than 25 times as much; legumes, up to 100 times as much. In this connection, it is interest that oranges, like apples, fall far below the vegetables insofar as a generous supply of mineral constituents is concerned." (1) The fruit at the end of the limb on a tree is too far removed from the minerals in the soil to compete with the vegetables which are closer to the mineral source.

High in pectin

In the content of pectic substances (jell-makers) and of tannic and malic acids, which are substances of significant dietetic and therapeutic values, the apple has a decided advantage over the orange. The latter has only the refreshing taste of citric acid. In addition, the orange is reported to contain 24 milligrams of oxalic acid per 100 grams of fresh substance.

A recent scientific report cited the unique ability of malic (apple) acid to serve as a "chelator" of the mineral elements, mobilizing their activity from the soil of the plant. Iron, put into a large, synthetic, organic-chelator compound (ethylene diamine tetra acetic acid, or EDTA) applied to soybean roots was soon found in the exudate from the cut-off stem. But instead of the iron's being still chelated by the applied EDTA, it was carried within the plant in chelation, mainly by malic acid, but also by malonic acid, both of. which are by no means of as complex chemical structure as EDTA. (2)

Here is a suggestion of nature that should prompt some biochemical research on the biological behavior of the organic and dietetic assets of the apple. Possibly we might learn the physiological bases for the widespread empirical belief of many years that "An apple a day keeps the doctor away."

(1) Werner Schuphan, Nutritional Values in Crops and Plants, Faber and Faber, 24 Russell Square, London, WC1.

(2) Science, 135: 311-312, No. 3500, January 26, 1962.

Lets Live Magazine: June, 1966

Nutritive Value of Apples

According to Biological Assay

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In these discussions of the qualities of our food plants as furnished by the soils in which they are grown, it has been pointed out that it is difficult to report quality in specific numerical units. We can use chemical measures in laboratory assays, but the results are not valid.

Spinach and its companion crops of the Goosefoot family all contain calcium in quantities sufficient to deliver what we would say is a good allowance in food. But this calcium is not digestible, because the spinach combines it with one of its metabolic waste products, oxalic acid, to give calcium oxalate, a compound which is not digestible in the human system. Yet, in the regular chemical assays, using strong acids or ignition to get ash, the calcium comes out soluble.

In studying the values of soil treatments in terms of the production of crops of varied nutritional values, much of the study at the Missouri Experiment Station employed the biological assay method. This method uses some form of life to feed on the same plant products grown with different soil treatments.

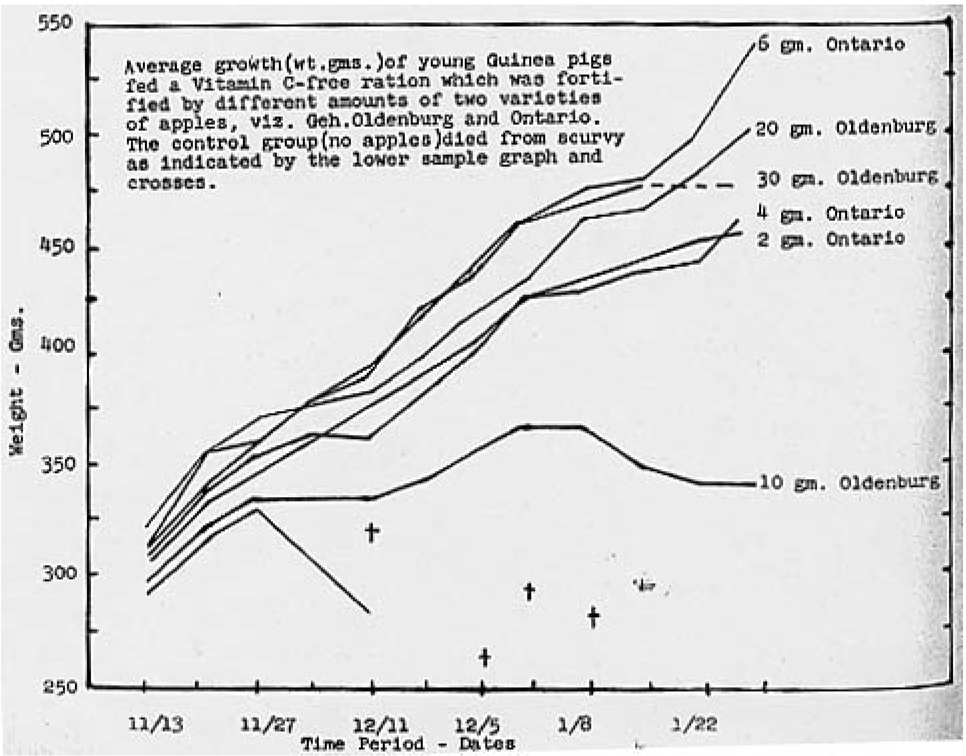
Two cuttings of hay, harvested simultaneously, but grown on plots given different fertility treatment, were offered to a rabbit. It took five times as much of one cutting as of the other. We could say that such discrimination was a quantitative comparison of crop quality. While our observations of the two hays would not lead us to believe them so widely different, we still respect the distinctive choices of the rabbit, for it was the consumer of the hay and the "customer" to be satisfied by the goods we offered.

Dr. Schuphan's tests

In Dr. Schuphan's tests of nutritional values of the vitamin C of apples, guinea pigs were used in making the biological assays. From among 134 different kinds of apples tested chemically and reported in order of their decreasing content of vitamin C, two were chosen. One was the "Ontario," number 14, with 20.6 milligrams per 100 grams of fresh substance. The other was the "Geheimrat Oldenburg," number 131, with 3.1 milligrams of this vitamin per 100 grams of fresh substance.

After chemical examination of 1260 of the former and 2806 of the latter apples to supply lots of fruits which were "high" and "low" in vitamin C, they were fed to guinea pigs from mid-November to late January. The Ontarios were fed in three separate quantities of 2, 4 and 6 grams per animal, while the Oldenburgs were fed in three quantities of 10, 20 and 30 grams per animal. The experiment employed 48 guinea pigs in six lots, with another control lot given no vitamin C.

The growth results are indicated in the accompanying graph. The base line (abscissa) indicates the time periods. The vertical line (ordinate) reports the increases in weights of the animals in grams. It is significant to note the lowest and shortest line ending December 12, which is for the control group. Dates of individual deaths of six animals are marked by crosses and the animals' weights at death are indicated. In two cases the weights fell below the base line, hence are omitted.



Here is evidence that the laboratory chemical measures of vitamin C in the fruit were quantitative evaluations of quality duplicated biologically by the growth and death performance of the guinea pigs. The latter assay was a decidedly quantitative measure when the first death occurred in 28 days and the others followed in such close sequence.

