Chapter 5

Breeding of The Cultivated Peanut
(ARACHIS HYPOGAEA L.)

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Introduction

Peanut breeding has had a continuing impact upon the peanut industry. Few of the varieties of even 15 years ago are still acceptable and in wide use today. This chapter presents some of the current objectives and progress of peanut breeding research, along with specific procedures and problems facing today's peanut breeders. The information available on peanut breeding is widely scattered and much of it is published in languages other than English. A large quantity of literature on peanut breeding has been published since 1951 when Gregory *et al.* (79) compiled the chapter "Morphology, genetics, and breeding" in the book, *THE PEANUT — The Unpredictable Legume.* Although a number of the questions concerning the botany and cytogenetics of the peanut have been answered, there are many problems that, if solved, would speed progress in the improvement and maintenance of varieties of this complex species.

The general breeding principles for peanuts are similar to those given in plant breeding textbooks under the section on breeding self-pollinated crops (4, 20, 41, 95).

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The importance of applying genetic information and statistical procedures to plant breeding problems are also dealt with in these texts. They generally do not place much emphasis on the breeding of specific crops, however, and present almost no specific information concerning the breeding of peanuts. The general peanut breeding procedures used in a number of West African countries are described by Gillier and Silvestre (63), in India by Seshadri (167), and in Japan by Takeuchi (177).

General Objectives

The broad objective of peanut breeding is the development of varieties that are currently in demand by the producer, the processor and the consumer. Thus, it is obvious that peanut varietal improvement research must be dynamic and continual. Changing trends in production and utilization have altered the objectives of the peanut breeder. For example, the objectives stated by Hull and Carver in 1936 in Florida were, "a variety that is of the best market type and also well suited to hogging off. Such a variety must be high yielding with the smooth, attractive appearance and sweet flavor of Spanish peanuts and the non-sprouting tendency of runner peanuts. It is also desired to obtain a Jumbo peanut that fills well and there is some need for a hay type" (107). The current program stresses the development of varieties more suitable to mechanization and with improved processing, flavor and end-use product qualities (147). Some of the highest yielding lines were not released to growers because they possessed features undesirable to the processor or consumer market.

Bailey (12) listed the following among the principal attributes sought in improved varieties: "higher yield potential; uniform maturity of seed; resistance to insects, diseases, and toxin-producing molds; resistance to visible and concealed damage of microbiological origin; adaptation to mechanical harvesting; superior flavor, texture, and keeping quality; improved shelling and processing quality; enhanced nutritional value; and greater consumer appeal".

Sources of Genetic Variation

Accessibility of the needed genetic variability is a prerequisite to varietal improvement. Gregory (73) emphasized that there are "only three basic sources upon which a plant breeder may draw for genetic material in the breeding of peanuts. These are: 1) the hereditary differences among varieties of cultivated peanuts; 2) the differences that may be created artificially by the use of mutagens; and 3) differences which occur among the wild relatives of the cultivated species". Dr. R. O. Hammons, in the chapter in this book entitled "Genetics of *Arachis hypogaea*" describes much of the genetic variability available to peanut breeders especially in the areas of disease and insect resistance.

Introductions

In 1968 Bailey (12) estimated that 75 to 80 percent of the peanuts grown in the United States were derived wholly or in part from peanuts introduced from foreign countries, and that this proportion would probably increase in the future. Since 1936 the U. S. Department of Agriculture has introduced more than 3,000 accessions of cultivated peanuts from the various peanut growing countries of the world and has sent five exploration expeditions into South America, their center of origin, (114) for collections of wild and cultivated peanuts. The procedures and problems involved in the propagation, evaluation and distribution of these introduced materials to in-

terested workers in the field of peanut breeding was reviewed by Gregory (73) and Bailey (11). Introductions are first carefully screened, well away from the commercial peanut producing areas, for possible seed-borne diseases which might be new to this country.

Interested breeders in the various states screen the introductions of their choice further for suitability in their respective programs. Frequently these latter evaluations are conducted in considerable detail and the results made available to other workers. This was the case for the evaluation of 29 Spanish plant introductions by Tripp (181) in Oklahoma. Tripp's evaluation included the organoleptic quality of peanut butter from each of the introductions in addition to a number of agronomic, physical and chemical properties.

In addition to the introductions available from the U.S.D.A. there has always been a free interchange of breeding materials between the peanut breeders of the various state experiment stations and the U.S.D.A.

Natural hybrids

The occurrence of natural hybrids in the cultivated peanut was reported as early as 1910 by van der Stok (184), and plants suspected of having originated by natural crosses are not infrequent in most breeding nurseries (83, 117). However, the cultivated peanut generally has been classified essentially as a self-pollinated species (79). In recent years, however, numerous studies of natural outcrossing were conducted using a dominant leaf marker called, "Krinkle" (83). Using this dominant marker, Hammons (83) found rates of outcrossing in Georgia varied between 0.73% and 2.56%. Culp *et al.* (37) obtained much lower rates in Virginia, averaging from 0.09% to 0.27% depending on the season and variety. More recently Gibbons and Tattersfield (62) reported from none to 1.67% outcrossing in Malawi, Rhodesia and Zambia. They attributed the low rates of outcrossing in their experiments to low bee activity. Hammons (82), Hammons and Leuck (90) and Leuck and Hammons (121) found that various wild bee species were the principal vectors of natural cross-pollination in the peanut and that the amount of natural crossing was associated with the production of atypical flowers that varied considerably for different varieties (121). The percentages of outcrossing in peanuts are comparable with other crops that are considered as essentially self-pollinated species.

Although natural outcrossing creates problems in trying to maintain the genetic purity of varieties, it does provide a source of genetic variability that occasionally can be utilized. Van der Stok (185) in 1923 stated that natural hybridization had been used to develop new peanut varieties in Buitenzorg, Java. Hammons (84) discussed the utilization of natural crosses as a new genetic technique he termed "pedigreed natural crossing". This technique permits the production of larger numbers of F_1 hybrids than is possible with the same expenditure of time using manual procedures. The chief disadvantage of this technique is that the marker stock must have in its genetic makeup those characteristics desirable for variety improvement. Hammons (84) indicated that "maximum utility of the pedigreed natural crossing technique should be expected when this method is employed in conjunction with, but not in replacement of the conventional procedure".

Mutations

Mutations have undoubtedly been occurring in the cultivated peanut ever since its origin. Among the more common mutations observed have been concerned with

seed coat color, chlorophyll deficiences, and dwarfism. Van der Stok (185) in 1923 observed the appearance of blue seed on two occasions, and could not determine its source except through spontaneous mutation.

Husted (109) believed the cultivated peanut to be at least partially allopolyploid, and also noted that the aberrant chromosome configurations did not occur in equal frequency in the different varieties studied. Gustafsson and Gadd (81), reporting the evidence concerning the origin of the species in 1965, stated that multivalent as well as trivalent and univalent formations in meiosis greatly influence population dynamics and mutation frequency. The multivalent formations, with crossing over in partially homologous segments, as well as other meiotic disturbances, may give rise to some hereditary instability, of different intensities in different varieties (81). Most mutations are recessive and, therefore, do not generally show their effect in the presence of a normal duplicate gene. A few naturally occurring dominant mutations have been isolated, such as the Krinkle leaf character reported by Hammons (83).

For over 20 years North Carolina scientists have been exploring the use of irradiation for inducing favorable mutations in peanuts. Their studies show that this can be a good means of obtaining useful genetic diversity (69). Radiation-induced mutants were found with both increased and decreased resistance to leafspot disease (36). Gregory (67) found the genetic variance for yield among the radiated progenies of the NC 2 variety to be four times that measured in the control progenies. Emery *et al.* (49) concluded that even though induced macro-mutations are generally deleterious, the diversified genetic background created by irradiation could be a valuable source of germplasm that could be stabilized in normal-appearing phenotypes.

