more easily lost to the consumer than any other of the nutrients mentioned in the Table of Recommended Dietary Allowances. The factor of safety applied to thiamine was less than that applied to several other nutrients. It was not supposed to cover cooking losses; yet it does so serve to some extent for that part of the population with requirements which are less than average. Losses from cooking in the case of thiamine and ascorbic acid are far greater than is the case with the other nutrients named in the table. Also loss after eating but before absorption is a factor to be reckoned with and can be expected to be greater in the case of thiamine and ascorbic acid than with the other nutrients. In other words, the need for a factor of safety for thiamine and ascorbic acid is greater than for any other nutrient in the table.

The objections of some scientific workers to the levels set for thiamine, riboflavin and ascorbic acid are based on recent evidence of minimal requirements. This evidence, although representing carefully conducted investigation, all relates to small groups of experimental subjects studied for periods—at the longest six to nine months—representing no more than 1 per cent. of the life span of the human species. Other studies with other subjects point to higher minimal requirements. Also much investigation with lower animals has shown that allowances which seem to be quite adequate to provide for health and vigor for short periods of the life span are quite inadequate to maintain good health for the life span as a whole. Furthermore, good nutrition must demand that the individual shall possess stores of nutrients as reserves to meet emergencies. There has been dispute about whether evidence of diminishing reserves is acceptable as a criterion of requirements. Be that as it may be, the fact remains that persons who possess reserves are better able to withstand not only temporary deprivations but also stresses such as are involved in surgical operations or disease than persons who lack reserves. This has long been well established for protein and iron, and evidence is now at hand that it applies as well, possibly even more acutely, to reserves of vitamins, and especially to the body's store of thiamine, which is relatively rapidly depleted when the intake falls below requirements.

On the other hand, the recent evidence suggests that requirements for thiamine and riboflavin are less closely related to the total calories of the diet or to total expenditure of energy than appeared to be the case when allowances for these vitamins were recommended. The present recommendations of 0.6 mg of thiamine and 0.9 mg of riboflavin for each 1,000 calories are readily defensible when the calorie intake is 2,500 or less. They are less defensible for higher calorie brackets. The great majority of diets for adult men and women provide not less than 2,000 nor more than 3,000 calories. Therefore, it is justifiable to consider setting a single allowance for thiamine (1.5 mg) and one for riboflavin (2.0 mg) for all normal adult men and women, with an accompanying suggestion that, when either the calorie value of the diet or the expenditure of energy is much more than 2,500 or 3,000 calories, additional thiamine and riboflavin may be necessary. A similar simplification may be desirable in the case of niacin.

Revision of the Table of Recommended Dietary Allowances is under consideration at the present time. As was the case before, the recommendations, when they are made, will represent so far as possible the consensus of informed opinion as to the amounts justified by available evidence respecting the range of requirements of normal persons.

PLANT BREEDING IN RELATION TO HUMAN NUTRITION[1]

By Dr. R. J. GARBER

DIRECTOR, U. S. REGIONAL PASTURE RESEARCH LABORATORY, U. S. DEPARTMENT OF AGRICULTURE

A PROMINENT economist[2] has stated recently that after ten years in which to reorganize its agriculture and to readjust its consumption, this nation could feed twice its present population at a higher level of health and of working efficiency than under present conditions. Here is a challenging statement to all agriculturists, regardless of whether they consider the establishment of such a goal as feasible or, perhaps, in one of its implications, even desirable. There can be no serious dissent from the idea of maintaining a level of human nutrition that assures health and working efficiency, but for the continued development of a higher order of civilization it is not unlikely that population should level off at a place well below the complete utilization for food of all that could be produced efficiently.

All available evidence indicates that man lived for a few million years as a savage when practically all his energies, aside from those required from time to time in fighting enemies, were expended in acquiring food and shelter. These he took more or less as nature had provided them or as he could prepare them by primitive means ready at hand. From this plane of

[1] Address of the vice-president and chairman of the Section on Agriculture (O) of the American Association for the Advancement of Science, Cleveland, Ohio, September, 1944.