Experiments with children

Feeding trials using these two different kinds of apples were carried out also with 39 children aged four to 16 years. The great differences in vitamin C contents, measured chemically, were actually proved again in the biological tests with the children. The results were summarized as follows: "(1) The vitamin C level of the blood of children who had received quantitatively sufficient fruit and vegetables, including apples of unknown variety and origin, was relatively low before the beginning of the experiment. In some cases it came dangerously close to the scurvy level. From this it follows, with regard to the supply of vitamin C: 'Fruit and fruit is not always the same; apple is not equal to apple.' 'One fruit is not the same as any other.' 'No two apples are alike.'"

Content varied

"(2) The two market dessert cultivars, of the same price group, used in our experiments, gave very different ascorbic acid contents in the chemical determination. The cultivar 'Ontario' contained about seven times the amount of ascorbic acid in the cultivar 'Geheimrat Oldenburg,' and this situation lasted over several months.

"(3) These differences, found in the chemical determinations, became noticeable in an enhanced degree in the experiment with guinea pigs and in the investigation of the nutrition of children. Ten grams daily of the apple variety "Geheimrat Oldenburg' failed to protect guinea pigs from scurvy, while even two grams of the variety 'Ontario' were sufficient to prevent the appearance of any symptoms of scurvy. Consequently, the chemical method of determining ascorbic acid completely can characterize the typical differences in the vitamin C content of apples."

Control group died

"The animals in the control group without additions all died of scurvy. The statistically significant results compel us, in the interest of a conscious responsibility for the form of nutrition, to demand that use be made of them in practice. This applies especially to hospitals, sanatoria, children's homes and every kind of communal and mass feeding (works kitchens). Consequently, in the future it can scarcely be justifiable to supply consumers, especially those having high vitamin C requirements such as children, invalids, convalescents, with any kind of apples to represent 'fruit', without taking the vitamin C into account." *

*Werner Schuphan, *Nutritional Values in Crops and Plants,* 1965, Faber and Faber, 24 Russell Square, London W.C.I.

Lets Live Magazine: July, 1966

Size and Weight Versus Nutritional Quality

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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We have accepted size and weight as quantitative criteria for the market qualities of most of our agricultural products. This considers their services and values as foods mainly in terms of satisfaction. That is expectable in the struggle against hunger for which the first concern is to get enough bulk or weight of food to eat and satisfy the craving by hunger.

In the business of agriculture, we are aiming for high yields per unit area of soil surface, or per acre. The first thought for years of bringing that about was the hope for larger units of the harvest. That emphasized growing bigger ears of corn; larger fruits like apples, peaches, and pears; larger carrots, turnips, sweet potatoes, Irish potatoes and other tuberous or root crops; and also bigger heads of cabbages, lettuce, cauliflower; whether the seed, the root or the leaf of the plant was the harvested edible portion. For many years the selection, and propagation for enlarging the harvested unit have been the major struggle for increased crop yield.

That had its economic advantage. It brought a larger edible unit with lesser waste as the inedible portion in preparation for preservation and consumption. It is a simple mathematical fact, that according as a near-spherical unit is larger, the less surface there is per unit volume or unit mass of contents.

Public exhibition of agricultural products, as invitations for purchase, have also invited more size and weight; prize-winning products catered to those characteristics. But now with increase in mechanical over manual preparation for consumption, like peeling potatoes, fruits or other food items, the; larger size is not considered a significant factor.

In recent years the yields per acre have been pushed up by aiming at smaller units but more of them by thicker plantings per row and less distance between rows or more of those per acre. As a consequence, the quality as nutrition is now coming in for closer scrutiny. With recognized decline in the percentage of crude protein in our corn grain from 10.30 to 5.14 percent, as illustrated by that grown for exhibition* in corn husking contests, and with accumulations in the plant of unmetabolized, or nitrate, nitrogen and its hazards as poison, the question is widely considered whether the nutritional values per smaller units cannot be lifted significantly.

In the first place, we need to remember that size and weight are genetically controlled. Variations in those are provoked by ecological influences, but though they occur their limits are set by birthrights. Temperature, water supply, and available nutrients in the soil are effective in giving more unit size and weight. It is common experience that generous supplies of water and nitrogen give bigger potatoes, cabbages, apples and other crop units. But those as external and physiological factors are coupled with the genetic or internal factors. The latter we can only choose and accept. The former we aim to manage and to improve.

In spite of the more ready acceptance of the genetic matter of size and weight limits, even they can be modified to our advantage biochemically, nutritionally, storage qualities and otherwise, by conscious effort in selection of the specimens, therefore, in the course of plant propagation.

For the relation of size to nutritional quality let us consider seed first and look at the pea. For this vegetable, it is almost a common contention that peas are more tasty, especially sweeter and less tough, according as they are smaller! That, however, is apt to be due to less of maturity and an early stage in the ripening or moving towards the end of physiological activities and dormancy. Should we not expect a certain limited stage in that process to represent the maximum in the several items making up the most pleasing taste and collection of nutritional values?

Table 1--Composition of Green Pea (Calcium as percentage, essential amino acids as gm. per 100 gm. Crude protein) "Kelvedon Wonder"			
	Small 6mm	**Medium 6-8 mm**	**Large 8-10 mm**
% Fresh wt.	18.40	19.71	21.55
Calcium % Fresh Wt.	5.63	5.44	25.8
Calcium % Dry Wt.	30.6	27.6	25.8
Protein Nitrogen	43.4	44.9	60.8
% Total Nitrogen Amino Acids, gm.			
Valine	4.4	4.1	4.0
Leucine	3.8	3.8	5.4
Isoleucine	5.1	4.0	3.5
Threonine	7.7	12.2	14.3
Arginine	1.7	1.5	1.7
Histidine	3.5	3.7	5.1
Lysine	3.5	3.7	5.1
Phenylalanine	2.2	2.3	2.9
Tryptophane	0.7	0.7	0.7
Methonine	0.7	0.8	0.6
% Amino Acids to Protein Nitrogen	33.4	37.0	42.8

The researches by Dr. Schuphan** report the concentrations of sugar and of vitamin C going lower with increasing physiological ripeness of the pea-grain. The pure protein behaves in the converse. That rises very suddenly after the pea-grain size reaches 8.2 mm. The tenderness and the taste quality diminish them.

Dr. Schuphan has made analyses of peas of different sizes to note the composition of those in terms of their essential amino acids. Data for one variety of peas are quoted in Table I. Of the ten amino acids, for five of them the concentration increases with size or maturity; for two of them there are decreases; and for three of them they remain nearly constant regardless of size or maturity of the pea-grain.

Since the seed is the power of maintaining the species in successive generations, one is dealing with genetic values and would scarcely believe size a significant factor save as stored reserve energy foods since the germ is very small and we cannot expect to measure its qualities by simple inspection. Quality in that respect is still deeply hidden. Studies of nutritional qualities of forages for livestock have very lately been telling us that size and weight, or bulk, per acre are deceptive as to nutritional values. Livestock choices guiding managed grazing tell us that the younger growing plant, not the large yielder or mature one, is the most concentrated and more nearly balanced in nutritional values for growing warm-blooded bodies. It is high time that more attention be given to nutritional values of vegetable products along with attention to economic values of bulk production.

