Chapter 20

A LOOK TO THE FUTURE

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The preceding chapters have dealt, for the most part, with the current state of the art of a specific topic area. It seems appropriate to have a concluding chapter dealing with future needs of the peanut industry. The authors of this chapter are indebted to the other chapter authors for their input of information about the future needs of their specialty. No attempt has been made to prioritize these needs nor are these needs to be considered all inclusive. Should information be desired on a priority list of research needs for peanuts, the reader is referred to a 1974 report on peanut research needs in the southern region available from the Georgia Experiment Station, Athens, GA. The objective of this chapter is to present an overview of the needs within the peanut industry and in doing so provide possible guidelines for the rising generation of leaders within this multifaceted group.

HISTORY

Cultivated peanuts are thought to have originated somewhere along the eastern front of the Andes in South America. Archeological remains recently found in northwest Argentina should give a better understanding of the antiquity of cultivation in that important evolutionary center. Cytotaxonomic classifications of recent collections of *Arachis* species and characterizations of the patterns of variation for additional landraces of *A. hypogaea* should provide new insight into the probable progenitors of cultivated forms and narrow the geographic zone of origin.

Descriptions and illustrations of the peanut from 18th century sources would make an interesting supplement to information reported in the early history section of this book. As additional manuscripts, particularly those in the archives of the Vatican and in Madrid, become available, further information could be gained concerning the first purposeful introduction of the peanut into Europe. The USA peanut industry from the Civil War to World War I needs the attention of historians.

GENETICS, CYTOGENETICS, AND BREEDING

Peanut breeding and genetics have contributed from 25 to 30% of the peanut yield increases during the past 4 decades. During recent years, emphasis has been placed on germplasm collection and maintenance, estimating quantitative and qualitative gene action, cytologically observing interspecific hybrids, and field testing. Exploitation of the vast germplasm array of both cultivated and the related species of *Arachis* is now necessary. Plant introductions of exotic cultivated peanuts must be screened for disease and insect resistances

and agronomic potential. Identification of genetic mutants, including ones controlling reproductive processes such as male sterility and cytogenetic stocks of aneuploids, and other cytological markers is needed to efficiently manipulate the available germplasm. Furthermore, identification and utilization of genes conditioning morphological, physiological and resistance traits is essential for improving cultivars. Associating these genes with specific chromosomes would also enhance genetic manipulation. Determining linkage relationships of alleles for all genetic traits would also be highly desirable. Several areas of research are needed to fully utilize the wild species of *Arachis*. Understanding cytogenetic relationships among species is far from complete. Progenitor species of cultivated peanuts must be identified to enhance chromosome pairing among interspecific hybrids. Pathways to circumvent incompatibility barriers must be identified, and mechanisms to incorporate favorable alleles from all species into the *A. hypogaea* genome must be discovered. The field of tissue culture and genetics, including in vitro hybridization, is in its infancy, but has enormous potential for plant improvement. Additional novel approaches to manipulate and utilize all the germplasm resources of *Arachis* are required to change the genome to improve yields and quality.

Other things being equal, success from plant breeding will be directly proportional to the volume of material handled. Improved methods of evaluating the available germplasm are needed as well as the development of breeding systems that would more effectively utilize the genetic variability. Development of techniques for doubling the number of plants or hybrids that can be screened and evaluated would be a major breakthrough.

Current short-term goals of peanut breeding programs must consider development of cultivars to fit specific standards of commercial acceptance, such as cultivars for oil or for confectionary uses. In this regard, improved analytical techniques for rapid determination of quality parameters are needed for handling large populations. There should be closer cooperation between processors and breeders. Long-term goals of developing cultivars better suited to stress environments, such as a shortage of water or nutrient elements, or cultivars resistant to soil-borne diseases, e.g., *Aspergillus flavus*, southern blight, pod rot, black hull, and Cylindrocladium black rot requires the use of broad-based populations. In utilizing wider ranges of germplasm, the breeder must have available screening techniques that easily and economically discriminate between resistant and susceptible genotypes.