Ashri and Goldin (6) in Israel and Avadhani *et al.* (9) in India found that diethyl sulfate was an efficient mutagen in peanuts and that most of the mutations obtained were monogenic and recessive. They found varietal differences in mutation rate and in physiological sensitivity and concluded that very few mutants may be of value in peanut improvement. Avadhani *et al.* (9) obtained mostly deleterious mutants but also obtained increases in the shelling percentage, oil content, and weight of kernels.

Interspecific crosses

Although a large amount of natural variability exists in the species *Arachis hypogaea,* resistance to a number of diseases, such as the *Cercospora* leafspots and to certain adverse climatic factors, has not been found. Resistance to these factors does exist, however, in some of the wild species of *Arachis.* Hull and Carver (108) in 1937 attempted crossing four different wild species with cultivated varieties. They obtained 25 pods from these crosses, using wild species as the male parent, but all the seed aborted when they were about 1.6 mm long and the pods from ½ to ¾ normal size. Gregory's (172) attempts in the mid-forties were similarly unsuccessful. In 1956 Johansen and Smith (112) attempted crosses between the tetraploid, cultivated peanut ($2n = 40$) and the diploid wild species *Arachis diogoi* ($2n = 20$) and found that fertilization was followed by embryo abortion and formation of empty pods.

Although most interspecific crosses in the genus *Arachis* have failed because of embryo abortion, a few successful crosses have been made (78, 171, 172). The hybrids from these crosses were sterile; but optimism was expressed by Smartt (170) that some of the sterility obstacles may be overcome by artificially doubling the chromosome number. Martin (136) conducted research on methods of *in vitro* embryo culture in attempting to overcome some of the interspecific hybridization difficulties. He has

been able to produce viable seedlings from ovules measuring 0.3 mm. Kubicek and Banks (116) postulated that the cause for these abortions is due, to a large extent, to irregular endosperm behavior and are presently studying this aspect of the problem.

Species hybridization by Gregory and Gregory (78) produced sterility, necrosis, dwarfism and other extreme phenotypic expressions that resulted in most of their primary species hybrids being useless. They concluded that something less than whole genome substitution is required in species breeding of peanuts.

A few species of *Arachis* are freely cross compatible with the cultivated species, *A. hypogaea. Arachis monticola,* a wild annual species, has the same chromosome number, a similar karotype and is completely interfertile with *A. hypogaea.* Because of this close relationship, *A. monticola* may be regarded more as a sub-species of *A. hypogaea* rather than a perfectly distinct species (170). The genetic variability in progeny resulting from crosses of *Arachis hypogaea* x *A. monticola* has been reported by Raman and Sree Rangasamy (162). The new 'Spancross' variety released by the Georgia Agricultural Experiment Station in 1970 was developed by continuous selection for Spanish type in progenies from a cross of *Arachis hypogaea* and *A. monticola* (85). Ramanathan *et al.* (163) obtained genetic improvement in the characters of the hybrids over those of the parental varieties in crosses between *Arachis hypogaea* and *A. glabrata* ($2n = 40$). They studied the number of pods per plant, shelling outturn, 100-pod weight and 100-kernel weight.

Induction of polyploids

Quader (159) and Lal and Mehrotra (118) found increased variability in a number of plant and seed characteristics by doubling the chromosome number of different varieties of the cultivated peanut. The autotetraploid ($4n = 80$) Spanish lines had increased pod and seed size. Lal and Mehrotra (118) found that two varieties, one spreading and one bunch, reacted quite differently to the colchicine treatments. They found enlarged foliage characters in the treated plants but a decreased number of pods and seeds per pod, while the weight of the dry pods and the pod length were increased. Raman and Kesavan, as cited by Gustafsson and Gadd (81), indicated that induced autoploidy in a species like *Arachis hypogaea* with high chromosome number does not seem to be promising.

Breeding Systems

Introduction and selection

In general, commercial varieties that originated from introductions were developed either by directly increasing the introduced stock or from mass or pure line selections made from the introductions. In mass selection a sufficient number of elite plants are composited from the introduction so that when the seed from these plants is bulked there is a sufficient quantity for comparisons with the original introduction or another local variety in yield tests the following year. The mass selection method is of more value when the introduction is variable primarily for simply inherited traits which are highly heritable. For less heritable traits, such as yield and quality, the pure-line method is more effective.

In the pure-line selection the individual plants selected are grown in separate rows the following year, usually with a check row of the local variety included between each ten or twenty rows of the selections. The yield from the superior rows may be bulked or further plant selections made. Replicated yield trials and/or seed multiplica-

tion plots are grown in the third year. Thus, the pure-line selection method requires a year or two longer than the mass selection method to produce an improved variety.

The first efforts at peanut variety improvement began early in this century with selections made from within different lots of farmers peanuts. Six of the seven varieties of peanuts described by Higgins and Bailey (99) in 1955 were obtained in this way. These varieties are 'G.F.A. Spanish', 'Dixie Spanish', 'Southeastern Runner 56-15', 'Virginia Bunch 67', 'Virginia Bunch G2' and 'Virginia Runner G26'. Only one of these varieties, Virginia Bunch 67, is still being grown to a limited extent in the southeast (87). Another of these varieties, Southeastern Runner 56-15 is a good genetic source of resistance to damage from the fall armyworm, *Spodoptera frugiperda* (88, 122, 123).

Other peanut varieties released in the United States that were developed by pure-line selection are the Spanish varieties 'Argentine', released to growers by the Oklahoma Experiment Station in 1951 (138) and 'Comet' released in 1971 (J. S Kirby, personal communication), 'Spantex' released by the Texas Agricultural Experiment Station in 1950 (138 and C. E. Simpson, personal communication). Virginia type peanut varieties developed by this method are 'Virginia 56R' distributed to Virginia peanut growers in 1957 (1) and 'Virginia 61R', released to growers in Virginia in 1962 (2). Hsi and Finker (104) recently released a Valencia variety 'New Mexico Valencia A' that was developed by pure-line selection in the 'New Mexico Valencia' variety, a descendant of the 'Tennessee Red' variety.

In a number of countries where peanut improvement programs are of fairly recent origin, the major part of the current program centers around the collection and evaluation of a wide range of materials. In addition to strains from other countries, peanut breeders in Rhodesia collected 2,300 different specimens of peanuts from within their own country (178). Natal Common (Spanish) types were found mainly in the low rainfall areas, Valencias in the medium rainfall areas and in the high rainfall areas where the weather is rather cool in summer. The late maturing (Virginia) types were found mainly in the warm wet areas (178). The variety 'Makulu Red' arose as a sport in the variegated red and white seeded 'Mani Pintar' variety (40) and 'Valencia R1', released in 1967, was the first improved strain of Valencia obtained from their variety improvement work (179).

Considering the substantial number of improved varieties released by the mass and pure-line systems of breeding in old varieties one can conclude that these systems certainly have some merit under certain circumstances in peanut variety improvement. A number of investigators, however, feel that the above procedures are inadequate to fulfill their objectives.

Stokes and Hull (174) in 1930 reported average yield gains of 22.8% of Spanish selections over the unselected check strain. However, no varieties were developed or released in Florida by strictly mass or line selection methods. In 1936, Hull and Carver (107) concluded that their objectives in an improved peanut variety could hardly be obtained except by hybridization. Umen (183) in 1933 regarded hybridization as essential, and Gregory, *et al.* (79) indicated that data from the North Carolina Agricultural Experiment Station supported the necessity of hybridization for the success of practical peanut breeding. Farrior (52) attempted without success to improve farmers stock Virginia-type peanuts by mass selection.

Hybridization

It is the opinion of the author that the possibilities for peanut improvement in

the United States by introduction and selection without hybridization has been practically exhausted. Hybridization provides the vehicle through which the breeder can combine the good features from parental stocks into a new variety. The merit of this system for breeding peanuts is attested to by the large numbers of varieties that have had their origin from hybridization.

