sites would tend to raise requirements because of malabsorption, the higher mean annual temperature of 25°C (compared to the reference standard of 10°C) would tend to work in the opposite direction. Similarly, estimated requirements are based on actual food intakes, which include a proportion of obese individuals who may be using energy inefficiently. Finally, no attempt was made to adjust for heavier work loads since the prevalence of seasonal unemployment in rural areas (which contain about 80 percent of the population) would probably be more than sufficient to counterbalance such effects.
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14. B. K. Watt and A. Merril, "Composition of foods," *U.S. Dep. Agric. Handb. No. 8* (1963).
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22. Since many of the wells have excess pumping capacity in relation to area irrigated, the power shortage leads to staggered hours and night operation, but not necessarily to reduced irrigation.
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24. The index is of rainfall during the monsoon period, 1 June to 30 September, weighted by the relative importance of each region in terms of food grain production. The correlation with winter crop production may reflect storage—both by humans and in the form of residual soil moisture—as well as precipitation, including snowfall in the highlands, which furnishes part of the river flow in the dry months.
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36. R. W. Cummings, Jr., "Long range agricultural adjustment analysis," unpublished memo (U.S. Agency for International Development, New Delhi, 1969), p. F-71.
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38. The data used were from *Bulletin on Food Statistics* (*6*), the *Draft Fifth Five Year Plan* (*7*), and the U.S. Department of Agriculture Economic Research Service (unattributed Xeroxed sheets).
39. *FAO Production Yearbook 1971* (U.N. Food and Agriculture Organization, Rome, 1971); *FAO Production Yearbook 1972* (U.N. Food and Agriculture Organization, Rome, 1972); D. G. Dalrymple (*37*).
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Agriculture in China

G. F. Sprague

The current ability of the Chinese people to produce enough food for over 800 million people on 11 percent of their total available land is an impressive accomplishment. This has been achieved, in large part, through the expansion and intensification of traditional practices. Water control practice—irrigation, drainage, and land leveling—now include nearly 40 percent of the cultivated area. The intensity of cropping has been greatly increased. China has probably the world's most efficient system for the utilization of human and animal wastes and of crop residues. The development of "backyard" fertilizer plants and the utilization of hybrid corn and kaoliang (sorghum) are new elements contributing to agricultural progress.

Relatively limited data are available either for current agricultural production in the People's Republic of China or for changes in agricultural practices that have developed since the Communist Revolution. The following generalizations are based on observations made by the Plant Studies Delegation on their recent visit, 26 August to 23 September 1974, and on conversations with the many scientists contacted. This trip involved a north-south transect from Canton to Kirin and an east-west transect from Sian to Shanghai (Fig. 1). In all, some 20 research institutes, colleges, or universities and seven communes were visited. Although extensive travel was involved, our view of China remains a very restricted base from which to generalize about agriculture and agricultural developments. It is believed, however, that the observations presented are broadly correct.

The land mass of China is approximately 970 million hectares, exceeding that of the United States (excluding Hawaii and Alaska) by approximately 25 percent. The area of cultivated land in the United States is roughly a third greater than that of China, but area alone provides an inadequate basis for comparison. In the United States a portion of cultivated land remains fallow each year whereas China makes extensive use of multiple cropping. This may involve either a succession of crops grown on the same tract during the growing season, or two or more crops grown in association during a given time period. Neither comparative crop yield nor total production figures are available and, even if they were, interpretation would be difficult because of the difference in production systems. China produces all of the major crops grown within the United States, but the relative importance of individual crops differs widely between the two countries. Furthermore, agri-

The author is in the Department of Agronomy of the College of Agriculture, University of Illinois, Urbana 60801.

culture in the United States is largely conducted under rain-fed conditions whereas China makes extensive use of irrigation.

The main objectives of the Plant Studies Delegation were to establish or extend communications with Chinese scholars in the plant science field and, through such contacts, to facilitate the exchange of germ plasm between the two countries. A secondary but very real interest of the entire group was the current state of Chinese agriculture, the adequacy of their current food supply, and the potential for further increase to meet an expanding population.

Efficiency of agricultural production may be measured either in terms of return per man-hour invested or return per unit area. In the United States the first measure has been adopted with a tremendous expansion of mechanization. The second alternative, followed by the Chinese, is labor-intensive with limited reliance on mechanization.