[2] Jno. D. Black, "Food Enough." The Jaques Cattell Press. 1943.

existence there emerged and developed an agricultural type of civilization. During several thousand years man learned to grow crops and domesticate animals to satisfy his wants but, owing to lack of agricultural knowledge, dependence on hand tools or crude implements, the surplus production was never very great. Partly because of this and partly because of poor transportation facilities large segments of mankind were periodically subjected to famines with all their disastrous consequences. It is only in the last two hundred years that man has acquired the agricultural knowledge and developed the machinery necessary to grow and process the vast surpluses which we in the United States are at present capable of producing.

We associate this modern era with the most remarkable and rapid progress known to man. We take for granted and accept the modern fruits of agriculture and industry, not always realizing that they could not have been developed except for an earlier and contemporaneous development of the physical and biological sciences. Of even greater importance to this and succeeding generations is the fact that continued and further progress is only possible with further scientific knowledge.

When man reached that stage in his agricultural development where not all his energy was required to produce the necessities of life, he began to have more time for thinking and theorizing and later for experimenting to determine the truthfulness of his theorizing. It was in such an environment that the sciences were developed. We should see to it that man never again is compelled to revert to the state of expending all or even the greater part of his energies in merely providing the essential necessities of life. For fear of being misunderstood let me emphasize that this is not necessarily a plea for more leisure, indispensable as that is for health and happiness. It is a plea for work of a kind that assures continued progress in man's struggle for a higher plane of living.

It is hardly necessary to mention to a generation that has experienced two disastrous world wars that social progress has not been all that could be desired. We are not particularly concerned with this problem here except to point out that social progress must go hand in hand with progress in other lines of human endeavor. In fact, if this does not happen we will probably continue trying to settle our differences by wars, each more terrible than its predecessor. I am inclined to agree with E. Parmalee Prentice[3] in his contention that the acquisition of adequate food has been one of mankind's strongest motivating influences in determining his social evolution. Periods of population pressure and consequent sharpened wants without ready means of gratification are associated with discontent, upheavals and tyranny. Two remedies suggest themselves: Reduction of population pressure and production of more food at relatively low cost. The former is not under consideration at the moment except to note that, unless a solution is eventually found to this phase of the problem, we are likely to find ourselves in a "vicious circle," for certainly there is a limit to the quantity and quality of food that may be produced.

What is the plant breeder's possible role in this world drama? He can help meet the food challenge by breeding more productive and more nutritious plants for direct or indirect consumption by man. I shall discuss the question by citing some objectives that already have been attained by breeding and by pointing out some possibilities for the future.

SOME ACCOMPLISHMENTS OF THE PLANT BREEDER

The plant breeder, in common with most other agricultural scientists, has devoted his major efforts toward increasing production at lower cost. While he has not neglected quality particularly in its more general aspects, the breeding of plants to enhance specific nutritive values for man is a relatively new venture and one that has not as yet received a great deal of attention.

Dr. M. A. McCall,[4] of the United States Department of Agriculture, has summarized recently some of the increased yields that have resulted from plant breeding. It is estimated that the increased yield from hybrid corn grown in the United States in 1943 was 669,480,000 bushels or the equivalent to 7,364,280,000 pounds of pork, enough to supply each man, woman and child in the nation with 54 pounds. The new varieties of oats resistant to smut and rust, Vicland, Cedar, Tama, Vikota, Control and Marion, will probably increase average yields at least 7.5 bushels per acre. Based on the estimated acreage occupied during the present year these varieties will result in an increased production of 75,000,000 bushels of valuable feed, or, if consumed directly by man as oatmeal, the equivalent of seven servings for each of the something over two billion persons in the world. Thatcher, a hard red spring wheat released in 1934, rapidly replaced the then existent varieties because of its resistance to stem rust. Unfortunately, Thatcher in common with other commercial varieties grown at that time was susceptible to leaf rust and as a consequence was damaged to some extent during years when this disease was present. In the meantime other new varieties, such as Regent, Rival and Pilot, that were resis-

[3] E. Parmalee Prentice, "Food, War and the Future." Harper and Bros. 1944.

[4] M. A. McCall, "Crop Improvement, a Weapon of War and an Instrument of Peace," an address presented at the annual meeting of the American Society of Agronomy. 1943.

tant to leaf rust as well as stem rust, had been bred. It is estimated that in 1942 when stem rust was present the growing of resistant varieties resulted in the production of 100,000,000 additional bushels of hard red spring wheat in the states of Minnesota, North Dakota and South Dakota. I am advised by Dr. H. K. Hayes, of the Minnesota Agricultural Experiment Station, that promising varieties released for distribution in 1944 include Newthatch from Minnesota and Midas from North Dakota.