**H. R. Lathrop. Arcadian News, Allied Chemical Company, 1956, New York 6, New York.*

*** Warner Schuphan. Nutritional Values in Crops and Plants. Faber and Faber, 24 Russell Square, London.*

Lets Live Magazine: August, 1966

Magnesium in the Soils of the United States

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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In the series of discussions of the importance of magnesium in plant nutrition, in these columns, from December 1964 to September 1965 inclusive, no attention was given to the broader pattern of magnesium of the soils of the United States as a whole. Yet for its companion cationic element, calcium, our country divides itself, soilwise, naturally into an East and a West. The 98th meridian of longitude marks the division closely. The division by soils runs roughly south from the northwestern edge of Minnesota to the southern tip of Texas. Those to the west are called "pedocals"--"pedo", for soils and "cals" for calcium, with free carbonate of it in horizons or concretions in the soil profile. Those soils of the East are called "pedalfers"--again soils with aluminum "al" and iron "fe" prominent in the profile under conditions implying the shortage of any calcium as active there in its carbonate.

In the development of a soil from various rock minerals, the movement of magnesium down through the profile has riot been given as much prominence as calcium. Yet in the drainage waters, as an average, from the country in its entirety, the mineral residues on evaporation of those waters--more often appreciated as the so-called "lime" clogging the coils in the water-heater--contain one-fourth as much magnesium as calcium, by weight. Calcium carbonate makes up nearly half of that residue from the waters, to make "lime in the tea-kettle," a common observation in Western United States.

The United States Geological Survey has done extensive chemical analyses of drainage waters. In its Professional Paper No, 135, 1924, Dr. F. W. Clarke gave an extensive collection of data. From those Mr. S. B. Detweiler, now retired from federal services, gave us the generalized magnesium map for the country, shown here as Figure 1.

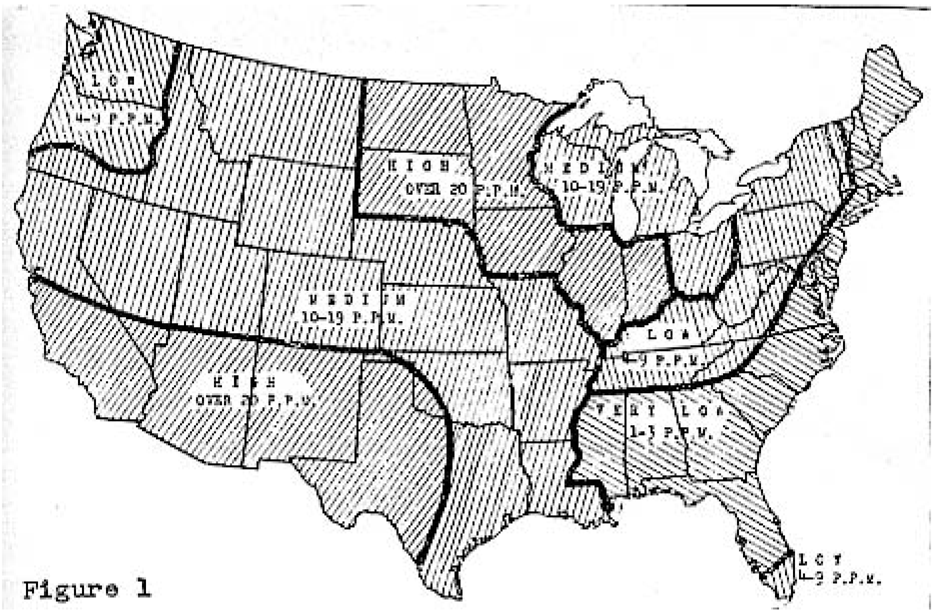

Figure 1

These data suggest their relation to the varied degrees of soil development under the climatic forces, especially the rainfall as it is in inches per year in excess of the evaporation from a free water surface, also in inches per year. The former may also be given as percentage of the latter. Consequently, we would expect low magnesium in our soil waters in the Southeastern states. Accordingly, in the states northeast and east of Ohio and east and south of the Mississippi and Ohio Rivers, the "very low" and the "low" magnesium, namely 1-3 ppm and 4-9 ppm, respectively, are expected as the map reports. Then, in the high rainfall of Washington and Oregon, where the extremes of rainfall occur, magnesium is also 'low," or 4-9 ppm. In the rest of the area and a much larger one, magnesium is reported as "medium" and "high," at 10-19 ppm and over 20 ppm. The Dakotas, Minnesota, Iowa, Illinois and Indiana with increasing annual rainfalls in that order from less than 20 to 40 inches per annum all show high magnesium. That fact serves to point out that the geological factor and not only the rainfall must come in for consideration. We therefore, speak of the geo-climatic setting as determining the development of the soil.

The "low" supply of magnesium in the soil as a deficiency in crop production came into prominence some thirty years ago* in the citrus groves of Florida, when attention first turned to the so-called "trace" elements. Emphasis had gone to the Marsh seedless grapefruit, which was giving larger yields as boxes of fruit than were the "seedy" ones. But when fertility elements, not common in commercial fertilizers, were applied separately on highly calcareous, sandy soils, it was the magnesium that increased the yields of the "seedy" fruits far above of the seedless. But also, the flavor and taste were so much improved that there was not much premium on the seedless for the customer looking for quality along with quantity.

Magnesium demonstrated its chemistry connected with the better survival of the species through healthy reproduction. But with that there came also the other products giving the quality as taste, possibly also assets in the reproduction of the species in passing over dormancy from the season of seed production to the planting of that, as it occurs in Nature. With our concern for the production of big bulk per acre, we are apt to forget that quality as fruit may be in the many compounds unknown, but coming along as aids in species survival. Magnesium is associated with many enzymes, and that element, like the enzymes, is a case where so little can do so much, without being necessarily spent in the service.

While magnesium, as mapped "very low" and "low" in Figure 1 may be a deficiency in highly developed soils, the converse, or excess of magnesium, may be the case in the less-developed soils in areas of lower annual rainfalls and mapped as "high" in magnesium. Early botanical literature says much about the required calcium-magnesium ratio. Irrigators suggest caution of magnesium-potassium ratios and calcium in relation thereto in the applied waters.** More recently with our appreciation of the adsorption-exchange activities by calcium, magnesium, potassium and sodium on the soils, colloidal complex and their suggestions as to what ratios of these cations on it are a balanced diet for legumes and other more nutritious plants, there comes the ecological suggestion that areas "high" in magnesium on the map may be disturbing to fuller plant nutrition and crop growths. Excess magnesium may be equivalent to calcium deficiency, if not also of potassium.