The main focus in Chinese agriculture, whether at the research or production level, centers on the eight points of Chairman Mao. These are to increase production by improving soil, fertilizer, seed, irrigation, close planting, double cropping, plant protection, and tools. Research not directly and immediately related to improvements in one or more of these points has very low priority. Basic or long-term research receives very limited attention.

Fig. 1. Map of eastern and central China. The delegation traveled from Canton to Kirin and from Sian to Shanghai.

Agricultural Research in China

The Chinese system for both research and extension has many unique features; projections of the adequacy of future food-population balances must recognize the characteristics of the current Chinese system. Since the People's Republic of China was established in 1949 and more recently following the Cultural Revolution, there have been extensive changes in both the educational system and in the organizations responsible for research. The situation is still fluid and the pattern which may eventually emerge is still uncertain. There appears to be a determination to prevent the development of a scientific elitist class. To this end, all scientific societies within the field of agriculture have been disbanded, but all scientists belong to the Association of Agriculture. Furthermore, the individual research institutes have a high degree of independence (self-reliance and self-sufficiency). This has resulted in a decrease in the degree of coordination of activities among institutes concerned with similar agricultural problems. Current arrangements are unlikely to persist in their present form, so the following discussions of research and education may be valid only for a relatively short time.

Agriculturally related basic plant science research is conducted under two separate agencies: Academia Sinica and the Bureau of Science and Technology under the Ministry of Agriculture and Forestry. In earlier years much of this type of research was done under the aegis of Academia Sinica. Since the Cultural Revolution there has been a great deal of decentralization. Some of the institutes remaining under Academia Sinica control were transferred to Shanghai, Nanking, or Tsinghai. Other activities became the responsibility of the Ministry of Agriculture and Forestry, which now has the major responsibilities for agricultural activities. Both agricultural research and education are the responsibility of the Bureau of Science and Technology of this ministry. Agricultural research is conducted by the provincial and municipal branches of the Academy of Science of Agriculture and Forestry and by the colleges of agriculture in cooperation with commune production brigades. At the present time, all agricultural colleges, with the exception of the Northwest Agricultural College at Sian, have been moved to rural areas and are being reestablished. All of these transfers and relocations appear to be designed to achieve a more intimate association of the scientist and the peasant to provide greater impetus to the solution of problems of rural development. At the same time this arrangement furthers the objective of limiting the development of a "white-collar" elitist class. Academia Sinica, the provincial and municipal institutes, and the entire educational system is still in a "struggle, criticize, reform" stage but with a growing degree of stability.

The individual research institutes follow a common organizational pattern. Each is headed by a scientist employed by the Ministry of Agriculture. In addition each institute has a Revolutionary Committee composed of representatives from the Party, administrators, research workers, and peasants. Individual institutes may be highly specialized—for example, dealing only with fruits or soils—or may be more broadly concerned with agriculture of an area. In either event, specialized groups are concerned with improvement, production, and protection aspects. Each institute is associated with a number of commune production brigades of the area. From one-third to one-half of the scientific personnel of an institute may be on assignment to these production brigades, on a rotation basis, for periods of a year or more. In addition, each staff member is required to spend 30 days per year in some public works project.

The research scientists fell into one of three groups with respect to academic training. One group, now near retirement age, received their advanced training abroad, frequently in the United States or Japan. The second group received their advanced training after 1949, usually in Russia. The third group, now constituting the bulk of the scientific staff, received all of their training within the People's Republic of China. This consisted largely of further training under supervision of staff members at one of the universities or agricultural colleges. There appeared to be no organized program for advanced study comparable to the graduate programs in many other countries. This younger group has had only limited exposure to agricultural developments in other areas of the world and has not participated in international cooperative activities such as the international rice or wheat evaluation trials. The current agricultural research in China is more nearly self-generated and self-contained than is true of any other area of the world.

Table 1. Some information on the communes visited, presented verbally at the time of group briefings.