The growing of disease resistant varieties not only increases average production but provides crop insurance. For example, in 1935 when stem rust was prevalent, Thatcher wheat on 31 farms located in 16 counties of Minnesota[5] yielded on the average 27.3 bushels per acre compared with 6.5 bushels for Marquis grown in the same fields. To the individual farmer the growing of resistant or susceptible varieties in epidemic years may mean the difference between success and economic disaster. Many other equally impressive examples of increased production of food or feed brought about by the efforts of plant breeders might be mentioned not only among field crops but vegetable and fruit crops as well. Likewise, a lengthy discussion would be required to present the marked advances that have been made in breeding plants for fiber, oil and other uses, but let us turn now to a brief consideration of accomplishments more in line with enhancement of nutritional values of direct use to man.

About fifteen years ago a close physiological association between yellow endosperm and provitamin A was found by the Indiana Agricultural Experiment Station[6] among the segregates from a cross between Reid Yellow Dent and Johnson County White corn. Shortly thereafter the Texas Station[7] demonstrated a quantitative relation between the inheritance of yellow endosperm and provitamin A in dent corn. Since endosperm is triploid, monohybrid inheritance for the dominant yellow color would lead to the following factorial compositions: YYY, YYy, Yyy and yyy. The triple recessive would, of course, be white. It was shown that the endosperms with these genotypes carried on the average 7.5, 5.0, 2.25 and 0.05 units of provitamin A per gram, respectively. It is probable that similar relations exist among yellow and white sweet corns.

The Louisiana Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture has shown that sweet potatoes may be bred for a higher carotene content. Among the F_1 seedlings from crosses between heterozygous parents, selections were made that far exceeded either of the parents in micrograms of carotene per gram of sample. This investigation, together with others that have been reported, indicate that varieties of sweet potatoes may be developed with distinctly higher nutritive values than those now in commercial production.

The U. S. Southeastern Regional Vegetable Breeding Laboratory is actively engaged in breeding certain vegetables for higher ascorbic acid (Vitamin C) content. Dr. B. L. Wade, in charge of the laboratory, has recently informed me that there have been released for general distribution two varieties of cabbage with distinctly higher ascorbic acid content than any commercial varieties now grown in the area. In cooperation with the Florida Agricultural Experiment Station, a variety of snap beans has been developed which possesses, in addition to hardiness and disease resistance, an ascorbic acid content as high if not higher than competing commercial varieties.

Poole, Grimball and Kanapaux[8] have obtained results which show that hereditary factors are more important than season or location in producing ascorbic acid differences among 25 lines of cabbage. Season to season differences were significant in six lines, but in only one was the ascorbic acid content greater in the fall than in the spring. A negative correlation was reported between ascorbic acid concentration and head weight. Wade, Heinze, Kanapaux and Gaetjens[9] have found in certain snap bean crosses transgressive segregation for ascorbic acid content, indicating that two or more complementary hereditary factors are operating to determine ascorbic acid content in this vegetable and that the chances are good for synthesizing a new variety distinctly superior with respect to this substance.

These few examples will serve to show that the plant breeder has already made a beginning in increasing the vitamin content of plant parts used directly for human food. It is, however, just a beginning in a field of activity that should be productive of gratifying results.

Substantial progress has been made in selecting and breeding plants for quality, flavor, sugar content and other characteristics that make the plants more desirable as human food when it was known what was desired by the consuming public. This statement is particularly true if one considers the prodigious effort of both the known and unknown plant breeders that has gone into creating the many highly acceptable vegetables, fruits and nuts we possess to-day. Selec-

[5] H. K. Hayes, E. R. Ausemus, E. C. Stakman, C. H. Bailey, H. K. Wilson, R. H. Bamberg, M. C. Markley, R. F. Crim, M. N. Levine, *Minn. Agr. Expt. Sta. Bul.* 325, 1936.

[6] S. M. Hauge and J. F. Trost, *Jour. Biol. Chem.*, 86: 167–172, 1930.