Calcium plays a role as a fertilizer defined as an element entering into the plant's growth of its tissues for larger yields. But it also serves as a "soil amendment," whereby the root hairs are maintained as highly calcerous, so called "semi-permeable" membranes. In that state, they are prohibiting the outgo of nutrients from plants back to the soil. Simultaneously they are fostering the ingo of nutrients--including nitrogen, phosphorus and potassium--from the soil to the plant. If magnesium in excess on the clay will saturate the root membrane by replacing the calcium there, should we not interpret that as a need to saturate the immediate seedling zone with calcium? Such is the suggestion coming from many farmers in the areas on the map where magnesium is labeled as "high" in the drainage water.

Agricultural crops as well as citrus are telling us that magnesium is coming into more concern with our soil exploitation of both the organic and inorganic aspects of fertility. The larger look at this element includes the soils of the country as a whole, and the testing of soil for magnesium makes this the fourth, even for labeling of commercial fertilizer bags, though commonly connected with calcium under the term "lime."

** B. R. Fudge, Relation of Magnesium deficiency in grapefruit leaves to yield and chemical composition of fruit. Florida Agr. Expt. Sta. Bul. 331. January, 1939.*

*** Frank M. Eaton, Formulas for estimating leaching and gypsum requirements for irrigation waters. Texas Agri. Expt. Sta. Misc. Pub. 1954.*

Lets Live Magazine: September, 1966

Health, As Different Soil Areas Nourish It

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part 1

It is at the super market that we get most of our food. There we come face to face with the prominently posted purchase price of each item. There the amount of food we take home is limited, all too often, by the funds which our budget allows. Accordingly, we cut ourselves short on quantity. But here we are considering food only in the light of its function at relieving hunger, Unfortunately this allows for little concern about its nutritional value.

Need fertile soil

Proper nutrition provides health which allows us to serve as useful, constructive citizens in the community and the country. But nutrition to keep health at that high level must look far beyond the supermarket and price tags. It must see healthy animals for our meats, healthy plants as their feed and as our food. These require fertility in rock-minerals and organic matter, providing health from the ground up in suitable geoclimatic settings. We need to appreciate the remark of a geologist who said, "We are what we are because of where we are." He was looking beyond the soil. He was including, in our nutrition, even the very rocks of the earth's crust from which the varied climates gave us varied soils in creative nutrition for life forms.

For the last couple of decades, our studies of agriculture have not been given so much to soil as to the economics of it. This looks as if agriculture were as simple as any industry, say manufacturing washing machines. But agriculture, quite differently from industry, is first the creative work of nature, by which growth of life processes is nurtured. It is not compelled or driven by man. It is only being hoped for through faith in the season, the soil, the seed and other natural factors.

The high percentage of rejections of inductees into the armed forces indicates a high degree of correlation between condition of soils and health of plants, annuals and humans.

Study of teeth

Defective teeth seem to be the most universal ailment of the human body. Animals are likewise affected. An interesting study of the health of teeth was carried out in 1949 and 1951 by Abraham E. Nizel, D.M.D., and Robert S. Harris, Ph.D., from Tufts Dental School, Boston, and Massachusetts Institute of Technology, Cambridge, respectively! (1) connecting the health of teeth with the soil which grows the food. The development of caries in hamsters was the quantitative testing tool.

The foods included cornmeal and dried whole milk. In the first part of the test, these products were obtained from the state of Texas, specifically from the Panhandle, near Deaf Smith County and its town of Hereford, and also from Lubbock. Not too long ago Hereford was in the news as the "Town Without a Toothache." This is the area of red and yellow soils, and of excellent cattle growth. The annual rainfall is near 25 inches. The soil shows neither leaching nor accumulation of alkalinity, as the precipitation and evaporation are approximately in balance.

In the second part of the test the corn and milk come from Orono, Maine, and St. Albans, Vermont, respectively. The soils there are said to be "podsolized," or highly mature as living soils. Annual rainfall is somewhere under 40 inches, a precipitation much above annual evaporation at that northern latitude. Alfalfa, also a part of the food in in the experiment, was obtained from Ithaca, New York, for both tests. The rations were made up of corn, 63%; dried, whole-milk weanling powder, 30%; alfalfa, 6%; sodium chloride, 1%; and distilled water.

Forty weanling hamsters (21 males and 19 females) composed the lot on Diet No. 1, the corn and milk from New England. Thirty-seven hamsters were started on Diet No. 2, the corn and milk from Texas. "Weighings were made weekly on each animal. After 15, 16, 17, 18, 21 and 28 weeks, representative hamsters (a total of 25 from each group) were autopsied. The teeth were examined, scored and charted according to the Keyes procedure. The scoring was spot-checked by others with experience with this procedure."

Results

They reported as follows: "The hamsters gained approximately 5 grams weekly on both diets. Caries was noted in the teeth of hamsters from both groups at the first autopsy 15th week): Male hamsters were more susceptible to carries than female hamsters; maxillary teeth were more carious than mandibular teeth; and there was a very striking preponderance of caries in the occlusal pits of the maxillary molars, particularly the second molars. Only two hamsters (both on the Texas diet) were caries-free.

Detailed data concerning percentages show that "there were approximately 40% more carious teeth, and approximately 50% more carious surfaces, in the group fed New England corn and milk. Both these differences were studied statistically and were found to be significant at the 1% level. It is evident that the area in which foods are grown may affect the prevalence of dental caries.

These data reinforce what nearly 70,000 inductees into the Navy for the Second World War revealed. (3) Their average age was 24 years. The mean data by longitudinal soil belts two states wide, coming out of the mid-continent west of the Mississippi River, were: cavities, 8.36; fillings 3.72; total cavities, 12.08. For the soil belt two states wide along the eastern seashore, the corresponding figures were 11.45, 6.10 and 17.5 respectively. Accordingly, inductees from New England, which falls into the highly-weathered soil belt of "murmuring pines and hemlocks," had 45% more cavities than the inductees from Texas, where the soils are of lesser degrees of development under moderate rainfalls, with prairies and plains. For New England alone, the data in the same order as above were: cavities, 13.5; fillings, 7.8, a total of 21.30 cavities or over 75% higher than in the jnductees from Texas.

These are facts which clearly tell us that the human is another biotic specimen, and our health, like that of other strata below us in the biotic pyramid, is different according as the different soil areas under the various geoclimattic settings nourish it. Apparently man is not yet "managing" his own health nutrition-wise as well as nature did that of the strata below him.

(1) Nizel, A. E. and Harris, R.S. Effects of foods grown in different areas on prevalence of dental caries in hamsters," Archiv. Biochem. 26: 153-157; 1950.

(2) Keyes, P. H., Journal Dental Research, 23:439. 1944.

(3) Albrecht, W. A., Our Teeth and Our Soils, Ann. Dent. 6:199-213, 1947.