Commune	Location	Arable land (ha)	Brigades	Teams	House-holds	People
Na Yuan	Peking	21,000	16	135	10,000	41,000
Nan Wai Tse	Kungchuling	500		11		
Red Flag*	Sian		5 Star	9	479	2,334
Rainbow Bridge†	Shanghai	1,320	16	121	6,681	26,647
Si Chow Shan	Canton	5,466	20	325	19,000	74,000
Lo Kang	Canton	7,333	14	210	11,000	53,000
Hsing Chiao	Canton	3,466	19	220		58,000

* These figures apply to the brigade only. † The allocation of total commune income was as follows: 11 percent, development; 4 percent, state tax; 3 percent, welfare (health, nurseries, and so forth); 30 percent, production costs; 52 percent, divided among members.

Organization of Communes

The association between the institutes and the production bridges provides the mechanism for the extension of new varieties or production practices. To understand this relationship, it is necessary briefly to outline the organization of the communes. At the lowest organizational level are the production teams. A production team involves the households of one or more villages, whose lands have been pooled and are operated as a single farm unit. Each production team is governed by a revolutionary committee including representatives of households, cadres, and others, who collectively decide how assigned quotas shall be met, what crops will be planted, what management system will be used, and so forth. Income is dependent upon productivity achieved above the assigned quota; all production other than market barter is sold to a State Cooperative Agency. This system of operation encourages limitations on population growth since the area farmed is static. Unless productivity increases proportionately with an increase in manpower, per capita income must fall.

Several production teams may be combined into a production brigade (Table 1). However, some production brigades may become highly specialized, providing certain services for the entire commune. Such services might include seed production, dairying, swine production, and so forth. In other cases a brigade may take on more the characteristics of a small factory, providing repair or production facilities for farm tractors and implements or for the formulation of fungicides and insecticides. Such services generate local income for the purchase of new equipment and for the education and health programs. Encouragement is given to the development of new industries or related enterprises that will provide new sources of income and absorb additional manpower.

The Plant Studies Delegation visited China under the auspices of the Committee on Scholarly Exchanges with the People's Republic of China as guests of the China Association of Agriculture. The members of the U.S. team, with their areas of special interest, are as follows:

Sterling Wortman, Rockefeller Foundation: Party chairman; plant breeding methodology, crop physiology, and international cooperation

John L. Creech, National Arboretum, Washington, D.C.; Vice chairman; plant introduction, germ plasm exchanges, and distribution of woody species

Alexander P. DeAngelis, National Academy of Sciences, Washington, D.C.: Group secretary; Chinese folk literature

Richard L. Bernard, U.S. Regional Soybean Laboratory, Urbana, Illinois; Soybean breeding, production, germ plasm including wild relatives

Norman E. Borlaug, International Research Center for Improvement of Maize and Wheat (CIMMYT), Mexico City: Cereal breeding, germ plasm collection, evaluation, and exchange

Nyle C. Brady, International Rice Research Institute (IRRI), Los Banos, Philippines: Rice breeding, plant nutrition, soils, and international cooperation

Glenn W. Burton, Coastal Plains Experimental Station, Tifton, Georgia: Breeding, genetics, and management of millets, turf grasses, and forages

Jack R. Harlan, Department of Agronomy, University of Illinois, Urbana: Domestication of cereals, crop evolution, genetic resources, and sorghum.

Arthur Kellman, Department of Plant Pathology, University of Wisconsin, Madison: Plant pathology, bacterial diseases of plants, and disease resistance

Philip A. Kuhn, University of Chicago, Chicago, Illinois: Chinese history

Henry A. Munger, Department of Plant Breeding, Cornell University, Ithaca, New York: Vegetable breeding and production, nutritive value of vegetables

G. F. Sprague, Department of Agronomy, University of Illinois, Urbana: Genetics, plant breeding methodology, breeding and production of corn

A much more detailed report of observations of the Plant Studies Delegation will be published by the National Academy of Sciences.

In selected communes at least one production brigade will have responsibility for experimental studies, and it is to such brigades that individual members of the institute staff are assigned. This brigade will evaluate new production practices, new varieties, intercropping patterns, cropping sequences, and so forth. Judgments based on these limited tests are then adopted throughout the commune. Thus, any new developments judged superior by the brigade are immediately adopted on an extensive scale. In the case of corn or sorghum, a decision to use a new hybrid would involve acquisition of the parental lines from the appropriate agency. Maintenance and increase of the parental lines and production of foundation single crosses and of the commercial seed crop are all handled by this brigade. Maintenance and increase of other types of improved varieties are handled in a similar manner.