While more research is needed on transferring genetic traits from the wild diploid species to the cultivated tetraploid species, discoveries in cytogenetics and cell culture accompanied by an adequately supported breeding program, will result in improved peanut cultivars. More information is needed concerning the direct effects of breeding for physiological or morphological traits such as optimum canopy structure, photosynthetic capacity, duration of growth, productivity per unit of water use, and biological nitrogen fixation. Breeding for consistency of yield is often more important than high yield potential. Development of improved cultivars for multiple cropping systems and cultivars with improved nutritional quality are also needed. The genetic modifications of the chemical components of protein, oil, and carbohydrates of peanuts have not been as extensively researched as they have been with other crops, such as maize, soybeans, and wheat.

PRODUCTION

Within the production area, the peanut continues its reputation as the "unpredictable legume" in that peanuts frequently fail to respond to added fertilizer or water. Research discoveries are needed in several areas for peanuts to remain competitive in world food markets.

Increased efficiency in biological nitrogen fixation, if obtainable, would lead to higher yields at lower production costs. New or improved strains of *Rhizobium* species are needed. Better understanding of biological nitrogen fixation may also unravel why peanuts respond poorly to direct fertilization. Research in these areas could lead to significant new discoveries in peanut fertility and nutrition technology.

Plant diseases devastate at least 10% of our peanuts annually. Research efforts to incorporate pest resistance into commercially acceptable peanut cultivars must be accelerated. At the same time, geneticists and plant breeders must concentrate on yield potential since high yields are required for reasonable profits.

The greatest potential impact on peanut production may lie with growth regulators. Many chemical companies are currently evaluating growth regulators which may be useful on peanuts. A needed aspect of regulation in peanut production relates to specific control of the growth phases. A growth regulator that delays or induces flowering could enhance quality by providing a more uniformly mature crop at harvest. Regulation would permit each grower to manage the total peanut crop in an efficient manner. Growth regulators that enhance nitrogen fixation, photosynthesis, flavor, etc., are definite possibilities in the future.

Growers need to improve their overall management practices. The 1981 production year clearly demonstrated the genetic potential for yields in excess of 6,726 kg/ha. Average yields, however, are less than one-half that potential. New agronomic practices must be developed that provide some control of soil moisture and temperature conditions. Peanut growers are rapid adopters of changes in production technology.

MINERAL NUTRITION AND SOIL FERTILITY

The current information available on mineral nutrition, fertilization, and liming requirements of the peanut provides gross estimates of the crop nutrient requirements and proper soil management practices. These requirements and practices should be refined. Perhaps the greatest hindrance to furthering our knowledge of nutrient needs is the lack of information on the importance of particular physiological processes at certain stages in the growth and development of the plant. It is known, for instance, that the calcium requirement is greater for pod fill than flowering, and it is greater for flowering than vegetative growth. Similar relationships may hold for other nutrients. Rate of early growth and flowering can certainly be affected nutritionally, but these reactions are not necessarily beneficial in terms of final seed yield. Isolating processes or stages critical to maximum fruit production would facilitate determining nutrient needs more closely. Soil management practices could then be devised to meet the requirements effectively.

While obstacles to complete understanding may be resolved eventually, certain fertilization practices should be studied immediately. The calcium requirement for pod fill often seems confounded with that for disease control, e.g., adequate calcium appears to allow the plant to resist pod diseases better. The critical levels for phosphorous and potassium by routine soil testing procedures are not well defined, and it is unknown if, or how much, critical levels may increase with increasing yields. Uptake of potassium and magnesium is influenced by the rate applied to the previous crop and to the amounts retained in the subsoil, but these factors are seldom considered in soil test interpretation. Application of gypsum for many years has changed the calcium/aluminum ratio in subsoils and improved conditions for root growth, but the extent and importance of this phenomenon have not been determined. Deficiencies of the micronutrient cations in calcareous soils are also difficult to interpret by soil tests, possibly due to interactions among these nutrients.