Peanut varietal improvement by hybridization and pedigree selection among and within hybrid lines was begun at the Florida Station in 1928, and all of the varieties released by the Florida Experiment Station have had their origin in controlled crosses. The varieties released by the Florida Station were 'Dixie Runner' in 1943 (29), 'Early Runner' in 1952 (30), 'Florispan' in 1953 (25), 'Florigiant' in 1961 (27) and 'Florunner' in 1969 (150). The variety 'Georgia 119-20' was developed through hybridizations of the Southeastern Runner with large-seeded strains of Virginia Runner and was released to Georgia growers in 1952 (89). Georgia 119-20 was grown on a substantial portion of the Virginia type peanut acreage in Georgia in the late 1950's but was replaced by other Virginia varieties in the 1960's. Georgia 119-20 was introduced into Senegal where it was grown on about 6,000 ha. with 900 ha. of this in controlled seed multiplication in 1970 (89). Virginia 72R was released by the Virginia Agricultural Experiment Station in 1971 as a variety particularly adapted to the coarser-textured soils of Virginia and North Carolina (3).

NC 2, released by the North Carolina Agricultural Experiment Station in 1952, was essentially the only commercial variety grown in North Carolina for the 10 years 1952-1962 (77). The more recent North Carolina releases NC 5 in 1964 (48) NC 17 in 1969 (46) were also developed by hybridization.

The Starr peanut variety released by the Texas Agricultural Experiment Station in 1961 was the first Spanish variety in the United States developed by hybridization (119). The Starr variety is currently the most widely grown Spanish peanut in the United States. However, two recent (1970) releases, Tifspan (86) and Spancross (85) are also the products of hybridization, will likely change this picture in the next few years.

Success in breeding through hybridization depends on the availability of transferable genetic variation and will be more likely if the objectives are clearly designated, the correct parents are selected, and if the hybrid populations are managed properly and selection successful.

Selection of parents

There are many unknowns in determining the proper parents to use for a particular objective. Because crosses are difficult to make and the subsequent evaluations very time consuming, the breeder can only make a few each year. Thus, he must use all of the information available to him and give considerable thought to his decision. He will learn in the early generations how effective his choice of parents was. If his choice was good he will generally have an abundance of superior material from which to make his selections.

Different viewpoints exist as to the methods to use in choosing the parents for a cross. If, as is often the case, the contemplated variety is planned as a replacement for one already established, then as is pointed out by Briggs and Knowles (20), the logical choice as one parent would be the existing variety. The weaknesses or factors limiting the productivity and utilization of existing varieties are generally well known. The second parent must complement the first for the charcter under improvement and should not be at serious fault in other characteristics.

If the objective is to improve yield, one approach is to select high yielding lines from the same area of adaptation, since the two parents are more likely to have many favorable genes governing the character. A majority of the crosses made in Florida in recent years have been between lines extracted from earlier crosses. Such lines have generally made better parents than older varieties and fewer off-type forms occur in their hybrid progenies. The Florunner variety released in 1969 and currently a popular runner-type variety in the United States was developed from this type of a cross (150). Another approach is to choose the second parent from widely different material or from a totally different region of adaptation.

Experience gained during the first thirty years of crossing peanuts in Florida and reported by Carver (26) in 1959 revealed that wide differences exist among parents in their ability to transmit desired characters. Carver reported that during this period the best parents found were White Spanish and Virginia Jumbo Runner. The varieties which made poor parents because of low seed yields, poor plant type, or poor seed quality in their progenies were Tennessee Red and White Valencia, North Carolina Runner, Rasteiro and Nambyquarae. Varieties which were intermediate in value as parents were Pearl Spanish, Georgia Bunch, and Virginia Bunch.

The diallel cross has been used as a method of evaluating varieties as parents in crosses. In the diallel cross, the varieties under consideration are crossed in all possible combinations. The data in F_1 and F_2 from all crosses with one variety are averaged and compared with others. The problem with this procedure is the large amount of work involved. With 15 parents, for example, 105 crosses would need to be made. Recently Parker *et al.* (156) crossed six lines of cultivated peanuts in all possible combinations to determine the feasibility of identifying superior parents by testing F_1 hybrids grown under controlled conditions, and Wynne *et al.* (190) conducted the same test under field conditions. They obtained more heterosis for vegetative plant characters from the Valencia x Virginia crosses than from the Virginia x Spanish or Valencia x Spanish crosses, and postulated that in their crosses the parental lines of Valencia and Virginia types were the most genetically divergent (156). In the field the Valencia x Spanish-type crosses gave the greatest heterosis for yield and fruit characters (190). A comparison of the field results with those obtained in a controlled environment (phytotron) showed that the latter may have only limited use in predicting field performance of hybrid progeny.

Making the cross

Although the peanut is difficult to hybridize, making the cross is the least time consuming phase of the breeding program. Van der Stok (184) in Java was probably the first to artificially hybridize peanuts in 1910 and Stokes and Hull (174) in the late 1920's were first in the United States. The basic technique for crossing peanuts has not been greatly changed over the years, but numerous aids and modifications have been reported (10, 18, 19, 151, 157, 168, 183). The following is a brief description of the procedure followed in Florida (151) and is quite similar to procedures used in other states and countries.

Seed of lines to used in crosses are planted in four-gallon stone containers on greenhouse benches during the late winter or early spring season. The lower temperatures common during the winter season and/or cloudy days result in erratic flowering and retarded floral development. Flower buds appear above the leaf axils during the afternoon on warm bright days, and emasculations can be accomplished without difficulty beginning as early as 5 P.M. On cloudy or rainy days, fewer flower buds

develop, and their growth is usually retarded to the extent that emasculations are easier to accomplish if delayed until 9 or 10 P.M.

The plants to be involved in the various crosses do not generally begin to flower at the same time, in which case, the flowers are removed daily until the majority of the plants are flowering. When pollen necessary for a cross is available, the flower bud on the maternal parent is emasculated by first removing the lower lip of the calyx and then the wing and keel petals to expose the anthers and stigma. After the anthers are removed, the standard usually returns to its original position curled over the stigma. One end of a small string is then attached to the calyx tube and the other end is draped over the edge of the container. No attempt is made to protect the emasculated flowers. In cases where emasculated flowers were left without hand pollination there has been no evidence of fertilization. Insects, however, are controlled by screens and insecticides. Watering and nutrient applications, when needed, are made in the evening immediately after the emasculations have been made.

On the morning of the day following emasculation, the standards are usually expanded and the stigmas exposed. Thus, application of the pollen is possible in many cases without handling the flower. Pollinations are accomplished between 7 A.M and 10 A.M. by removing a healthy flower from the male parent plant, squeezing pollen onto forceps, and transferring the pollen by means of the forceps to the stigma of the emasculated flower. When changing from one pollen source to another, the forceps and fingers of the operator are dipped in an alcohol solution to reduce the possibility of pollen contamination. The plants and flowers must be handled very carefully following pollination as the pollen grains are easily dislodged from the stigma. To provide shade and a more natural environment for the germination and subsequent growth of the pollen, a paper towel, approximately 12 x 12 cm in size, is dampened with water and placed carefully over the flower, without touching the stigma, immediately after it is pollinated.

In India, Sharma (168) found that by placing a polyethylene tube cover, punched with a few holes to allow aeration, over the female plants after pollinating resulted in better pollen germination and ultimate fertilization, without the necessity of covering the pollinated stigma. He reported having little success when he covered the pollinated stigma with the keel, probably because the pollen was dislodged from the stigma in the process. After the pollinations are completed, any unpollinated flowers remaining are removed by breaking the hypanthium near the base with large forceps by 10 A.M.

If fertilization was successful the aerial peg will usually be visible 7 to 10 days after pollination, rarely as long as 15 days. It is safe to assume that there has been no fertilization if the aerial peg is not visible after 20 days. Hassan and Srivastava (94) obtained visible pegs in 3 to 7 days in bunch varieties and 4 to 6 days in the spreading varieties. The developing pegs with withered flowers and strings still attached are identified by means of a color-coded wire which is looped around the peg before it penetrates the soil. The other end of the wire is attached to a stake that supports the label of the female plant. Discarded sections of telephone cable provide an excellent source of different colored wires for identifying the crossed seed. The use of a different wire color each day provides the opportunity for allowing each hybrid seed a prescribed period of time in which to develop and mature.