Stress is laid on "learning from workers, peasants, and soldiers." Any contributions from these groups, however, were difficult to identify or evaluate. Certainly they contributed their accumulated experience on suitability of certain crops, interaction of climatic conditions and planting data, and other subjects. They undoubtedly had some influence directly and indirectly on the types of studies conducted by the institutes. Contributions to varietal improvement or to planting practices, however, appeared to be minimal.

The major portion of China's crop production area is located in the Manchurian Plain (provinces of Heilungkiang, Kirin, and Liaoning) and the drainage and delta areas of the three great river systems (the Yellow, Yangtze, and Pearl) and their tributaries. Approximately 40 million hectares are irrigated, a larger area under irrigation than in any other country of the world. Water availability and control have been a major factor in the shift toward increased productivity through multiple cropping, closer spacings, and increased use of fertilizers. Additional land reclamation projects will continue to receive attention as winter work projects, but figures are not available on the magnitude of additional areas that may be reclaimed. Such additions will be small relative to the area currently under cultivation. Increases in productivity therefore will largely result from a more efficient use of land now under cultivation by means of increasing use of improved varieties; increased fertilization, disease or insect control; or other improved management practices.

Fertilization

China has made more extensive use of human and animal wastes and crop residues than any other country. Green manures are limited in use due to the intense cropping patterns. These plus organic wastes, however, are inadequate to maintain an acceptable yield level in the long run.

The consumption of chemical fertilizers has increased markedly since 1960. In 1973 it was estimated that 4.2 million metric tons of fertilizer were used, of which 2.8 million tons were produced domestically and 1.8 million tons were imported. In the past several years China has been the world's largest importer of nitrogenous fertilizers.

Beginning in 1959, China has built many small widely dispersed factories producing anhydrous ammonia and ammonium bicarbonate from lignite. The use of ammonium bicarbonate as a fertilizer is unique to China. In 1973 China contracted for the installation of ten anhydrous ammonia and urea factories of 1000-ton-per-day capacity. Natural gas or crude oil will provide the energy. When these plants come into production in 1977 and 1978, they will add approximately 2.7 million tons of nutrient nitrogen to the present supply. This will represent a substantial increase over current usage and will permit more nearly optimum rates of nitrogen fertilization for all crops.

Cropping Systems

Cropping patterns are determined by both the length of the growing season and the availability of adequate water. In the south it is customary to grow three grain crops sequentially, while in Kirin and the other northern provinces sequential plantings are replaced by intercropping, two or more crops grown in combination. Considerable variation exists among communes as to both varieties used and the patterns followed.

From Kiangsu province south a common pattern would include a crop of wheat or barley followed by a crop of indica rice followed in turn by a crop of photoperiod-sensitive japonica rice. A second pattern would include barley, cotton, and rice. In the northern part of the province the cropping sequence might include some combination of wheat, sweet potatoes, fallow, and corn.

In Kirin province interplantings of corn and soybeans, corn and wheat, and corn and millet are common. Comparable combinations with sorghum replacing corn are also used. Interplantings involving tall and short sorghum types are also seen but this practice appears uncommon.

In areas where sequential plantings are common the sequences appeared to be highly standardized, whereas diversity best describes the interplanting system. Rice is universally transplanted, thus saving at least a month for each crop. Where water is available, the possibility of transplanting wheat is also receiving some attention.

Sequential plantings are also used extensively in the production of vegetables. Under the most intensive system, as many as 12 vegetable crops may be grown in sequence in a given year. Under such a system all crops are started in seedbeds and transplanted, often with two crops in different stages of development occupying the land at any given time.

Plant Protection

The plant protection system is organized around county units. Each county team involves a staff of four to eight technically trained people who conduct surveys on the prevalence of disease and insect pests. They also maintain observation plots at selected field stations. If conditions develop suggesting the need for timely application of a spray or dust, all communes within the county are notified. Information would also be relayed to adjoining counties.

In addition to the work of the county units, a wheat disease survey is conducted yearly in all provinces where this crop is important. The plant collections and disease survey field records are sent to the regional rust research laboratories, where race identifications are performed and survey findings summarized. These laboratories are located at the Northwestern Agricultural College, Shensi; the Agricultural University of North China, Hopei, and the Agricultural College of Heilungkiang.