Lets Live Magazine: October, 1966

Health, As Different Soil Areas Nourish It

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part 2

With the glib tongue of a memorized recitation, we say that good nutrition requires carbohydrates, proteins, fats, minerals and vitamins. Then we list the foods to supply these factors and assume that by assembling these foods we have compounded a ration complete for for healthy growth. Courses in feeds and feeding of livestock have been taught as if the task were that simple.

We say, "Milk is a complete food; corn is a good source of carbohydrate; legume hays can supply the proteins, some of the vitamins and minerals; corn carries fats." On such knowledge we start out to fatten pigs and calves--mainly castrated males. But during many past years no attention was paid to the unknown factors in nutrition; to the differences in nutritional values of feeds and foods dependent on the fertility differences in the soil on which the vegetation was grown. Considering only the inorganic elements coming from the soil, we have not yet catalogued all the essential ones with a high degree of certainty.

Belief should be encouraged

Our belief in the essentiality of more soil-borne elements should be encouraged whenever any one occurs in the blood of animals and man; and, also when it occurs in the milk of any of the mammals. "Whole milk," reports John J. Miller, (1) "contains all the vitamins, minerals and amino acids officially admitted to be essential in human nutrition; but also additional vitamins and minerals whose essentiality is not generally recognized. For example, folic acid, pantothenic acid and vitamin E, among the vitamins; also manganese, vanadium, molybdenum, aluminum and boron, among the minerals. The amino acids include the so-called nonessential as well as the essential--indicating that the body prefers to ingest them together, because of their synergistic action in the synthesis of protein.

"Note well that some of the minerals in the best quality of milk are present in very small, or so-called 'trace' amounts and this has raised a question in the minds of some nutritionists in years gone by as to the essentiality of such elements, e.g., cobalt, copper, manganese, molybdenum, zinc and even magnesium." We might well ask whether one could not apply to eggs what has just been said for blood and for whole, fresh and unheated milk.

In the September 1966 issue of *Let's Live* it was reported that experimental tests by Doctors Nizel and Harris, in 1950, showed that hamsters fed on corn and milk produced in Texas showed decidedly less caries in their teeth than those fed on corn and milk from New England, even when the same alfalfa and salt were supplements to both rations.

Second study

This study was followed closely by a second one to learn whether the cariogenic factor was in the corn or the milk or both. (2) The details of this procedure duplicated those of the previous tests. The study included: Group A, hamsters given New England corn and New England dried whole milk; Group B, given Texas corn and Texas milk. Then there were added the groups with interchanges of the sources of corn and milk, namely: Group C, given New England corn and Texas milk; and Group D, given Texas corn and New England milk, again supplemented by a common alfalfa from New York and the ordinary salt.

Again, the hamsters were sacrificed at the end of the test period, and the dental caries scored according to the Keyes procedure. The data for groups A and B were a close duplication of those obtained in the first test reported in these columns last month. Accordingly, this second trial showed again 43.1% decrease in carious molars and 50.9% decrease in carious surfaces for Texas-fed hamsters over the New England-fed hamsters. This agreed very well with the corresponding values, namely 41% and 47%, respectively, obtained in the first test.

Less difference

However, the data for groups C and D showed differences of but 6.4% for the number of carious teeth and only 2.4% differences for the carious surfaces. "There was no statistically significant difference in the caries index. This indicates that neither the Texas corn alone nor the Texas milk alone inhibited the dental caries."

"Diets A and B were analyzed for 13 nutrients, and only the riboflavin was found to be significantly different; it was approximately 0.30% higher in Diet A. It appears from these results that the caries-promoting property of the New England foods outweighed any caries-inhibiting property of the Texas corn and milk, and that a mechanism operated in the New England foods which aided materially in production of dental decay."

The single-factor question

Stated more simply, the nutritional requisites for healthy bodies were not met by a fragmented ration assembled from foods grown only in part--either for carbohydrate or protein--on the highly; calcareous and phosphatic soils of the Texas area near the town of Hereford. Such rations did not prevent degeneration of the enamel structure of the.teeth. This reports nothing about the probable disturbance of other metabolic aspects. Is the nutritional failure for natural self-protection apt to be due to a single positive factor or mechanism of degeneration ? Isn't it more apt to be caused by an absence, or even by an irregularity, in a chain of many contributors to self-protection?

The training and education of professionals ministering to our ailing health seem to encourage search for only positive, damaging factors. Seemingly, dental caries should invite, thinking about missing factors, or in the negative, the failing maintenance of the high level of our biochemical complexity guaranteeing good health. Of course, thinking of a single factor means single cause and single cure. This is inviting for prescription of a single drug or single element, like fluorine.

But in the naturally healthy setting for cattle in Texas and in the good human teeth discovered there, that "single-factor" thinking is apt to be erroneous when it attributes good teeth to the fluorine from the surface soil going into the: drinking water enroute to the sea. That ionic fluorine comes from the natural weathering of the magmatic mineral, apatite. While activating the soluble fluorine, it is simultaneously releasing to the surface soil calcium and phosphorus in more available forms for the better nutrition of plants and animals. For this reason there is better bone-building in that area, according to a report by Lewis B. Barnett, M.D., Dallas, Texas.(3) Doesn't it suggest erroneous reasoning to ascribe better teeth and bones to one anionic, highly-corrosive element in the drinking water than to the two cationic ones, calcium and phosphorus, the most abundant nutritive elements in the ash of the warm-blooded body? The prize Hereford cattle, drinking surface water, gave the town its name long before the newspaper publicity characterized it "The Town Without a Toothache."

Single organic factors in nutrition, like either Texas milk alone, or Texas corn alone, did not prevent or eliminate dental caries, but moved decidedly in that direction when working together. This said nothing pro or con about including alfalfa from New York, as was done in the scientific tests by Doctors Nizel and Harris. In dealing with the biochemical complexity of healthy teeth, does not a single factor, like fluorine in our drinking water, seem a highly illogical premise on which to prescribe and enforce mass medication in an area where health is failing?

(1) John J. Miller, "The influence of soil minerals upon human and animal nutrition." *Clinical Physiology,* pp. 21-30 (Atlanta, Texas).

(2) Abraham E. Nizel, D.M.D. and Robert M. Harris, Ph.D., "The caries-producing effects of similar foods grown in different soil areas," *The New England Journal of Medicine,* 244:361-362, 1951.

(3) Lewis B. Barnett, M.D., "New concepts in Bone Healing," *Journal of Applied Nutrition,* VII :318-323, 1954.

Lets Live Magazine: November, 1966

Soil Phosphorus —Activated Via Soil Organic Matter

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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When Nature built up the fertility of our soils, she followed two major practices. First, to soils with reserve rock-minerals she added surface deposits of similar material by means of wind and water. Second, she also returned, in place, the crop residues grown there. She used only natural, organic and mineral-rock fertilizers.