All flowers and developing pegs, without strings or wires attached, are removed daily for a period of ten days after the last crosses have been completed. In addition,

the lateral vegetative growth and fruiting branches that do not contain hybrid pegs are kept pruned back. When more than 5 to 10 pegs are developing per plant, the efficiency of the operator's time, in terms of the number of crossed seed harvested relative to the number of pollinations made, is reduced.

The above procedure of artificially hybridizing peanuts has consistently resulted in over 70% of the hand pollinations achieving fertilization.

Various attempts have been made to find methods of improving the current procedures of emasculating and pollinating peanuts. Tsui (182) tried clipping the flowers at various levels to remove the anthers and upper part of the stigma and style followed by pollinating the resulting style stump but was unsuccessful in achieving any fertilizations. Banks (15) used a male gametocide (maleic hydrazide), also without success, in attempting to eliminate the emasculation process. Banks, in continuing his effort to lessen the work involved in hybridizing peanuts, has developed a technique in which he grows the peanut plants in growth chambers and is able to emasculate and pollinate immediately, during the hours 8:00 to 10:00 A.M., utilizing pollen from greenhouse grown plants (D. J. Banks, personal communication).

Nicholaides *et al.* (146) found positive significant correlations between the highest and average daily temperature which had occurred three days earlier and the number of flowers on a given date. In their studies, the daily relative humidity values were not related to subsequent flowering. Zamotajlov (192) reported that increases in temperature also increased the rate of the fertilization processes. Oakes (153), studying the germination of peanut pollen on a culture medium, found that germination was increased as the temperature increased from 18° to 30°C. He obtained no germination below 18° or above 35°C, but found that peanut pollen remained viable for several days in an ordinary household refrigerator. Hassan and Srivastava (94) kept pollen viable up to 8 days when stored in a refrigerator at 6°C over calcium chloride in sealed desiccators and up to 8.5 hours when stored at room temperature (28.3°C) and a relative humidity of 56.5%.

Handling the hybrid populations

Growing the F_1 plants

Enough F_1 plants should be grown to produce the desired F_2 population and provide a remnant in case of crop failure. Frequently, in hybridization programs the number of F_1 seeds are insufficient to produce the large F_2 populations desired, in which case the F_1 hybrids may be multiplied by vegetative propagation. Techniques for vegetatively propagating peanuts by cuttings have been described (5, 79, 93). Nuchowicz (152) cultured excised embryos and sections of embryos of peanuts as a means of increasing the number of descendants, but found that the divided embryos grew poorly. Although this latter method appears to be of doubtful value, Nuchowicz suggested that induced or natural adventitious budding should be investigated as a means of increasing the number of vegetative descendants from a plant.

To enable F_1 plants to produce large quantities of seed they should be widely spaced, (from 45 to 90 cm apart in rows 90 cm apart), depending on the growth habit of the parental varieties. The F_1 plants should be compared with the parental varieties to be sure they are hybrids. F_1 plant examinations can also at times provide information concerning the mode of inheritance of characteristics in which the parents differ.

Handling the segregating generations

The general procedure for handling segregating hybrid populations for a self-pollinating crop such as the cultivated peanut usually involves the use of the bulk or the pedigree system or numerous modifications of the two. Experimental evidence concerning the merits of using one of the systems to the exclusion of the other for breeding self-pollinating crops is contradictory. In peanut breeding no reports of comparisons were found and both methods are sometimes used by the same breeder.

Both the bulk and pedigree methods have advantages and disadvantages. If natural or artificial selection pressures eliminate large proportions of undesirable plants and if achieving a high level of homozygosity is important to the breeder, then the bulk method would be the logical choice. If the plant breeder is trying to get the most out of a few crosses in the shortest possible time, the pedigree method is the best choice (20). This method permits the elimination of a great deal of unpromising material in the early generations as well as the evaluation of selections based on several years data and more opportunity for early generation testing. A principal objection to the pedigree system is that the increased time required to handle the individual plant selections restricts the amount of material that the breeder can evaluate.

A number of peanut breeders of the United States and in foreign countries, with which the writer has been in contact, are using modifications of the pedigree system. The current procedure in North Carolina (D. A. Emery, personal communication) is to produce the F_2, F_3, and F_4 generations by taking a single seed from each plant to produce the subsequent generation. By advancing two of the generations in the greenhouse 6 generations in 4 years are produced. Seed from F_4 plants are increased as plots in the field and from this point on the pedigree system is followed. The peanut breeding projects in Texas (C. E. Simpson, personal communication) and Georgia (R. O. Hammons, personal communication) utilize both the bulk and the modified pedigree methods. At the Salisbury Research Station in Rhodesia a modified pedigree system is used (G. L. Hildebrand, personal communication). The F_2 to F_5 generations are handled in bulk, with limited discarding of the very obviously defective plants. Single plant selections are made beginning in the F_6 generation. In Florida the pedigree system has been used almost exclusively.

Selection indices

It is difficult to evaluate quantitative characters such as yield in the early generations. In general, the type of selection is subjective and consists of a "mental picture" of the desirable attributes a variety should possess. However, there are a number of indices that have been used with some degree of success, such as seedling and plant vigor, fineness and number of branches (both primary and secondary), length of internodes, number of fruiting branches, number of pegs per branch, and size of fruit.

A limited amount of experimental data has been published concerning selection indices for peanut yield, and a number of these are contradictory. The statement by Gregory *et al.* (79) in 1951 that today's peanut breeder must increase the precision of estimating genetic differences within segregating populations is no less true today.

In 1933 Hayes (96), reporting the correlations of 15 characters in 35 varieties of peanuts, found that no characters which exhibited clear-cut segregations showed any association with one another. Eight of the characters he studied were found to influence yield. These were length of leaves, petiole, rachis, and sheath; width of leaves; corolla color; hairs on petiole; and number of seeds. Of these he stated that

number of seeds and hairs on petiole may be of immediate use in selecting or breeding for high yield.

Lin (126) collected data on six quantitative characters (days to flower, length of main stem, number of branches, length of branches, number of pods per plant and weight of pods per plant) in the F_2 and F_3 generations of a cross between the Spanish variety Tainung No. 1 and Florispan. He found the genetic variance for days to flower to be largely additive while that for number of branches to be largely dominance. He obtained high estimates of heritability for days to flower and relatively small heritability estimates for number of pods and weight of pods per plant. The relationship between number of branches and number of pods and weight of pods per plant was positive.

Raman and Sree Rangasamy (162), in the progenies of a cross between *Arachis hypogaea* and *A. monticola,* found that variability in length of primary branches, number of secondary branches, and shelling percentage is controlled by additive gene effects. They obtained heritability estimates of 89% for number of primary branches, 99% for number of secondary branches, and 78% for shelling percentage.

Lin and Chen (127), in a study on yield components in different types of peanuts obtained a positive relationship between the number of branches and number of pods in all types, but only in the Spanish type was the relationship between the number of branches and the average weight per pod positive; in the Virginia types it was negative. They concluded that in the Spanish type the number of branches markedly affected yield. In the Virginia bunch and runner types they found that the number of pods and average weight per pod had only a small effect on yield.

Ramanathan and Raman (164) obtained significant positive correlations between shelling percentage and pod weight ($r = 0.78$), kernel weight ($r = 0.75$), and percentage of well-filled kernels ($r = 0.61$) in populations of an interspecific cross of *A. hypogaea* × *A. glabrata.*

Stokes and Hull (174) obtained a negative correlation of $r = 0.21$ between yield of nuts and the yield of vines and roots, and this has also been the trend in terms of the variety releases in Florida. Lin, *et al.* (129) obtained significant negative correlations between length of internode and yield of pods in both spring 1967 and fall 1966 crops of peanuts in Taiwan.