The effects of nutrient stress are also known to vary among cultivars, but aside from breeding for iron tolerance, little attention has been paid to this approach to correct problems or to reduce fertilizer inputs. Calcium requirement differs among cultivars and tolerance to low soil calcium levels could be incorporated into commercial cultivars. Some cultivars now in use respond to nitrogen. The need for nitrogen fertilization could and should be eliminated by breeding cultivars that nodulate properly and fix adequate nitrogen when provided the appropriate rhizobia.

IRRIGATION, WATER USE, AND WATER RELATIONS

Due to the limited water resources available, major advances must be made in the areas of irrigation and water use. From the viewpoint of irrigation and crop water use, future energy and water shortages will probably translate into higher costs for these inputs. This, coupled with the absence of price supports, may necessitate a reevaluation of peanut irrigation strategies. Producers will continue to irrigate peanuts to pay for existing or future irrigation systems, but peanuts will likely be one of several crops intensively rotated under fixed irrigation systems.

It may be difficult to improve the biological water use efficiency of peanuts; however, in terms of crop and irrigation management, management decisions may be improved on more efficient use of water. Future research on water management technology may include simulation of peanut growth, yield, and water balance in response to weather, irrigation, cultural practices, pest, and fertility conditions, followed by a budget generator to consider fixed and variable crop production costs for systems, equipment, water, energy, and chemicals. To implement this type of management technology, further research on irrigation management and basic studies of soil-plant-water relations of peanuts is needed. The latter area should be further investigated to develop relationships between crop processes (carbon exchange, transpiration, leaf expansion, and fruit expansion) and water-related parameters of soil, plant, and atmosphere. Careful measurements of soil and plant water potential components will be essential in such basic studies.

Research should continue on physiological traits to improve yield under drought conditions; however, peanuts are considered relatively drought-tolerant and biological water use is primarily controlled by environment. It may be hard to decrease evapotranspiration because of externally imposed evaporative demand. Nevertheless, it may be possible to improve yield by genetic means within the constraints of the same length of season and same water use by features such as partitioning, length of pod filling period, and root extension to stretch water extraction between rains and minimize water loss to deep percolation. *Arachis* appears to have some drought avoidance and tolerance traits such as leaflet folding, leaf thickness, long fruiting period, and deep rooting. These could be further exploited. One report indicated the association of lower water potential with better yielding genotypes under drought. Stomatal closure likely occurs at the same threshold turgor potential as other agronomic plants, but deep rooting may improve water extraction and delay the time to reach the threshold for stomatal closure.

WEED CONTROL

The flow of candidate herbicides, which characterized the period between 1950 and 1975, has slowed to a trickle and eventually may cease. Therefore, it is essential that new systems of weed control be developed which utilize a bare minimum of herbicide intensity and a maximum suppression of weeds from peanut competition. Since production controls and guaranteed price supports seem increasingly untenable, farmers in the future may no longer be able to afford the expensive weed control systems of the past. Weed research therefore should be geared to maximum cost effectiveness. In order to effectively utilize cost-benefit ratios, threshold levels of weeds as related to the yield and quality of peanuts and to net profit per hectare need to be established. No data are available on the effect of marginal or threshold populations of weeds on the quality of peanuts, on harvesting difficulties, or on the weed seed reservoir in the soil.

Concurrently, the capacity of different peanut types and cultivars to suppress weeds completely and to respond to manipulations in crop row spacing must be determined. Data are unavailable on the effectiveness of the herbicide-crop rotation approach when peanuts are subjected to various manipulations in row spacing. It should be noted that wherever the row spacing variable is involved (or any other variable that substantially affects maturity of the peanuts) the latest and best method should be used in determining the digging dates for the different treatments.