The survey information on both disease and insect prevalence and distribution should provide information useful to the breeders in establishing priorities in the development of resistant types. With the exception of rice and wheat, however, relatively little attention has been devoted to seeking and utilizing genetic resistance. Control has largely been achieved through the use of chemicals and rapid turnover of crops, especially vegetables.

Recently the use of DDT and other chlorinated hydrocarbons for insect control has been restricted along with that of organic mercury compounds used for seed treatment. In many crops, seed treatment is regularly practiced. Crop rotation, sanitation, removal and destruction of diseased plants, and the restrictions on movement of infected seed have served to minimize losses from both disease and insect pests.

Rice

Rice is grown on about 34 million hectares with an annual production of approximately 100 to 110 million tons. It is thus China's most important grain crop as measured by either area utilized or total production. It is the predominant crop in southern and southeastern China, about equal to wheat and barley in acreage in the lower Yangtze Valley and less important than maize, wheat, or kaoliang in the north and northeast. Both indica and japonica types are grown, indica types being used for the main crop in the south and southeast.

Rice breeding of varying degrees of sophistication has been under way for many years. Varieties developed in earlier years were relatively tall and weak-strawed. They could respond to the limited quantities of fertilizer supplied through the use of organic wastes but tended to lodge badly with increased levels of nitrogen fertilizers. The development of short-statured indica varieties began in Kwangtung province about 1956. The dwarfing gene is believed to have been supplied by the ai-Tze-Tzang variety from Kwanghsi province. The first variety released from the International Rice Research Institute (IRRI), IR-8, was tested in China in 1968, 2 years after its initial release. Other IRRI varieties were tested subsequently but none of these have met with commercial acceptance. The growth period for these types is too long to suit China's double or triple cropping system. Thus the dwarf-statured rices comprising the major portion of China's current acreage are entirely a product of China's own research effort and represent a very rapid rate of adoption of a new development.

The bulk of the rice crop is transplanted, with five to ten seedlings placed per hill. In some areas mechanical planting and harvesting are being introduced. The primary objective is a saving of time rather than labor. A few days saved at either the planting or harvesting season permits a greater degree of flexibility in the multiple cropping scheme.

Rice takes precedence over other grain crops in fertilizer allocations. The use of night soil and other organic wastes has not been adequate to achieve the level of productivity desired. Imported nitrogen and aqua ammonia irrigation water or ammonium bicarbonate from local plants appears still to provide inadequate nitrogen for maximum yields. Although rice is currently the most productive cereal grown, still further increases may be expected when more adequate nitrogen supplies become available from the new plants under construction.

Diseases have generally not been serious; rice blast (*Pyricularia oryzae*) is the most prevalent, followed by bacterial leaf blight (*Xanthomonas oryzae*) and sheath blight (*Corticum sasakii*). Possibly the multiple cropping scheme with indica grown in the first crop and japonica in the second has provided sufficient genetic diversity to minimize the buildup of the several disease-inciting fungi. Green leafhoppers (*Nephotettix viriscens*), brown plant hoppers (*Nelaparvata lugens*), stem borer (*Chito suppressalis*), shoot maggot (*Hydrallia philippina*), and leaf roller (*Chaphalocrosis medinalis*) are the most important insect pests.

Wheat

Wheat is the second most important crop in China in terms of both area sown and production. Both winter and spring types are grown, with the spring types limited primarily to the three northeastern provinces. Types with winter growth habit constitute 80 to 85 percent of the total wheat acreage. Barley is of some importance as a winter crop in the Yangtze and Yellow river deltas, where winter temperatures are moderate and early ripening is essential to permit two succeeding crops of paddy rice or one each of cotton and rice.

Sizable quantities of early-maturing, short-statured, spring-habit wheats have been purchased from the Mexican government. Certain of these have outyielded the commercially grown improved varieties in Kirin province by 30 percent. Such spring-habit varieties may be fall-sown in areas with mild winters and may thus extend the areas where wheat is grown without adverse effect on multiple cropping potential.