Majumdar, *et al.* (132) analyzed the genotypic and phenotypic variability for 17 characters in 45 varieties of peanuts in India in 1967. He obtained the highest genetic coefficient of variation for number of branches, followed by number of leaves, number of nodes, number of peg bearing nodes, number of pod bearing nodes and length of pod. Heritability estimates ranged from 49.6% for pod yield to 98.6% for days to maturity. All the characters except number of pods and pod yield were found to possess high heritability. Asoka (7) in India in a study of eight characters in 14 varieties obtained high estimates of heritability for number of days to flowerng, number of leaves per main stem, pods per plant and 100 pod weight.

Gupton and Emery (80) in 1966 calculated heritability estimates for maturity in early, intermediate, and late pegging groups of pods in F_4 and F_5 generations of a cross between two Virginia type varieties, NC 2 and Georgia 119-20. They obtained estimates ranging from 69% in the early pegging group to 95% in the late group, indicating that a high degree of genetic control may be exerted over the maturity level of a peanut variety.

The environment often produces differential effects among varieties in the degree

of expression of various characters. Lin *et al.* (129) found that the number of pods per plant was negatively correlated with the number of branches per plant in a fall season planting and positively correlated in the spring planting. A positive correlation between number of pods per plant and the yield of pods was found in both the spring and fall crops as well as between the number of branches and yield of the crop. This latter correlation was especially significant in the spring crop.

Ojomo and Adelana (154) obtained significant variety x environment interactions for yield in a test of 16 varieties at three locations during 3 years (1965-1967) in Western Nigeria. They noted that differences in soil types, rainfall amounts and distribution, and disease incidence at the different locations influenced the yields. They suggested that Western Nigeria be divided into sub-areas for which varieties showing specific adaptation could be developed.

Frey (56) obtained more rapid progress from selection for grain yield in oats when grown under non-stress conditions (good moisture and high fertility) than when the oats were grown in a stress area (low fertility and droughty). He reported mean heritabilities for grain yield in the stress and non-stress areas of 32 and 45%, respectively. Although no reports of peanut experiments with this objective were found, it is the author's opinion that the theory may also hold true for peanuts. In the peanut breeding nurseries in Florida, attempts are made to hold nutrient and moisture stress conditions to a minimum.

Optimum spacing of plants

In any generation in which the breeder contemplates making single plant selections, the plants must be spaced a sufficient distance apart to permit uniform opportunity for the expression of each plant's potential and permit visual evaluation by the breeder. In Florida a spacing of 30 cm apart in rows 91 cm apart is used. The spacing could be somewhat closer if one were working with only upright growing Spanish types, and a wider spacing would be more convenient if handling primarily prostrate growing types. Although more effort is required in disentangling the branches of the runner types at the 30 cm spacing than at a wider spacing, most of the pods can be saved. Since, in the segregating generations, the breeder must make visual evaluations among thousands of individual plants, he cannot afford to spend much time untangling plants during the critical harvest period.

There have been reports with other crops that single plant performance in a space planted nursery is not necessarily related to population performance under the normally much closer spacing used in field plantings. From observations and a limited amount of experimental results thus far reported, this apparently does not hold true for peanuts. Lin *et al.* (130) found from a recently completed study using three planting densities, 35 x 30 cm, 35 x 20 cm and 35 x 10 cm that selection for peanut yield in the wide spacing was the most effective.

The results of three years tests at Marianna, Florida, Norden and Lipscomb (149), using four essentially homozygous lines of peanuts to study the relationship between growth habit and genetic background at different row spacings, indicated that superior yielding genotypes selected in conventionally spaced rows (91 cm) would also be superior in close-row (46 cm) spacings. Their results also indicated that the confounding effects of seasons is a greater problem in isolating superior yielding genotypes than effects of variations in growth habit or row width.

In addition to varying maturities, breeding lines of peanuts vary over a considerable range in plant height and in the length and carriage or angle of the branches.

Hull and Carver (107) stated in 1936 that one of the difficulties in testing yields of experimental peanut lines with the commercial types is to obtain optimum spacing for each kind. They conducted tests for three years and obtained considerable overlap in the spacings which produced optimum yields for the three types tested (28). In rows spaced 76 cm apart, the upright Spanish type produced optimum yields when spaced 10 to 20 cm apart, the runner growth habit produced highest yields from spacings of 15 to 25 cm, and a hybrid variety with intermediate growth habit produced the highest yields at 10 to 25 cm within row spacings.

Shear and Miller (169) studied the influence of plant spacing of Jumbo Runner peanuts on fruit development, yield, and border effect at the Tidewater Research Station in Virginia during 1954, 1955, and 1956. They found that spacings as close as 15 cm between plants resulted in highest yields but retarded the rate of fruit development. Border effects were greater when the spacing was 15 by 15 cm than when the spacing was 23 by 23 cm or 30 by 30 cm.

Size and shape of plots

Robinson, *et al.* (165) in North Carolina during the 1940's and Gopani, *et al.* (65) in India in 1967 investigated the optimum plot size for peanut yield tests from uniformity trials. In both studies the coefficients of variability decreased with increasing plot size. Robinton *et al.,* with 6 replications and a plot size of two rows, 7.6 m long or with 1-row plots 15.2 m long, obtained coefficients of variability of less than 10 which is generally considered an adequate level of accuracy. Gopani *et al.* stated that a plot size of about 20 m^2 with 5 to 6 replications is adequate for conducting tests of breeding material of peanuts with runner growth habit at Junagadh, India.

Soils of tropical regions are considered to be very heterogeneous. Ollagnier (155), reporting results of uniformity trials conducted with peanuts in Senegal in 1950, indicated that: (a) the length of trial plots should be four times their width; (b) the size of each plot should not exceed 50 m^2; (c) 10 or more replications should be made.

No studies concerning the use of hill plots in peanut research were located in the literature. However, peanut breeders at the Salisbury Research Station in Rhodesia sometimes utilize a modified hill plot procedure (9 hills/plot) (G. L. Hildebrand, personal communication). Frey (57) found the hill-plot method to be a useful technique in oat breeding. He found that hill plots evaluated oat varieties for yield as accurately as rod rows, but with less precision; consequently, more replicates of hills are needed.

Heterosis in relation to peanut breeding

Although some data have been published, the degree of heterosis in peanuts is largely unknown. In 1930 Stokes and Hull (174) summarized data on plant vigor and the total number of blossoms and pegs per plant from 25 F_1 plants representing 11 different crosses, three between Spanish and runner types and the others between Spanish varieties. They obtained a small amount of hybrid vigor in the number of blossoms produced but none in vegetative characteristics. However, their data were not extensive. Since 1940 there have been a number of studies conducted in which a considerable amount of hybrid vigor was obtained (100, 156, 167, 176, 190).

Syakudo and Kawabata (176) in crosses among Virginia, Spanish, and Valencia peanut types obtained pod setting percentages from F_1 plants ranging from 9 to 59%, with the lower values obtained when Valencia was used as the pollen parent. A high degree of heterosis appeared for air-dried top weights of F_1 plants of the cross between

Virginia types and Spanish or Valencia. No hybrid vigor was observed in the F_1 plants between varieties within each type and between Spanish and Valencia types. The length of main branches, leaflet, pod and kernel, and the flowering date of the F_1 plants was intermediate between the parents. Somewhat similar results were reported by Parker, *et al.* (156) and by Wynne, *et al.* (190) in North Carolina. The latter workers, however, obtained more heterosis for vegetative plant characters from the Valencia x Virginia crosses than from the Virginia x Spanish or Valencia x Spanish crosses. Heterosis for yield and fruit characters, under field conditions, however, was greatest in the Valencia x Spanish-type crosses.

Although the exploitation of heterosis for commercial production of hybrid varieties has been realized in a few species of self-pollinated crops (41, 161) it is a very remote possibility in cultivated peanuts as they exist today even if significant heterosis in peanuts is demonstrated. Peanut flowers are borne on exceedingly short branches in the axils of foliage leaves near the ground, and thus are not exposed to the wind. Also, the amount of pollen produced by peanut plants on a given day is so small that effective cross pollination would likely require a special type of insect.