New weed problems, especially perennial weeds such as horsenettle (*Solanum carolinense*), will require special attention. New problems may emerge gradually or suddenly, and new or improved methods of weed control will be needed. Sensing devices with the ability to differentiate between weed and crop may be the key to new vistas of weed science research in the future.

PREHARVEST INSECT MANAGEMENT

Currently, chemical pesticides comprise the mainstay of peanut crop protection tactics; yet published research depicts a tremendous potential for the development of multitactic integrated pest management (IPM) strategies sufficiently adaptable to particular ecological areas and pest complexes. The tactics available, other than pesticides, are host resistance, biological control, and cultural control. More research and implementation emphasis is needed with the non-pesticidal tactics. Resistant germplasm has been identified for most key and many occasional pests, yet this tactic is utilized sparingly because resistant germplasm cannot be incorporated into major agronomic cultivars. Biological control, especially importation, has been completely ignored. *Aphis craccivora,* the key pest in Africa, is an excellent candidate for the introduction of natural enemies to lower the mean population density. *A. craccivora* is probably native to the Mediterranean—mid-Asia region which is rich in *A. craccivora* parasite fauna, but there are no known parasites to it in Africa. The polyphagy and mobility of this pest further suggest that IMP tactics should be aimed at population management.

In the developing countries of the world, research must concentrate on non-chemical tactics. As a general rule, non-chemical tactics require less technology for implementation and less capital investment at the user level. Available cash for capital investment (e.g., pesticide and pesticide application equipment) and literacy (e.g., ability to read and comprehend pesticide label directions and limitations) are presently rare commodities in regions of subsistence agriculture.

PEANUT PLANT DISEASES

The direction of future pathological research in peanuts will depend on changes in production technology. Recently, increased use of irrigation in humid regions has greatly enhanced the severity of several diseases including Sclerotinia blight, leafspot, and pod rot. Modifications in tillage practices also changes the overall disease picture. Further understanding of the peanut plant, the pathogen, and the environment is fundamental to advancements in disease control. Emphasis will be on correct pathogen identification and the use of specific pesticides being applied only when needed. Disease control strategies must consider the cost-benefit relationship to all production practices. The economic threshold of each disease must be determined. Growers may find it more profitable not to strive for total disease control with fungicides. Plant pathologists must work closely with peanut breeders to develop agronomically acceptable cultivars resistant to disease-causing organisms. Release of cultivars without full knowledge of their resistance and susceptibility to the major peanut plant pathogens should be avoided.

The two most destructive peanut diseases in Virginia (Sclerotinia blight and Cylindrocladium black rot) were almost unheard of 10 years ago. Rhizoctonia foliage blight became a serious disease problem in Georgia only recently. Thus, an acute awareness of the changing disease picture is necessary to insure proper disease control. The possibility that pathogens may develop resistance to certain pesticides or develop strains that are pathogenic on resistant cultivars makes continued research necessary. Also, more research directed toward the controlling of disease-causing organisms by predator organisms is likely since some success has been reported with biological control. This would minimize pesticide usage and possible chemical pollution. Success in maintaining a continuous supply of nutritious and wholesome peanuts to the world consumer will require a research effort that is multidisciplinary and in which plant pathology will play a major role.

GROWTH PHYSIOLOGY

Certain nutrients such as calcium and boron are essential during seed development for producing high quality peanut seed. Comparatively, high quality peanut seed produce more ethylene during germination and grow at a faster rate than low quality seed. Further research into "quality" and its physiological and biochemical basis is needed. From the practical view, a test to rank seed for "quality" needs to be developed. Such a test would be very useful if it were devised to correlate with estimates of field emergence.

Information is needed on how the peanut plant partitions its photosynthate between vegetative and reproductive growth, particularly in stress environments (water and heat). Peanut plants show a wide range in photosynthetic capacity. This capacity needs to be more clearly defined in terms of plant age, growth conditions (controlled environment and field), and genotype. Peanuts also show a response to photoperiod that requires further study in order to develop cultivars better adapted to photoperiods that occur during the growing season.