Stem and leaf rust, glume blotch (*Septoria nodorum*), and *Helminthosporium* leaf blight intermittently can cause severe losses. In the winter wheat zone, stripe rust (*Puccinia striaformis*) and powdery mildew are also of importance. At one time covered smuts (*Tilletia foetida, T. caries*) were a cause of loss, but these seed-borne pathogens have largely been controlled through the use of resistant varieties and of seed treatment.

An active spring wheat breeding program is under way at the Kunghuling station (Kirin province). Two generations of breeding material are grown each year; one generation in Kirin and the second as a winter nursery on Hainan Island. Recently, in addition to locally developed segregating populations, a large number of Mexican selections have been evaluated each year. Disease resistance has received considerable attention along with yield and maturity. Some success has been achieved in developing types with rust resistance, but the levels of resistance to scab (*Gibberella*), glume blotch, and *Helminthosporium* leaf blight are still not adequate. With intensification of cropping, these diseases may be expected to become of even greater importance.

Winter wheat breeding is under way at Peking, Wu-Kung, Kiangsu, Nanking, and Shanghai. The general approach is rather similar at the last four stations except for differences required to meet local problems such as winterhardiness or resistance to a particular disease. Short-statured wheats of local development are in commercial production.

The winter wheat program at Peking is devoting considerable effort to the development of new uniform varieties using the doubled gametophyte approach. In one case this is achieved through anther culture and in the second by delayed pollination of *Triticum aestivum* types with *T. durum* pollen. Some success has been achieved with both methods. Unless the frequency of doubled types can be greatly increased, however, it appears that these approaches will not provide adequate opportunity to isolate recombinants with improved yielding ability, growth habit, and disease resistance.

Corn

Corn is grown from southern to northern China. In the south it is a minor component of a multiple cropping scheme. In the north it becomes the primary crop, being grown alone or in combination with other crops, usually wheat or soybeans. In the northeastern provinces corn has only recently replaced sorghum as the primary crop.

Corn was probably introduced into China early in the 16th century by Portuguese traders through the ports of Macao, Fuchow, or Canton or overland through the province of Szechwan. The first introductions were undoubtedly Caribbean tropical flints. Introgression of dent types occurred at a later date, but Caribbean characteristics are still evident, particularly in the south.

In the northeastern provinces it is estimated that 60 to 70 percent of the current acreage is planted with hybrids, primarily double crosses. Because of genetic diversity, lines of U.S. dent corn origin combine well with lines developed in China from local varieties. Many of the hybrids in current use involve crosses between lines of Chinese and U.S. origin. The U.S. lines in most extensive use are of about 1940 vintage and thus do not represent the more recently developed lines which form the backbone of current U.S. hybrids.

The development of inbred lines and their evaluation in hybrid combination is done by the research institutes. The more promising combinations are further tested and observed by the production brigades of the participating communes. It is at this level that decisions are made as to which hybrid is to be produced commercially. When this decision is made, the communes are provided seed of the component lines and from that point on assume full responsibility for inbred maintenance and all intermediate steps in the production of double cross seed. There appears to be only minimal cooperation among communes, each, in accordance with its concept of self-reliance, assuming responsibility for its own seed needs. Cooperation among breeders and the exchange of materials and information appears to be less extensive than was true in the United States at a comparable period of hybrid development. Breeding work is facilitated through use of a winter generation on Hainan Island.

Some selection work for insect and disease resistance is under way. Common smut (*Ustilago zeae*), head smut (*Spacelotheca reiliana*), *Helminthosporium* leaf blights, and stalk rots appear to be the more common diseases. The importance of the several stalk rots is probably minimized by the practice of cutting and removing the stalks from the field at about the stage of physiologic maturity of the grain. The first brood of the European corn borer (*Pyrausta nubilalis*) appeared to be the most common insect pest.

Sorghum and Millets

Sorghum was probably introduced from Africa at an early period. The Chinese words *kaoliang* or *kao shu* mean "tall millet," indicating that sorghum was introduced after millet was a well-established crop. The original African introductions became modified in the new isolated environment, and the type now widely distributed in China (kaoliang) has no exact counterpart in other parts of the world.

The local varieties of sorghum in China exhibit considerable variation in height, grain and glume coloration, and type of inflorescence. Some types have very long panicle branches resembling broomcorn, while others are characterized by fairly compact heads.