Backcrossing

In backcrossing the objective is generally the transfer of a certain simply inherited characteristic to an otherwise desirable variety, disturbing the genotype of the desirable or recurrent variety as little as possible in the process. Success in backcrossing depends on the ease with which recombinations take place and on being able to select the desired characteristic in the succeeding generations. Near the centromeres and certain other areas of the chromosomes little or no crossing over may occur.

Only in the relatively simple cases of transferring one or two dominant genes is it advisable to do all the backcrossing on F_1 plants. As a general rule, progeny should be grown to the F_3 after alternate backcrosses. There is merit in a breeding program of combining backcrossing or modifications of it with recombination or "transgressive" breeding. Elliot (41) concluded that "a combination of backcrossing, modified backcrossing, and recombination breeding should provide more balance and opportunity for progress than exclusive use of any one approach", and a number of peanut breeders are following this procedure. Ashri and Goldin (5) make cuttings from desired F_1 hybrids growing in the field and plant them in 30.5 cm pots in the greenhouse where they are used in making backcrosses. Krapovickas, *et al.* (115) have used backcrossing to improve the dormancy and disease resistance of the variety, 'Colorado Manfredi'. The backcross method is being used in Texas and Honduras to transfer leafspot resistance (C. E. Simpson and J. Romero, personal communication). Backcrossing is being used in Oklahoma (D. J. Banks, personal communication) and was initiated in Rhodesia to transfer improved shelling ability (G. L. Hildebrand, personal communication).

Recurrent selection

Recurrent selection is a system of breeding which, through cyclic selection and crossing, is designed to increase the frequency of desirable genes and gene combinations in the population. Hull (106) introduced the name "recurrent selection" for this cyclic breeding method and proposed its use for improving specific combining ability in corn. Recurrent selection for specific combining ability was designed to capitalize upon non-additive genetic effects while recurrent selection for general combining ability is designed to capitalize upon additive genetic effects.

In a self-fertilizing species such as peanuts, one of the principal handicaps in using recurrent selection is the difficulty in making sufficient crosses to initiate the recombination portion of each cycle. Another major problem encountered with this method in North Carolina, where it has been extensively used since 1944, is the length of time involved before a new cycle of recombination can be made. Since many of the characters evaluated are quantitative, it may be necessary to advance the material to the fourth or fifth generation before making selections based on yield (D. A. Emery, personal communication). Dr. W. C. Gregory in 1944 initiated the first cycle of crossing using 10 selected lines. The selected progenies of the first cycle plus several new lines were recombined in 1952; the second and third cycle selections were intercrossed in 1958 and 1966, respectively. The varieties NC 1 and NC 2 traced back to the original cycle, while NC 5 traces back to the second cycle. To help speed up the generation per year rate of progress the North Carolina workers have modified the pedigree system by mass producing the F_2 generation in the greenhouse with the objective of getting a minimum of one fruit per F_2 plant, and the same procedure is followed to produce the F_3 and F_4 plants. Seeds from F_4 plants are increased as plots. They have been able to grow six generations in four years using these procedures. (D. A. Emery, personal communication).

Mutation breeding

Elliot (41), in his book on "plant breeding and cytogenetics", devoted a chapter to mutation breeding and the book "plant breeding", edited by Frey, includes a general review by Gregory (75) on mutation breeding. Induced mutations, like spontaneous ones, are nearly always recessive and deleterious in their effect on the genotype (70). This phenomenon necessitates the testing of large second generation populations and requires efficient screening techniques for detecting the desirable mutations.

Intensive research on mutation breeding of peanuts has been carried out by a group of investigators in North Carolina since 1949. The results obtained, largely of a fundamental nature, have been recently reviewed (76). Gustafsson and Gadd (81) also reviewed the literature on mutation breeding of peanuts.

In peanuts, as it has been said for soybeans and most other crops, more variability can be created through hybridization than a breeder can utilize. However, mutation breeding offers the peanut breeder hope as a source of genetic variation for certain characteristics, such as resistance to *Cercospora* leafspot disease, which is not presently found in the germplasm bank of cultivated peanuts. Although the range of genotypic variability artificially produced in peanuts is impressive (67, 72, 125) it probably falls far short of duplicating the natural variability. Reasearch in North Carolina has shown that, along with the origin of drastic morphological mutations (macromutations), X-irradiation frequently causes genetic background mutations which give rise to a series of modifier mutations (micro-mutations) (72, 74). Plants may contain mutations of the modifier type and be seemingly normal in appearance. The variety NC 4x, released in 1959 by the North Carolina Agricultural Experiment Station, was derived from normal appearing plants that were obtained following the irradiation of approximately 23 kg of seed of NC 4 in 1949 (71). The new variety, NC 4x, was higher yielding than its mother strain and had better fruit and seed quality than the popular NC 2 variety. Another desirable characteristic produced from the irradiation work in North Carolina was resistance to *Cercospora* leafspot disease (36).

Although a considerable amount of research has been conducted on mutation breeding of peanuts, there still remains much to be learned, especially concerning envir-

onmental effects and procedures which would selectively eliminate the undesirable changes induced by mutagens while permitting the breeder to obtain the changes desired. Many complicating factors are present, such as the wide range of x-ray and fast neutron sensitivity which exists between different strains of peanuts (68, 125). It is unlikely that irradiation will ever be used exclusively in a peanut breeding program. However, in North Carolina it has proven to be an effective tool to use in conjunction with conventional methods, and it is currently being used in Oklahoma to induce mutations and attempt to break some possible linkages and transfer desirable characters between Virginia and Spanish botanical types (D. J. Banks, personal communication).

Specific Objectives and Techniques

It's been said that plant breeding is the art and science of improving the genetic potential of plants for human needs. As a science it bases its methods on the principles of genetics and statistics, insuring predictability in its results. As an art it depends on the breeder's knowledge of the crop and a feeling for the effects of the environment on the selections. To identify the infrequent valuable types it is important to make frequent visits to the breeding nurseries to take notes and carefully observe the various lines as they develop. However, when the conditions necessary for the expression of a character do not occur, the breeder is often forced to devise special techniques. The following examples of specific breeding objectives and techniques are briefly discussed samples from among a great number described in the literature of plant breeding, genetics, entomology, phytopathology and food science.

Higher yield

By necessity, much of the emphasis in peanut breeding throughout the world is placed on improving yield. This is partly in response to the increased food requirements caused by an increasing population and limited land resources. This emphasis is also due to the ever increasing costs of production. Producing higher yields on a per unit area is one of the ways that the grower has to counteract the cost-price squeeze. Thus, it would he highly unlikely that a grower would accept a new variety if it were not higher yielding, unless the new variety provided him with some other way to increase his net return per unit area. The increasingly higher annual peanut yields obtained in the United States are due to a combination of factors among which genetically higher yielding varieties is but one. There is no way of estimating the contributions of inventive crop production scientists, growers, engineers, pest control personnel and others toward these increased yields. Procedures employed in breeding for higher yields were discussed in the section, "handling the hybrid populations", and will not be repeated here.

Pest resistance

Greater peanut yields will be accomplished, not only by breeding basically higher yielding varieties, but also by the development of varieties that help to stabilize production through resistance to various pests, drought, etc. With modern day environmentalists exerting pressure against the use of pesticides, breeding for pest resistance looms as one of the more important aspects of many current peanut breeding programs.

Diseases

Since Gregory's, *et al.* (79) review in 1951 of the early work concerning breeding peanuts for disease resistance, the literature has become too extensive to be covered in this chapter. Leafspot disease is the most common disease of peanuts, and in many

countries throughout the world a concerted effort is made to develop leafspot resistant varieties. Frank (53) in Israel found that in a collection of some 200 peanut varieties, the variety 'Tarapoto 1556-63' had moderate field resistance to leafspot caused by *Cercospora personata.* Leafspot resistant peanut lines were developed in North Carolina using irradiation breeding techniques (36), and work is currently underway utilizing the wild species as sources of leafspot resistance (D. A. Emery, personal communication). Breeding for leafspot resistance in Malawi by the use of wild species began in 1968 (141).