Results thus far do not give a clear understanding of temperature requirements for optimum vegetative and reproductive growth. Existing cultivars apparently have temperature optima for each growth stage that do not correspond well with those that occur during the growing season. For example, optimum temperatures for vegetative growth are warmer than those that occur during spring planting; and for reproductive growth, temperatures near optimum are cooler than those during summer when the reproductive phase is dominate. Research to develop cultivars that are more closely adapted to the environments in which they are grown is essential. The disastrous effect of high temperatures on yield in the 1980 growing season supports the need for such research.

The peanut plant—rhizobium bacteria symbiotic association is very sensitive to environmental extremes of drought and heat. Improved peanut crop performance can be achieved by research to identify effective host-plant bacteria symbiosis for nitrogen fixation that is more tolerant of such environments.

From the physiological view, none of these goals will be easy to accomplish, but from the information available and that being developed in ongoing research programs, the future is bright. In some instances, temporary solutions may be found in the use of exogenously applied chemicals. The long term and more satisfactory solution will be the development of cultivars that tolerate biological and environmental stresses to a greater degree than those presently being grown.

HARVESTING, CURING AND ENERGY UTILIZATION

Foremost in the mind of the peanut grower is when to harvest the peanut crop for maximum dollar return. Experimental results have indicated large differences in yield and grade may occur due to a few days difference in digging

date. Techniques for more fully evaluating the current crop condition and predicting on a probability basis the effects of expected weather conditions need increased research emphasis. This will involve the ability to predict both the further development of the crop under expected weather conditions and deterioration, shedding, etc., of the existing crop. Once peanuts are dug and placed in windrows, the optimum division between windrow and artificial drying must be estimated in order to maximize producer profits. This will involve further development of methods for: (1) predicting rate of drying in the windrow, (2) predicting costs for artificial drying, and (3) predicting windrow losses under expected weather conditions.

Energy conservation and cost effectiveness is another area of prime concern. To assist in meeting this challenge, there is a need to develop improved artificial drying procedures that can reduce energy consumptions and/or cost while providing a maximum quality product. This research should include the development of adequate devices for controlling drying conditions so that the process is optimized.

AFLATOXINS AND OTHER MYCOTOXINS IN PEANUTS

Of the mycotoxins, aflatoxins appear to be the most significant threat to peanut production, since *Aspergillus flavus* and *A. parasiticus* are omnipresent in soils and air throughout the world. When environmental conditions are favorable, *A. flavus* may rapidly invade and contaminate peanuts with aflatoxin in the field both before digging and during curing in the windrow. Drought stress has been the factor most frequently correlated with aflatoxin contamination before harvest. Basic research is needed to determine whether the drought stress—high aflatoxin correlation is an effect on the susceptibility of the peanut pod and seed, or on the fungus in making it dominant and more aggressive as a parasite or pathogen by depressing the competing soil microflora, or both. Well-managed irrigation has been successful in preventing drought stress effects, but with the lowering of aquifer levels and water shortages, irrigation is becoming less feasible as a method for preventing preharvest aflatoxin contamination. The use of rotations, fungicides, and soil insecticides has not greatly reduced pod invasion by *A. flavus* and/or aflatoxin contamination in the field or windrow. Breeding for resistance is a sound, long-term approach to control. Basic research is needed to determine the nature and mechanisms of resistance and to develop a method for evaluating peanut genotypes for resistance to *A. flavus* and/or aflatoxin formation in peanut seed. The inversion of peanut pods in the windrow reduces the extent of aflatoxin contamination during curing. However, contaminated peanuts must be diverted from the human food chain by inspection or eliminated by sorting and other techniques during processing. Aflatoxin detoxification or removal by chemical treatments, usually ammonia, is feasible for animal feeds. More research is needed to make detoxification procedures more efficient, less expensive, and suitable for commercial quantities of peanuts.