[7] P. C. Mangelsdorf and G. S. Fraps, SCIENCE, 73: 241–242, 1931.

[8] Chas. F. Poole, Paul C. Grimball and Margaret S. Kanapaux, *Jour. of Agr. Res.*, 68: 325–329, 1944.

[9] B. L. Wade, P. H. Heinze, M. S. Kanapaux and C. F. Gaetjens, "Inheritance of Ascorbic Acid Content of Snap Beans." In press. *Jour. Agr. Res.*

tions made by early man, even though they may have been made more or less unconsciously, were undoubtedly an important determinative factor, but rapid progress was not made until the importance of inheritance was appreciated. A mere listing of accomplishments in this general field would fill pages. There are practically no vegetable, fruit or nut crops in common use to-day that have not been improved in quality, flavor or some other important characteristic by plant breeding. It may be profitable now to consider some possible future activities.

POSSIBLE FUTURE OBJECTIVES OF THE PLANT BREEDER

The plant breeder who is attempting to improve the nutritive value of plants for man is oriented in his efforts by developments in the field of nutrition. We know enough about plants to assert with confidence that every plant character, whether it be morphological or physiological, is conditioned in its expression by two sets of forces, environmental and hereditary. Effective progress of the breeder will depend upon the range of hereditary variation in the plant material. As the nutritionist learns more and more about the plant substances essential to the nutrition of man, the breeder may correspondingly focus his attention on the more important substances and particularly those that show a wide range of hereditary variation.

As has been pointed out already, some progress has been made in breeding plants for increased vitamin content, but this field of endeavor has barely been opened and prospects for the future appear promising indeed. Newman[10] reported consistent differences in thiamin (B_1) content between varieties of spring wheat grown at different locations in the prairie provinces of western Canada. Similar differences have been found between varieties of winter wheat grown in the Great Plains of the United States. These facts suggest that it would be entirely feasible to produce by breeding a wheat with a higher B_1 content than any now commonly grown. Moreover, it may even be possible to change by breeding the relative thiamin content of different parts of the wheat kernel separated in milling. If this could be done it might prove of importance, as present milling processes and the preference of the consuming public for white bread make it difficult to recover the desired amount of B_1 in the flour. Making up this deficiency by "enriching" the flour is now quite generally practiced, but I understand there are some experts in human nutrition who believe that until we know more about the specific functions of the vitamins and their interrelations, it is preferable to "enrich" by natural rather than by artificial means. Be that as it may, when one considers the importance of wheat flour in the human diet, it behooves plant scientists, millers and nutritionists all working together to make this product as wholesome as is possible.

Adams and Smith[11] have recently summarized results that have been obtained at various agricultural experiment stations in studying varietal differences of fruits and vegetables with respect to vitamin content. The Maine Station has shown that onions varied widely with respect to ascorbic acid content, depending on variety. Similarly, workers of the North Carolina Station and the U. S. Department of Agriculture have demonstrated differences with respect to this substance among varieties of blueberries, blackberries, dewberries, raspberries and muscadine grapes. Varieties of peaches may be a poor or good source of carotene (provitamin A), according to the Arkansas Station. Seventeen varieties ranged from 20 to 500 micrograms of carotene per 100 grams of peach or the equivalent of 33 to 833 International Units. Both the carotene and ascorbic acid contents of avocados vary widely, as shown by studies in Florida. These few examples of varietal differences are undoubtedly typical of many that may be found among other fruits and vegetables. While it is true that environment, stage of growth, storage, processing and other factors are all important in determining the vitamin content of plant parts at the time they are consumed by man, the existence of significant hereditary differences with respect to these essential substances is all the assurance the trained plant breeder needs in order to proceed with confidence in his ability to produce new forms superior with respect to vitamin content. *However, this is probably not sufficient justification to launch an extensive breeding program.* The breeder should have the assurance of the nutritionist that an important nutritional need will be met if the proposed breeding program is successful. I think it is fairly obvious that the nutritionist and the plant breeder must work together if the latter's efforts are to be most effective in raising nutritional levels for man.