The most destructive disease of the fall-planted peanut crop in Taiwan is wilt, or stem rot, caused primarily by *Sclerotium rolfsii.* Breeding for *Sclerotium* wilt resistance was initiated there in 1954. Lin (124) artificially inoculated 19 Virginia type lines and found that Early Runner had the lowest percentage of disease plants (43.2%). Of the 11 Spanish varieties tested, E. G. Red was the most resistant with 36.6%. Cheng and Lin (32) selected eleven resistant lines from crosses between Spanish and Virginia types, with eight of the eleven lines being derived from the cross of Tsingtao × Florispan Runner. Frank and Krikum (54) screened 28 varieties for resistance to *Verticillium* wilt *(V. dahliae)* in Israel and found 'Mwitunde 3' completely resistant and 'Schwarz 21' fairly resistant. *Verticillium* wilt is a serious disease of potatoes, tomatoes, eggplant, and cotton and recently has been found on peanuts grown in rotation with the above crops in Israel under irrigation. Bromfield and Cevario (21), in greenhouse screening of 173 peanut accessions for resistance to 2 races of peanut rust *(Puccinia arachidis),* found PI 314817 and PI 315608 resistant to both races. In breeding for resistance to some diseases, such as rust, pathogenic variability can be so great as to impede progress in developing resistant lines. In recent years peanut rust has been appearing in the United States and causing a few yield reductions (21, 91).

Hsi (103) in New Mexico evaluated the reaction of 138 Valencia peanut lines, mainly from South and Central America, to blackhull disease *(Thielaviopsis basicola).* The lines were grown in two locations; he found that only seven of the lines had less than 75% of the pod surface discolored by the fungal growth in both locations.

In India, Chohan, *et al.* (33) screened 734 peanut varieties from various countries of the world for resistance to collar-rot disease, also known as Crown rot, caused by *Aspergillus niger.* Only 20 of the varieties showed freedom from this disease following artificial seed and soil inoculations. The other varieties showed an incidence of collar-rot varying from 3.7 to 100 percent. Aulakh and Sandhu (8), in later studies under artificial epiphytotic conditions, found only one of the above 20 varieties (EC21115 from Sudan) to be highly resistant to the disease.

Culp and Troutman (38) rated several hundred peanut varieties, introductions and lines for plant reaction to natural infection of peanut stunt virus and found none immune, but several showed less severe symptoms than others. Breeding for rosette virus resistance by the Institute for Research on Oil and Oilseeds (I.R.H.O.) in the Upper Volta of West Africa has been effective. Gibbons (61), utilizing seed received from the West African countries of Senegal, Ivory Coast and Upper Volta has developed rosette virus resistant varieties in Malawi.

Cooperative research to identify peanut lines with resistance to toxin-producing molds was initiated recently in Alabama, Florida and Georgia. Although much of the preliminary work has been devoted to the development of suitable screening techniques, a number of lines were found which show greater tolerance to invasion by

certain isolates of *Aspergillus flavus* than the commercial varieties currently being grown (A. C. Mixon, personal communication).

Insects

Leuck, *et al.* (122) visually rated 14 advanced peanut genotypes for preference resistance to the foliage-feeding insect complex in the field and found meaningful levels of resistance ranging from the most preferred variety, 'Starr' to the least preferred variety, 'Southeastern Runner 56-15'. In greenhouse studies conducted during the following years, Leuck and Skinner (123) found 12.2% fewer moths emerged from larvae of the fall armyworm *(Spodoptera frugiperda* J. E. Smith) fed on foliage of Southeastern Runner 56-15 than from larvae fed the more susceptible variety, Starr. Of 1700 plant lines screened for foliage resistance to the larval species at Tifton, Georgia, 40 entries were found to be more resistant than Southeastern Runner 56-15. PI 196613 was 13% less preferred than Southeastern Runner 56-15 (123).

In Oklahoma, Young (191) screened 872 peanut entries in the field tests in 1966 and 1967 to identify germplasm resistant to thrips, and 59 of the better entries were re-evaluated in the laboratory. PI 268661 and PI 280688 appeared to be the most resistant, and the latter was non-preferred by thrips in laboratory tests. Lueck and Hammons (120) found resistance to the mite *(Tetranychus tumidellus)* in plants of 3 wild species of *Arachis.* However, special techniques in hybridization may be required to use this germplasm, since 2 of the 3 species are diploids ($2n = 20$) and the other is undetermined.

Seeking resistance to the southern corn rootworm *(Diabrotica undecimpunctata)* has been a part of the peanut breeding program in North Carolina for 12 years (D. A. Emery, personal correspondence). One line, GP 343, was released in 1971 because it had decidedly more resistance to the larvae than did the common commercial variety NC 2 (24). Southern corn rootworm resistance is also being sought in Virginia (173) and in Georgia (31).

Nematodes

Breeding work to develop peanut varieties that are resistant to damage by the Northern root-knot nematode *(Meloidogyne hapla)* has been underway since 1966 in Oklahoma. Some of the initial work was concerned with the development of an effective screening procedure (14). After three years, Banks (13) reported obtaining mild resistance in a few lines of cultivated peanuts and moderately good resistance in some of the wild species. In Georgia, Minton, *et al.* (140) found a variable response among six peanut varieties to infection by root-lesion nematodes *(Pratylenchus brachyurus),* Woodroof (188) indicated that basic research is needed to clarify the relationship of nematodes (root-knot, sting and root lesion) to fungi almost always found in peanut roots, stems, or pods.

Drought resistance

Drought resistance is a difficult character to evaluate under field conditions because only in certain years are conditions favorable for a differential response, and the response is often confounded by soil variations within the breeding nursery. The writer knows of no laboratory tests in use for measuring differential drought resistance of peanuts.

Gautreau (60) in Senegal found that the relative transpiration of a drought-resistant variety was significantly lower than the drought-susceptible variety and attributed this to the earlier and more effective stomatic adjustment of the drought-resistant variety. He suggested that the comparison of varieties for the purpose of selection

is best carried out in the morning, on plants at least two months old, during a period of moderate water supply.

A narrow leaf mutant discussed by Gopani and Vaishnani (66) in India possesses a hard, thick cuticle layer on the leaf and fewer stomata in comparison with normal varieties. The authors suggested that the mutant may have a potentiality of resistance to drought.

Seed dormancy

A degree of dormancy of peanut seeds at harvest is an important attribute in a peanut variety as it can, in times of excessive rain at harvest prevent undue loss of the crop from germination. Genetic differences in seed dormancy between strains within the different botanical groups have been demonstrated by a number of investigators (105, 128, 160, 180). Toole, *et al.* (180) and Lin and Lin (131) found that dormancy decreased with maturity and that immature seed were more dormant than the more mature seed. Toole, *et al.* (180) found that sealing peanuts with apples in a plastic box or the use of ethylene gas was effective in breaking dormancy of cured imbibed mature seed as well as fresh seed.

Maturity

Unlike many other cultivated crops, the Virginia-type peanut has an indeterminate flowering and fruiting pattern which results in a crop with many maturity groups. Emery (43) and Emery, *et al.* (51) described a method of tagging the consecutive pegs on a prominent branch upon penetrating the soil whereby the fruit will be harvested in specific peg to pod growth periods. This method served to differentiate maturities of 14 varieties of Virginia type peanuts. Later Emery and Gupton (50) found that oil pigmentation, when applied to specific growth periods of nine varieties of Virginia peanuts, was the most objective method of estimating maturity. High light transmission-low pigmentation oils identified good maturity. Heritability estimates of maturity using the latter method ranged from 69 to 95% (80).