INSECT CONTROL IN POSTHARVEST PEANUTS

Peanuts are subject to attack by a variety of insect species from time of harvest until they are consumed. The list of insects associated with peanuts is long, but only about a dozen are considered to be major pests. The problem of insect damage takes on increasing importance when it is recognized that these pests are rapidly developing resistance to approved insecticides. In some instances, malathion resistance levels of greater than 200 fold have been found in insects taken from peanut storage facilities. Insect resistance to malathion in recent years has become widespread and severe throughout the peanut production areas, resulting in control failures and substantial economic losses. There is an urgent need to find, develop, and register for use new insecticide replacements for use as residual sprays, aerosols, and peanut protectants. New potential and acceptable insect control procedures may be found in the use of insect pathogens, pheromones and other semiochemicals, parasites, and predators. The value of natural enemies of insect pests of peanuts has been recognized for many years, but their importance in storage and handling facilities has never been quantified. Such new procedures will need to be studied in the peanut marketing channels to demonstrate methodology and to prove their efficacy. Fumigant research for new gaseous chemicals and for new and improved methods and rates of fumigant application is urgently needed. The use of modified atmospheres, that is, carbon dioxide and nitrogen, will need further exploration and exploitation. Finally, there is a need for new and improved insect sampling and detection procedures and their automation for use in pest management programs to delineate treatment schedules and minimize the use of insecticides for controlling insects in peanuts.

GRADING, CLEANING, STORAGE, SHELLING, AND MARKETING

New and improved methods, techniques, and equipment are needed to sample, grade, clean, store, handle, shell, and market peanuts. Improved methods to measure quality are needed so that additional incentives can be provided to growers, handlers, warehousemen, and processors for producing good quality peanuts. Reducing the levels of aflatoxin and foreign material and the energy required to process peanuts will continue to be primary research objectives of the future. Since much of the cost of peanut products results from postharvest operations, considerable research is needed to improve the efficiency of marketing and processing operations.

POSTHARVEST PHYSIOLOGY AND MATURITY METHODOLOGY

Postharvest research needs include the effects of environment on peanut composition, the subsequent effect of the particular composition on raw and roasted flavor and many other factors. Storage of peanuts is a multifaceted high-need area ranging from determining how storage affects particular seed lots to evaluation of climacteric-type phenomena which occur during curing and storage. Physiological change in various types of warehouse, cold, and low oxygen storage need extensive evaluation. The relationship of maturity to "normal" and "variant" physiological processes during curing, storage, and processing and other maturity quality relationships are areas requiring investigation. Determination of these factors or processes denoting physiological maturity (i.e., the point at which peak quality is obtained) is another research need.

In the area of maturity methodology, a need continues to exist for a crop maturity predictor that works adequately under conditions of extreme stress, such as severe drought. Relationship of maturity to environmental factors such as light, moisture, and temperature are yet to be extensively investigated.

COMPOSITION AND QUALITY

The extensive studies of volatile flavor components present in roasted runner and spanish peanuts provide valuable information on the complex nature of peanut flavor. However, they do not tell which of these chemicals contribute more to roasted peanut flavor or which ones correlate best with consumer perception of roasted peanut flavor. Research studies are needed to elucidate these relationships. Another area of research interest is the study of volatile flavor components in raw peanuts and the profile of their changes during and after roasting. It is also possible that changes in volatile components (quantitative or qualitative) occur as a function of the extent of roasting. Special attention should be directed toward the quantification of antinutritional factors present in raw, roasted, and processed peanut products.