In our management of soils for crop production we have associated the inorganic nutrient elements calcium, magnesium, potassium, sodium, iron, aluminum, zinc, copper, cobalt, manganese and others of positive, ionic characters with the soil's colloidal clay-humus fraction of the opposite, or negative, electrical characters. But the essential nutrient elements nitrogen, sulfur, phosphorus, boron, chlorine, iodine, molybdenum, and others of negative, ionic characters have been more empirically the orgianic matter of the soil.

Shall we not envision the anions, or negative, elements.corrected with decay stages of organic matter, when its wider carbon-nutrient ratios serve as a source of energy, by the carbon--first to the fungi and then to the bacteria in the soil? May the negative elements not serve simultaneously in plant nutrition as chelated and larger molecular complexes of microbial origin?

It is significant to note that calcium, a cation, or positive element, is the most abundant "ash" element in warm-blooded bodies and, likewise, among those adsorbed and held by the negative, silicate clay, in form available to plants. The second most abundant ash element is phosphorus. It is a negative element, or anion, hence is not similarly held on the clay. Instead, it is associated--along with the other anions, like nitrogen, sulfur, boron, etc.--with the active soil organic matter.

According to recent research, phosphorus is connected with photosynthesis by chlorophyl, where the first step in forming glucose consists of a three-carbon chain with phosphorus at one end. This connects with a similar chain reversed to unite the carbons into a six-carbon chain by dropping out the two phosphorus elements. As another case of phosphorus in energy-source materials, or organic matter, this element is active in the cycle of reactions for the oxidation of glucose within the cell for its energy source. Phosphorus is intimately connected with both the biochemical synthesis of organic matter and its oxidation within living tissue; yet we have been emphasizing its roll in the soil as if it were performing much like the inorganic cations do.

Chemistries used together

"Organic materials that reach the soil," said Sing Chen Chang in 1931, (1) "generally contain considerable phosphorus, ranging from 0.1% to 0.5%. Much of the phosphorus in the materials is in organic combinations which are not readily available to plants; the release of this great quantity of phosphorus in the form of readily available phosphate depends upon the decomposition of the organic cpmpounds by microorganisms. From the point of' view of phosphorus conservation, the farm manures, green manures and composts of various organic residues should not be considered merely as a source of nitrogen. The idea that phosphorus is completely mineralized during the decomposition of organic matter and can all be absorbed by the plant is, (also), too generally accepted."

The biological transformation of the inorganic to the organic phosphorus was reported as early as 1911 in the Russian literature by one Egorov. (2) In similar literature a report stated that "in addition to the physico-chemical absorption of the phosphorus in the soil, there is also biochemical absorption and fixation, which increase with an increase in the amount of the organic matter (starch) added and also with the length of time." (3) Also, Doryland, (4) our American pioneer in emphasizing the carbon-nitrogen ratio of organic matter relative to nitrogen release as ammonia, or the fixation of the latter by organic matter's decomposition, pointed out that "molds (fungi) are active in assimilation of plant-food constituents during the first stages of decomposition of crop residues when there is a high energy-nutrient ratio; the molds may later play just as important a part as do bacteria in liberating plant-food constituents when the ratio is low."

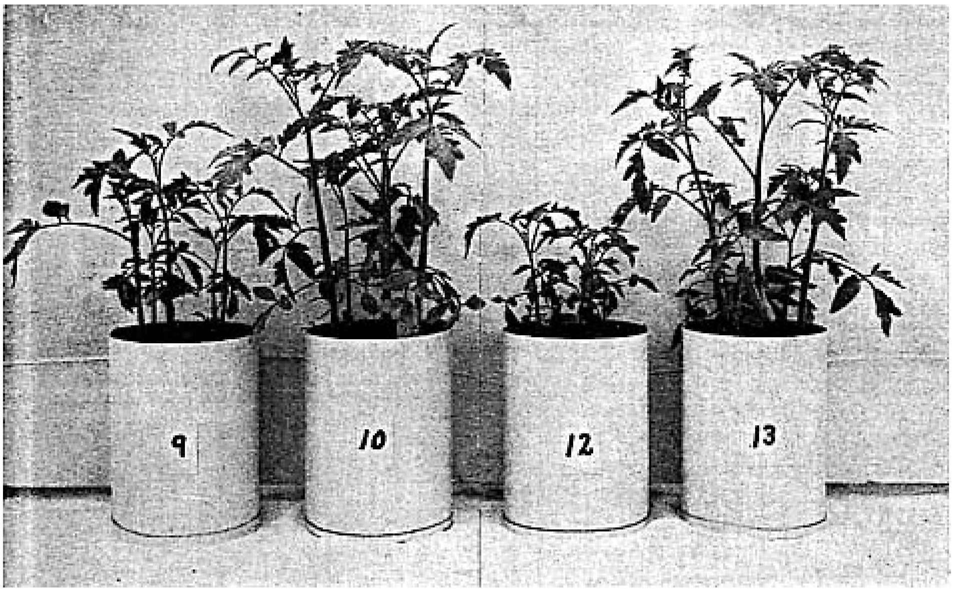

Photo courtesy of Prof. A.B. Medgley,Vermont Agri. Ext.Sta.
Photo shows improved growth resulting from mixing phosphate with manure before applying them to the soil. Manure and phosphate werea pplied saparately to the soil through a depth of 3 inches (pot 9) and 6 inches (pot 12). Manure and phosphate in combination were applied to the same depths, respectively, in pots 10 and 13.

In our disregard of the hastened depletion of the soil organic matter in conjunction with chemical salt fertilizers (especially nitrogen), we have known of the carbon-nitrogen ratio. But we have said nothing about the soil's supply of cabon, much less its ratio to phosphorus, to sulfur and all the others, along with nitrogen, and in the anionic category within the surface horizon of the soil where the activities of fungi (more than the bacteria) consuming the crop residues of wider ratios of the carbon to all these negative nutrient elements prevail, and function in maintaining the enhanced availablities of phosphorus in connection with ample organic matter is the real phosphorus problem of our soil management.

Need research study

Phosphorus transformations within organic residues occur in connection with the higher energy supplies of these residues; with their wider carbon-phosphorus (nitrogen, sulfur, other anions) ratios; and when fungi seem to be the dominating microbial flora decomposing the organic matter to mobilize the phosphorus. Therefore, don't we need more research given to fungi in agriculture than to their therapeutic potentials in antibiotics? If the benzene ring can be split, as has been recently reported; if the use of the aliphatic carbon chain to fix atmospheric nitrogen in the soils is not a vain vision, as recent studies by Brookside Research Laboratories (5) of Ohio attest, can we see how Nature built up nitrogen in our soil by non-legumes as well as by legumes?

Within the last year, it has been reported that the cohabitation of fungi with plant roots in what has been called "mycorrhiza" was demonstrated as symbiotic nitrogen fixation, using radioactive gaseous nitrogen in the soil to find it grown into the plant tissue. (6) From the private laboratory of S. C. Hood, Florida, the better plant growth with mycorrhiza present suggested nitrogen fixation via symbiosis, but such improvement occurred only in the less-disturbed soils, well stocked with recent organic matter, and where commercial fertilizers were not generously applied.