The development of improved varieties has concentrated on the taller types with brown seed coloration. The cytoplasmic-genetic male sterile system was introduced from the United States by way of Africa and is now used extensively in the production of hybrids.

Sorghum production reaches its greatest concentration in the northeast provinces where, prior to the development of corn, it was the predominant crop. Even with the advent of hybrid sorghum, preference continues for both tall stature and brown seed coloration. One would assume that the tall types would be less suited to the increasing practice of intercropping. The use of stalk for fencing and other purposes apparently outweighs this possible disadvantage. The use of brown seed types is less easily accounted for. These sorghums tend to be high in tannin, which imparts a bitter taste and, more important, tends to interfere with digestibility and protein absorption. The brown seed trait is the basis for so-called "bird resistance," but birds are not sufficiently plentiful in the main growing areas to cause any real problem.

Diseases of sorghum do not appear to be serious. The most prevalent leaf diseases observed were *Ramulispora sorghi*, *Cercospora* sp., and *Kabatiella zeae*.

Two types of millet are grown: *Setaria italica* and *Panicum miliaceum*. Setaria millet has been an important grain crop in China for more than 6000 years. It was undoubtedly the food grain grown by China's first farmers. The crop may be grown in pure stands or interplanted with corn or other crops. A number of improved varieties have been developed and are in commercial use. Yield of straw has received nearly as much attention as yield of grain; as a result, the types commonly grown may be 1.5 or more meters tall, depending on water and nutrient supply.

Setaria millet is a self-pollinating species, and no serious attempt has been made to find a cytoplasmic-genetic system that would permit the commercial use of hybrids. The F_1 hybrids produced in the course of breeding operations give yield increases of 20 to 40 percent over their parents. Proso millet (*P. miliaceum*) is not grown extensively, its culture being limited to less favorable environments.

Soybeans

China is the center for domestication of soybeans, and the crop is widely grown. In the central and southern areas, soybean culture is largely limited to small fields, gardens, ditch banks, and other waste lands. Only in the northeastern provinces does it become an important field crop. Here it is grown in pure stands or interplanted with other crops, primarily corn or sorghum.

Soybeans are used for food in the green stage, but the more common use is in the manufacture of soy sauce and the various bean curd products. The vines, pods, and waste grain are also used as livestock feeds.

Some soybean breeding work is done at the Genetics Institute in Peking, but the major breeding effort is concentrated in the northeast provinces of Kirin, Heilungkiang, Liaoning, and at the Northwest College of Agriculture in Shensi province. Factors of major importance in the breeding program include yield, oil, resistance to pests, adaptation to intercropping, and strong stems. Winter plantings on Hainan are utilized to hasten the development of new lines. Most of the work follows the conventional system of crossing of selected parents followed by the selection among the subsequent progeny. Some effort is also being devoted to mutation breeding. Both determinate and indeterminate types are grown, but the indeterminate types are more prevalent. Several improved varieties have been developed and are in commercial use. An early variety, Nau-Mao-huang, which permits double cropping with wheat has been developed in Shensi.

The primary insect pest is the pod borer (*Encorma glycinivorella*). Infestation of pods may reach 10 to 20 percent unless the fields are treated with insecticide. Aphids are also common. Three virus diseases are of importance: soybean mosaic, soybean stunt, and bud blight. Bud blight is caused by the tobacco ring spot virus.

Mung beans and cowpeas are grown to a limited extent as grain crops; both are of importance as vegetables.

Vegetables and Fruits

Vegetables constitute a very important component of the Chinese diet and probably provide most of the vitamins A and C and a fair portion of the minerals. In addition to vegetables produced in the home garden, a number of communes specializing in vegetable production are found near every major city. It appeared that most of the traffic near any large city was comprised of trucks, carts, or bicycles hauling vegetable produce to the state cooperative stores.

Fifty or more species of plants are grown as vegetables, many being represented by a large number of varieties. The Nan-yuan commune near Peking produced over 80 varieties of vegetables. In terms of land use the four most important vegetables are tomato, cucumber, Chinese cabbage, and cabbage. Multiple cropping and intercropping reach very high intensities, in extreme situations as many as 12 crops being harvested in a single season.