POTENTIAL USES OF PEANUTS AND PEANUT COMPONENTS

Peanuts are recognized as a valuable source of protein. Notable advances have occurred in (1) technologies to produce high quality peanut protein products; (2) techniques to extract, fractionate, and characterize the proteins; (3) methodologies to define the physicochemical, functional, and nutritional properties of peanut proteins; and (4) identification of appropriate applications for utilizing peanut proteins in foods. Specific contributions of the basic physicochemical properties of peanut proteins to functionality should be elucidated. New methodologies may need to be developed to establish and clearly define these physical functional relationships. Intrinsic protein properties may need to be modified by physical, chemical, enzymatic, or biological means to maximize their functional and nutritional contributions to food systems in which they are present. In anticipation of changes in economic conditions to improve the competitive position of peanuts as a source of protein, efforts to develop appropriate food applications for their utilization should be expanded.

EXTENSION AND MARKETING

Peanut production has long been a cornerstone to the economy of the southern states and individuals who have grown peanuts. The peanut marketing system is changing from a strictly governmental regulated industry toward a free enterprise system. Sustaining a viable and economically healthy peanut industry will call for a closer coordination of efforts from within the entire industry. Extension programs can and should play a large role in this coordinated effort.

The basic extension challenge is to improve the relevance and speed with which educational information is disseminated, and the effectiveness of decisions made on the basis of this information. Extension educational programs must be up-to-date, accessible, comprehensible, and relevant. The delay between the completion of basic research and its application by producers will receive major emphasis by extension specialists. Highly trained extension specialists will have more input into the development of new technology through research. Production technology will be developed and disseminated by multidisciplinary teams rather than by individuals. Producers will also need to be highly trained in production technologies and have more marketing skills than at present. Through development of peanut production models, coupled with the exciting advances in computer and communications technology, tremendous opportunities exist for extension programs of the future. These concepts will enable complete production systems to be studied. Only those systems which result in higher net profits to the producer and product quality to the consumer will be recommended and used.

Currently, uncertainties and presssures are prevalent within the peanut industry. This has been brought about by escalating production costs coupled with the elimination of restricted acreage and, in time perhaps, support prices. The immmediate years ahead may see a shift toward production being brought more in line with demand. To assure an adequate supply, shellers will likely resort to more contracting for their specific needs with producers (i.e., high quality, size, shell, and seed color). Storage facilities will be available to segregate lots destined for these specialized uses. USA marketing promotion will emphasize peanuts as a highly nutritious food as opposed to peanuts as a snack food.

Conversion Factors for United States and Metric Units

To convert column 1 into column 2, multipy by	Column 1	Column 2	To convert column 2 into column 1, multiply by
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.540
	Area		
0.386	kilometer^2, km^2	mile^2, mi^2	2.590
247.1	kilometer^2, km^2	acre, acre	0.00405
2.471	hectare, ha [0.01 km^2]	acre, acre	0.405
	Volume		
0.00973	meter^3, m^3	acre-inch	102.8
3.532	hectoliter, hl	cubic foot, ft^3	0.2832
2.838	hectoliter, hl	bushel, bu	0.352
1.057	liter	quart (liquid), qt	0.946
	Mass		
1.102	ton (metric)	ton (U.S.)	0.9072
220.5	quintal, q	pound, lb	0.00454
2.205	kilogram, kg	pound, lb	0.454
	Yield or Rate		
0.446	ton (metric)/hectare	ton (U.S.)/acre	2.242
0.892	kg/ha	lb/acre	1.121
0.892	quintal/hectare	hundredweight/acre	1.121
	Pressure		
14.22	kg/cm^2	lb/inch^2, psi	0.0703
14.50	bar	lb/in.^{2}, psi	0.06895
0.9869	bar	atmosphere, atm*	1.103
0.9678	kg/cm^2	atmosphere, atm*	1.033
14.70	atmosphere, atm*	lb/in.^{2}, psi	0.06805
	Temperature		
1.80C + 32	Celsius, C	Fahrenheit, F	0.555(F-32)

*An "atmosphere" may be specified in metirc or U.S. units.