From Mr. Hood's reports (7) the theory seemed inevitable that fusarium, the scarcely visible fungus, associated with gliocladium and trichoderma in mycorrhiza, most commonly was a symbiont on the plant root in soils well-stocked with organic matter, but became the wilt parasite in the vascular, or conducting tissues, of the plants growing on soils of low organic matter, and treated with chemical fertilizers.

Chang, in his laboratory studies of composted organic matter and its transformation of phosphorus from inorganic to organic forms and vice versa, observed rhizopus, pennecillum, aspergilus, trichoderma, and chetomium, the last especially abundant, as early invaders. Later there were the many actinomycetes. (8) These various fungi of decomposition sources seem to cover the wider front in close connection with transformations of organic matter of help, even via nitrogen fixation, as well a recycling both cationic and anionic nutrient elements.

Still ignorant of value

All of this merely points out that our knowledge of agriculture for its nutritional sources for feeding the strata in the biotic pyramid has not yet gone far into the area of life's unknown processes. The value of recycling residues, or the value of residues returned to the soil as organic matter, is still one of extensive ignorance in the area of soil chemistry.

(1) Chang, Sing Chen. "The Transformation of Phosphorus During the Decomposition of Plant Materials." *Soil Science* 48: 85-99, 1939 (No. 2).

(2) Egorov, M.A., Expt.Sta. Record, 26:123 (1911)

(3) Duscheckin, A.I., Expt. Sta.Racord, 27: 216 (1911)

(4) Doryland, C.J.T., "The Influence of Energy Material upon the Relation of Soil Microorganisms to Soluble Plant Food, N.D. Agr. Expt. Sta. *Bul.* 116: 319-401, 1916.

(5) Private Communications by the Author.

(6) Beching, J.H. (Wageningen, Netherlands), "Nitrogen Fixation and Mycorrhiza in Podocarpus Root Nodules," *Plant and Soil* XXIII: 213-226, 1965 (No. 2, October)

(7) Mr. Hood's Reports were discussed in 11 issues of *Let's Live,* closing November, 1964.

(8) Ibid, page 2.

Lets Live Magazine: December, 1966

Balanced Soil Fertility--Better Start of Life

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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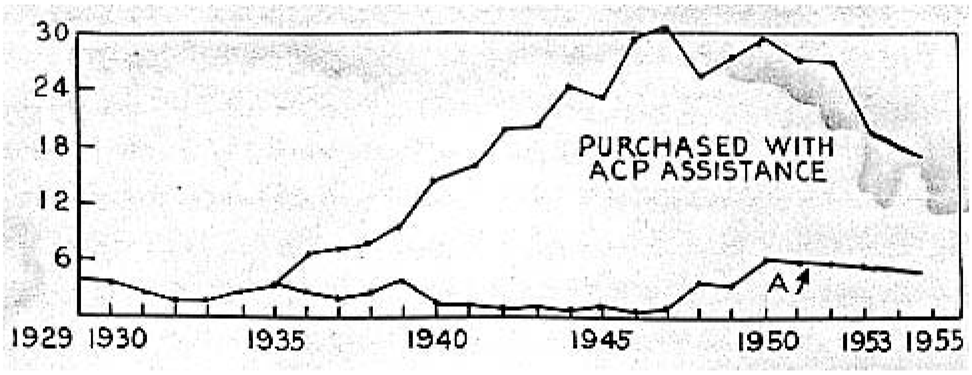
We regret to announce that this article is Dr. Albrecht's final contribution to LET'S LIVE. *He is curtailing his writing in order to devote more time to personal interests. Dr. Albrecht has written for our gardening department since January, 1950, and we wish to express our thanks for his valued articles over the years.--Ed.*

The agricultural use of limestone on soils is still mainly a practice based on empiricism; that is. upon experience or observation alone, without much theory put under scientific test. Since the early 1900's it has been contended that limestone (calcium carbonate) applied to the soil improves crop growth because the carbonate part of the compound lowers the degree of soil acidity. Various kinds of limestone, including that which is wholly calcareous or dolomitic in varied degrees and all those crushed to varying degrees of fineness, have been widely used.

Such stones have not been a costly commodity, for the finer lime-rock fractions have been a by-product of the rock-crushing industry. The limestone fractions have served well for crop improvement, especially on soils in humid climates. This improvement of plant growth has not been widely attributed to the physiological or biochemical effects of calcium (and magnesium) resulting in better balanced soil fertility for both soil microbes and plants.

Cannot support its own research

The neglect of basic research into the biochemical services rendered soil microbes and plants by calcium (and magnesium) may well be expected, since the farmer's income cannot underwrite it. Nor can the stone-crushing industry finance the necessary basic research, since the economics of so limited a manipulation of a naturally plentiful mineral--simply crushing and sieving--does not provide a great enough profit to allow the industry to underwrite research, much less set up its own laboratories.



Even the maximum tonnage of limestone used on soils in 1946-50, under federal ACP subsidy, was not equal to soil needs. Missouri's tonnage figures reached high at that date. In 1955 they decrease by about half, but have risen steadily in the last 10 years.

Beginning with the year 1935 a federal subsidy (AGP assistance) for applying limestone to soils increased the practice (See chart) But even that was by no means enough to add the needed limestone over extensive areas. More recently, since federal subsidy, coupled with state funds, is building concrete highways which are utilizing the finer by-product limestone, the stone-crushing industry has little interest in researching the use of limestone in agriculture. Our farmer's knowledge about research seems to be confined to what salesmen and their literature give him as "scientific" information.

Considered aid for new nations

Yet while one hears little about the application of limestone for calcium and magnesium for plant nutrition, much is still heard about nitrogen, phosphorus and potassium being used on the soil as commercial fertilizers. These are in the limelight for national support of younger nations in their struggle for freedom. Fertilizers carrying mainly these three nutrient elements, and new industries abroad to make only these, seem to be considered the major uplift factor in self-support through increased food production. One hears nothing about balancing fertilizer with the calcium (and magnesium) of limestone. We forget that calcium appears in vertebrate species in the largest amounts of the "ash" elements. We forget also that its deficiency in the soil is the major factor to be considered in classification of soil according to its productivity.

Demonstrated higher milk values

The importance of calcium in balance with phosphorus and potassium in the soil for feed crops was nutritionally demonstrated by Prof. W. B. Nevens, et. al., of the Dairy Department of the University of Illinois, (1) when wheat grain and lespedeza hay (plus salt) were fed to New Zealand white rabbits. This ration grown on the same soil given fertility additions, differing in calcium only, demonstrated forcefully the importance of calcium in the soil. The soil with calcium produced crops which provided high nutrition for nursing mother rabbits and a better start in life for their offspring.