In considering possibilities for enhancing vitamin content of plants by breeding, the lower forms such as algae and yeast should not be overlooked. In a recent report by Spoehr[12] it is pointed out that because of the rapidity of growth of certain algae supplied with air, light and simple mineral nutrients, they may become an important source of vitamins. Species of algae were found to vary greatly with respect to carotene content. Yeast may become a more important source of B vitamins as well as pro-

10 T. H. Newman, *Jour. Am. Soc. Agron.*, 109–116, 1942.

11 Georgian Adams and Sybil L. Smith, *U.S.D.A. Misc. Pub.* 536. 1944.

12 H. H. Spoehr, "Annual Report of the Chairman of the Division of Plant Biology." (Reprinted from Carnegie Institution of Washington Year Book 42. 1943.)

tein for human food. Burkholder[13] has estimated that the breweries of America could supply annually about 200 million pounds of yeast, half of the dry matter being nutritious protein. This estimate is based on an output of 65 million barrels of beer and on the assumption that the brewers fully utilized their yeast by-products. In connection with a study of some 200 kinds of yeasts with respect to their production of vitamin B_2 Burkholder reported a strain isolated from sour milk that was particularly efficient in the production of riboflavin. Here is a fascinating field for the breeder of the lower plant forms.

Taking up next the mineral constituents in human food we find that in recent years significant advances in our knowledge have been made. Early nutritionists placed major emphasis on proteins, carbohydrates and fats with some attention to water and minerals. Later vitamins came into prominence. As a result of numerous studies in recent years, minerals are now recognized as essential factors in most if not all metabolic processes taking place in the body. The ash of the body is composed primarily of calcium, magnesium, sodium, potassium, phosphorus, sulfur and chlorine. The trace elements known to be essential to animal life are iron, copper, iodine, manganese, cobalt and zinc. With the exception of sodium, chlorine, iodine and cobalt, plants require these same elements and in addition boron. The significance of other trace elements found in the ash of plants is not understood at present. It is known that certain elements, such as selenium, arsenic, lead and fluorine, may be definitely poisonous in relatively low concentrations to both plants and animals. Since practically all man's food except fish and common salt must come directly or indirectly from land plants, the importance of the soil-plant relation becomes obvious. One of the Federal Bankhead-Jones Regional Laboratories is concentrating on a study of the three-way relation between soil, plant and nutrition.

It is well known that the mineral and other constituents of plants reflect within biological limits the mineral and other constituents of the soil on which they grow. The mineral deficiency diseases of animals in certain areas are good examples of how serious may be the consequences of a deficiency in the soil. It is also well known that different species of plants growing under similar conditions may vary widely with respect to their mineral contents, although less is known regarding variation between strains and varieties. Dr. R. R. Robinson, working at the U. S. Regional Pasture Research Laboratory, found significant and consistent differences with respect to calcium and phosphorus in clones of white clover when grown on different soils. It is reasonable to expect that hereditary differences exist among plants in mineral assimilation just as in other respects.

[13] Paul R. Burkholder, *The Yale Scientific Magazine*, 18: No. 1, October, 1943.

The plant breeder undoubtedly could produce strains of plants that would be relatively efficient in extracting certain elements from the soil, and such strains might be useful at least temporarily in controlling some deficiency diseases. It should be recognized, however, that regardless of the success of plant breeding efforts in this direction, eventually, depleted or missing elements in the soil must be supplied by artificial means. On the other hand, the plant breeder is probably on more stable ground to breed for the enhancement of those plant constituents which for their development draw largely on elements that are normally present in abundance such as nitrogen, carbon, oxygen and hydrogen. In this category of plant constituents occur proteins, carbohydrates and fats. Much has already been accomplished along this line, but there is still much to do. As soon as more is learned regarding the function and relative importance of the various fractions of these three food essentials in the diet of man, the breeder will be in a position to select plants for the desired characteristic.

Another approach to improving dietary values both with respect to quantity and quality is by breeding for better animals or better animal products to be consumed by man. Marked progress has already been made, as is evident from the better types of meat, dairy and egg producing animals that have been bred, but much still remains to be done. To point out but one line of work that promises a bright future, breeding for disease resistance may be mentioned. The control or elimination of bovine mastitis would increase greatly milk production or the subjugation of avian leukosis would add enormously to egg production. Breeding may never completely control such diseases, but certainly such an attack would be helpful in solving the problem. Some recent results from swine breeding would appear to justify a further application in animal breeding of methods so successfully used by plant breeders, namely, inbreeding as a means of selection followed by the incorporation of hybrid vigor in the commercial variety. It is not within the scope of this paper to discuss animal breeding, but I think it is fairly obvious, as in the case of plant breeding, that work in this field may be expected to continue to make substantial contributions to raising the nutritional level of mankind.