In spite of the importance of vegetables, relatively little attention has been given to genetic improvement. A very considerable degree of plant-to-plant variability was observed in all crops, quite unlike the uniformity in rice, wheat, or other cereals. Doubtless the species and varietal diversity is a major factor in this apparent difference, neither time nor manpower having been devoted to production of highly uniform types. The apparent diversity may also have a strong environmental component; transplanting shock and overcrowding may be of importance.

Each commune attempts to satisfy its own seed needs. However, some seed exchange is necessary, since certain vegetables are used in provinces where seed production is either hazardous or impossible.

With the large number of vegetable species being grown, a large number of diseases are to be expected and were observed. Work on the isolation of disease-resistant types has not been extensive, and field losses must sometimes reach serious levels.

China produces both temperate and subtropical fruits. The temperate fruits include apple, peach, pear, persimmon, and grape. The subtropical fruits include orange, banana, pineapple, litchi, and the so-called olive (*Canarium albidum*). In season these provide important additions to the diet and some, of course, may be stored for long periods or processed or dried to extend their availability.

Fruit breeding is under way at several institutes of fruit research. Improved varieties of apples, peaches, pears, and others have been isolated from intervarietal crosses and clonally propagated for distribution. Such new developments, however, have not yet come into widespread usage. Several of these improved varieties, because of increased winter-hardiness or other desirable characteristics, appear worthy of evaluation in the United States.

Animal Production

Large numbers of animals, primarily sheep and goats, are produced in the areas of China unsuited to intensive agriculture. In the more densely populated areas, animal production is limited to swine, poultry, a limited number of dairy cattle, and the horses, donkeys, and buffalo needed for power or transportation.

In the region of intensive agriculture, swine are the most important and most common of the farm animals. It is estimated that 250 to 260 million swine were produced in 1972. This represents about fourfold greater production than that in the United States, a nation noted for extensive swine production. If swine production followed the U.S. pattern, China's production would represent a severe drain on the available food supply. In fact, production practices in the two countries differ drastically.

Swine production in the United States depends upon the use of balanced rations, based largely on corn as an energy source, soy meal for protein, and additions of the necessary minerals, vitamins, and antibiotics. Market weights approximate 100 kilograms, usually achieved in 6 months or less.

In China, swine are raised primarily as a private household enterprise, although some are raised in large-production brigade units. In the private sector, swine are valued almost as much for their manure as for their meat. They are fed on waste materials not suitable for human food: vegetable refuse, ground and fermented rice hulls, corn husks, sweet potato and soybean vines, water hyacinths, and so forth. Grains are used to only a limited extent, and this practice is most extensive in the northeastern provinces where fresh vegetable wastes are not available during the long winters. In consequence of the low-concentrate diet, pigs do not reach a minimum weight of 50 kg in less than 8 months to a year.

The numbers of dairy cattle are limited. Dairying is handled by production brigades usually located near the larger cities. Pasture is almost nonexistent and the animals are fed vegetable wastes, grass trimmed from roadsides and ditchbanks, grassy weeds pulled from crop fields, plus a small amount of grain and grain by-products.

Poultry, including chickens and ducks, is handled both as a household enterprise and in more concentrated production brigade units.

Outlook for Expanding Crop Production during the Next Decade

Under any system of agriculture, the potential for further increases in productivity is dependent upon developments in the relevant basic sciences and the efficiency and rapidity with which such new developments are translated into agricultural practices. China's population is probably increasing by at least 15 million people per year. Further increases in productivity will be required to feed this expanding population.

China is currently a rice-exporting nation. Some further increases may be achieved through increased rates of nitrogen fertilization and the development of still better varieties.

New varieties of wheat have been developed, and extensive commercial evaluation of some of the short-statured Mexican wheats is under way. Here again, both varietal development and increased rates of fertilization may be expected to produce further increases in yield.

Major yield increases may be expected for both corn and sorghum. A substantial increase will be achieved through further substitution of hybrids for open-pollinated varieties. The development and use of new and better lines should produce still higher producing hybrids.

Some additional lands will be brought under extensive cultivation with the development of new dams and water delivery systems. Increased protection of watersheds through reforestation and the use of sod-forming grasses will improve both the amount and quality of water available for either irrigation or other uses.

Longer-term increases in productivity would appear to require a greater emphasis on supportive basic research.