Dr. Nevens took advantage of the Newton Experiment Field of the Agronomy Department and fed the two crops grown in 1945, after fertilizer treatments had been continued since 1912. These treatments consisted of raw rock phosphate (a total of four tons per acre), kainit (2.25 tons per acre), and muriate of potassium (0.5 tons per acre) on each of a pair of plots. Also, on one of these limestone had been added (12 tons per acre) during the 33 years. The wheat grain and the lespedeza hay were grown on the plots with those soil treatments which are designated in this discussion by the symbol "PK" for the phosphorus and potassium treatments, and by "PK + Ca" for those treatments coupled with the limestone on the soil. Also the symbols "0" and "W" will be used to represent plot, animal, feed, or young, associated without and with limestone on the soil, respectively.

Not due to calcium alone

It is significant to note that the lespedeza hay crop "0" consisted of 33% lespedeza plants and 67% weeds. For the "W" hay crop the figures were 71.5% lespedeza and 28.5% weeds. The nitrogen content of the hay from the "0" plot was 1.96%; for the "W" plot it was 2.36%. The wheat grain from the "0" plot had a total nitrogen concentration of 1.53%; that from the "W" plot had 1.94%. The weeds were removed from the hay crop for the feeding trials.

So far. reports on the effects of limestone suggest more than can be readily explained by the uptake of calcium by the plant. The increase in lespedeza plants suggests that more seeds germinated and more seedlings survived because of added calcium in the soil. Dare we say that such results were due to lime as a neutralizer of soil acidity only? If so, limestone was only a "soil conditioner." But it has been shown that calcium applied at the time of seeding increases germination and plant stand (for clustered seeds like the sugar beet, in particular). (2) Calcium mobilizes more phosphorus into the lespedeza crop. (3) It also brings a higher percentage of the exchangeable potassium from the clay colloid into the crop. (4) These results are probably due to the fact that a higher degree of calcium saturation of the soil colloid modifies the root hair membrane to enable it to control nutrient in-go and out-go of the roothair in contact with the soil's organo-inorganic colloids.

Methods of demonstration

The paired feeding technique was used to equalize the feed intakes. By this method, the amount of feed offered the pairs each day is equal to the smallest amount consumed by one of the two pairs on the preceding clay.

Six pairs of litter-mate female white rabbits and two related males were used. After three weeks of preliminary feeding, the females were mated with the males. In most instances, the young were born at the end of the 31st day after conception. As soon as possible after birth, the young were counted and weighed. Usually by the third day after birth the litters were standardized to six young or less. These could not have access to the rations fed to the mothers, hence milk from the mothers was the only feed-source of the young.

Weights of the litters were taken daily until the 46th day after conception, that is, 15 days after birth, when the litters were sacrificed, individually weighed and measured for length. The gastrointestinal contents were removed; the carcasses were weighed, frozen and later ground for chemical analysis as to (a) dry matter, (b) total nitrogen and (c) ash. In all, 46 carcasses were analyzed, an equal number being from group "0" and group "W." Two litters were omitted since one doe on "0" ration died 35 days after conception, hence her litter mate "W" and young were omitted in making up the paired sets of data.

Results affected by calcium

As indicated by the quantity of feed which remained in the feeders each day. the PW + Ca ration was slightly more palatable to the females than the PK ration. Four of the five on the PK ration limited the daily feed intakes of their pair mates on the PK + Ca ration.

Seventeen pairs of matings with the male by females on the two rations resulted in 90 young from 14 females on PK rations, or 6.43 individuals per litter; but in 93 young from 12 females on PK + Ca rations, or 7.75 per litter. Here calcium stands out for its creative power in the mere "handful of dust." While the conception rate of does on the PK + Ca ration was lower (12 out of 17) than for does on the PK ration (14 out of 17), yet the total number of young from the 12 does on the PK + Ca ration exceeded that from the 14, because of the higher fecundity resulting from the PK + Ca ration.

On each of the two rations, there were 23 young nursed by five does. The average daily weights of the litters per dam on the PK + Ca ration were larger than those of litters by dams of their paired mates on the PK ration. The differences in these weights were apparent at a week after birth, or 38 days after conception. These differences increased during the 15 days between birth and sacrifice.

The average body length for the 23 young from mothers on PK rations was 18.5 centimeters. For the 23 young from mothers on PK + Ca rations, the difference was 19.9 centimeters, an increase of 7.5%, due to the calcium factor.

The average weight of the stomach and intestinal contents of the 23 young resulting from PK rations was 12.6 grams. The corresponding weight for the same number of young from PK + Ca rations was 16.8 grams, an increase of 33%.

The chemical contents of the carcasses as (a) dry matter, (b) total nitrogen and (c) ash, all in terms of average weights in grams for PK + Ca rations, were (a) 39.66, (b) 4.42 and (c) 5.36; but for PK rations they were (a) 35.36, (b) 3.86, and (c) 4.79. This shows the larger amount of synthetic or creative organic results from the ash contributions of the soil when it was balanced by calcium, or limestone.

Considering only the percentage compositions as measure of difference between the results from PK + Ca ration and the PK one, the former ration was represented by (a) 24.65%, (b) 2.75% and (c) 3.39%; the latter ration was represented by (a) 25.52%, (b) 2.78% and (c) 3.51%. The calcium in the soil did not modify significantly the percentage concentration of (a) dry matter, (b) total nitrogen or (c) ash of the carcass or body. Its effect was to increase the weight of body tissue, not to change its chemical composition.

Calcium is powerful in building more living tissue or in helping to bring into play other nutritional factors. Accordingly it is valuable for its service in "amending" the soil rather than merely as a fertilizer to increase plant growth.

All of this tells us that we are not yet fully familiar with the biological functions which the soil-borne elements perform in plants and in animals consuming them. Much less do we understand the role of these elements in the mother's function of multiplying the species and sending them forth to be healthy and to populate the earth. We are slow to study the importance of soil fertility to the quality of food, for this is not yet to our economic advantage in the marketplace.

(1) K. A. Kendall, W. B. Nevens and O. R. Overman, "Lactation Response as Limited by Feeds Produced Under Two Systems of Soil Fertilization," *The Journal of Nutrition* 36: 625-637, 1918 (No. 5).

(2) Wm. A. Albrecht, "Calcium as a Factor in Seed Germination," *Jour. Amer. Soc. Agron.* 33: 153-155, 1941.

(3) Wm. A. Albrecht and A. W. Klemme, "Limestone Mobilizes Phosphates into Korean Lcspedeza," *Jour. Amer. Soc. Agron.* 31: 284-286, 1939 (No. 4).

(4) H. E. Hampton and Wm. Albrecht, "Nodulation Modifies Nutrient Intake from Colloidal Clay by Soybeans," *Proc. Soil Sci. Soc. Amer.* 8: 234-237, 1944.