Just as plants, within certain biological limits, reflect the nature of soils on which they grow so, likewise, animal products reflect to some extent the composition of plants on which the animals feed. This suggests still another approach for the plant breeder, namely, to improve crops from the standpoint of animal nutrition. Forage crop breeding, although recently developed, seems to offer unusual opportunities. Not only is it important to obtain greater yields and yields more uniformly distributed throughout the growing season, but it is likewise important to obtain forage of such a composition as to be highly nutritious to grazing animals and therefore of indirect benefit to man. The most economic feed for cattle, sheep and other farm animals is pasture. To provide adequate nutritious herbage throughout the grazing season is the aim of the breeder working with pasture plants. Breeding for some qualitative characteristics in forage crops will have to await the further development of information regarding the nutritional requirements of man and of the animals that help to sustain him.

CONCLUSION

To conclude, the plant breeder has a very definite responsibility in helping to place man on a higher nutritional plane and hence to help make him a more effective and contented member of society. I like to think of the problem from this angle rather than from the standpoint of producing more food just to feed more people. Plant breeders collectively have played an important role in bringing about the high agricultural production of which we are capable at present. Only a beginning has been made in improving the nutritional qualities of food by plant breeding, but results already obtained indicate a promising future for this field of activity. The nutritional values of various plant constituents are guideposts for the plant breeder and in many instances information is incomplete. He can probably accomplish most by seeking to enhance those plant constituents of a high nutritive value that are largely dependent for their development on elements abundantly present in the plant's environment. A natural corollary is to breed plants for a reduction of constituents that inhibit nutritional value. In the long run the problem of mineral deficiencies in the soil can probably best be solved either by adding the deficient element to the soil or directly to the diet. The breeder already possesses the techniques and methodologies to enhance heritable nutritional factors in plants once those factors have been clearly identified. However, in order to proceed with confidence in the value of the final outcome of his endeavors in this direction he should have the constant guidance and counsel of the nutritionist. They working together must answer the significant question, What will be the real value of enhancing this or that component of the aggregate that constitutes the human diet?

OBITUARY

SAMUEL J. RECORD
1881–1945

FIFTY years ago when Samuel Record was sawing and splitting wood for the family stove he would have objected emphatically had he suspected that he would spend half his life working with that very substance which to a boy was so loathsome. It must be admitted that the tropical woods to whose study he later gave attention were more glamorous if not more practical than the oak and hickory of Indiana.

The abundant and detailed knowledge incorporated in his last and most important publication, "Timbers of the New World," was not acquired easily or quickly but as the result of long and tedious inquiry into the nature and composition of American forests, their various kinds of woods and the practical purposes to which they can be put.

Born at Crawfordsville, Indiana, on March 10, 1881, he attended Wabash College, the alma mater of a substantial number of men eminent in botanical science. He graduated in 1903 and received the M.A. degree in 1906 and an honorary doctorate in sciences in 1930. His interest turned to forestry after his graduation, and he received the degree of Master of Forestry from Yale University in 1905. He gained practical knowledge of forestry problems during several years spent with the U. S. Forest Service. He was the first supervisor of the Arkansas and Ozark national forests, which lie in a region celebrated for the great variety of its trees. He joined the faculty of the Yale School of Forestry in 1910 and was appointed professor of forest products at Yale in 1917. Thereafter he was associated with the university until his death on February 3, 1945, having been in charge of tropical forestry since 1923, and Pinchot professor of forestry and dean of the School of Forestry since 1939.

Professor Record's keen practical interest in woods caused him to visit Guatemala, Honduras, British Honduras and many parts of the United States, to make collections himself and to interest and instruct others in the collection and proper preparation of specimens. He soon learned that many of the older collections of tropical woods in museums were useless since they obviously were not from the trees which they were said to represent. He elevated wood collecting from its former status of guesswork and curio gathering to a truly scientific occupation, insisting that the samples of wood should be accompanied by determinable herbarium specimens and thus be associable with described species of plants. Through an unbelievably large number of correspondents scat-