In Japan, Takeuchi (177) cited the need for early maturing peanut lines with a high level of disease and nematode resistance because of continuous peanut culture or peanuts must often immediately follow the harvest of a previous crop. In Israel, earliness is important to enable growers to complete the harvest during the usually rain-free month of September and free the land earlier for the succeeding crop (64). The early maturing variety, Shulamith, derived from a cross between Florispan and Florigiant and released in Israel in 1968, currently occupies 80-90% of the Virginia peanut acreage grown in Israel (E. Goldin, personal communication). In Rhodesia, Meikle (139) reported that early maturing types are better adapted in the main peanut growing areas and constitute 85% of the peanuts grown in the country. Umen (183) in 1933 stated that earlier maturing varieties was an objective of peanut breeding in the U.S.S.R.

Mechanization

Since 1950 virtually 100% mechanization was attained in the production and harvesting of peanuts in the United States. Therefore, the development of peanut lines more suited to mechanization is stressed in a number of breeding programs (92, 147 and R. O. Hammons, personal communication). In the development of varieties with characteristics more suitable for mechanization, emphasis is placed on uniform maturity; uniformity of pods and seed; stronger peg attachment; break resistant pods; tough seed coats; suppressed radicle; plants with spreading bunch growth habit or, if prostrate, with the pods clustered nearer the tap root.

Sample shelling equipment described by Dickens (39) has been used to evaluate the toughness of the pods and seed coats of different breeding lines. Baumann and Norden (16) used a mechanical force gauge mounted on a lever device to differentiate peg strength among peanut genotypes. However, in the latter study, the variable pod sizes and depth of pegging in the soil among the genotypes caused some difficulty in interpretation. To avoid excessive pod loss during harvest a line with large pods and a deep pegging zone requires stronger pegs than a line with smaller pods or one in which the pods develop nearer the soil surface.

Quality

Higgins (98) discussed the relationship of breeding and varieties to quality for specific uses. He cited research indicating that environmental factors under which the peanuts are grown have no appreciable effect on iodine value or unsaturation of the oil, and stated that "Genetic purity of the variety, maturity of the seeds, and method of sampling may be more important in obtaining reproducible results". Recently, Worthington and Hammons (189) found slight year to year variation in the fatty acid composition of 14 peanut varieties grown at Tifton, Georgia. They examined 110 genotypes during one or more growing seasons and concluded that the genetic variability among the genotypes should permit the development of new varieties with improved stability characteristics and more desirable fatty acid composition.

French (55) analyzed the oil composition of eleven peanut genotypes and found little association between the different botanical types, which he attributed to the intercrossing of the types by the breeders. Norden (147) reported iodine values among lines of the Virginia type, ranging from an average of 85.7 to 100.5 for the 3-year period 1964-1966.

Martin (134) in Senegal obtained differences in the oil content between the seeds within two-seeded pods. He found the basal seed always higher in oil content than the apical seed, which gives rise to sampling problems for the quantitative analysis of oil. Martin obtained increased variability in oil content in the progeny of irradiated peanuts (133) and in a cross between two varieties found that oil content had a high heritability (135).

Chopra and Bhatia (34) in India obtained wide variations in lysine content among 50 peanut varieties, indicating that selection for high lysine is possible. They found that none of the 50 varieties had sufficiently high methionine content to be of breeding value. The environment appeared to have little effect on the contents of methionine or lysine. Heinis (97) in Florida evaluated 25 experimental lines of peanuts and found that four of the entries contained about twice as much methionine than the lowest ranking selection. The methionine content of the highest line was 45% deficient relative to whole egg, whereas peanut meal in general is reportedly 77% deficient. Stone (175) found that the organoleptic quality of 74 introductions of Spanish peanuts was not greatly influenced by environment and that none of the introductions was significantly better than the check variety, Argentine, for peanut butter or roasted peanuts. None of the introductions was significantly higher than Argentine in percentage of oil or protein.

Mozingo (144, 145) described procedures and presented 1968-1970 results of peanut variety and quality evaluations in Virginia and North Carolina. In these evaluations manufacturers and other segments of the industry cooperate in the evaluation of the shelled samples for end-use product flavor and quality.

Peanut quality evaluations are complicated by many factors such as season and

genotype (102, 137), soils and curing methods (137), and processing methods (143). Bailey (12) emphasized the need for more objective measures of peanut quality that can be used with confidence by individual research scientists. Watson (187) questioned whether our current U. S. peanut grading system measures all of the important quality factors and Emery (42) also pointed out serious limitations of the peanut marketing system.

The peanut quality committee of the American Peanut Reseach and Education Association, under the chairmanship of C. E. Holaday, recently published suggested procedures for measuring organoleptic quality (Cler score) and oil quality, including determination of the average maturity of a sample of peanuts by the density of yellow pigmentation in the freshly pressed and filtered raw peanut oil (101). The latter technique is based on the progressive disappearance of oil-soluble yellow pigments, including various carotenoids, during the process of maturation.

Varietal Mixtures

Planting mixtures of species or of varieties within self-fertilizing species is not new. It has been used with varying degrees of success in small grains for many years. Experimental results with peanuts (45) and with a number of small grain crops (4, 41, 59, 110, 111, 158) has shown that genetically diverse populations have greater stability in performance over a number of environments than does the pure line. Frey and Maldonado (59) showed that the advantage of heterogeneous oat populations increased as the environment became more stressed.

The genetic base of the self-pollinated peanut may be broadened in inumerable ways. A degree of genetic resilience may be built into a variety by the breeder in the initial stages of development or on an individual character basis after the variety has been released to the farmer. Emery (44) described the "synthetic variety" concept (peanut seed mixtures of pure lines) as one method of providing genetic variation to maximize the farmers' returns and meet the more refined needs of the market.

Emery (45) and Emery, *et al.* (47) conducted experiments with mixing seed of Virginia peanut varieties in various proportions. Their experiments were not designed to contribue genetic information on the long range potential of peanut seed mixtures but rather to determine under what circumstances seed mixtures would be expedient in satisfying the rigid demands of a marketing system. They found that by adding varying proportions of a "booster" line they could generally improve the yield and value of a commercial variety. A mixture of two-thirds Va. 56R and one-third booster (Fla. 393) increased the four-year mean for yield per hectare 242 kg, 94 kg, and 433 kg, respectively, over that of Va. 56R alone when harvested on September 20, October 5, and October 15. This did not effectively change the seed size patterns in the mixture. Emery (45) concluded that the principle virtue of the mixture was its stability over the very different seasons.

The use and control of genetic diversity within populations by the blending of "pure lines" can allow the breeder maximum utilization of experimental lines which in themselves may not have all the attributes desired in the trade but have certain qualities in excess. Norden and Block (148) blended two highly homozygous breeding lines to study the practicality of blending selected lines of peanuts for improving oil quailty and market value. Their results indicated that, insofar as chemical composition of the oil is concerned, selected peanut lines may be blended to render peanut oil with qualities desired for specific purposes. Blends or mixtures, however,

could result in problems in production arising out of differences in seed and plant characteristics and maturity and in processing due to differences in roasting and blanching properties. All of these aspects would need to be considered in the selection of lines to blend for commercial production.

Multiline Varieties

With a number of self-pollinated crops the interest, in recent years, has been shifting toward the utilization of genotypic mixtures (with similar phenotypes) to provide more adaptability. Where environments are variable, the pure line, with only one genotype, is at a disadvantage. A recent review of the literature on multiline varieties as a means of disease control was written by Browning and Frey (23).

Jensen in 1952 (110) suggested intravarietal diversification in oat breeding by developing multiline varieties of similar phenotypes which have different genetic backgrounds for disease resistance. A multiline variety might reasonably be expected to have a longer life span as a variety if sufficient genetic diversity is present and should show greater stability of production. The seed increase and maintenance of the components of intravarietal mixtures should remain under the control of the breeder and lines added or withdrawn as conditions warrant. The first multiline variety for commercial production was 'Miramar 63' wheat, released in Colombia in 1963. The first multiline variety of oats was released in Iowa in 1968, 'Multiline E68' (58). In developing oat Multiline E68 the most agronomically desirable line was obtained without regard to rust resistance. Backcrossing was used to add rust resistance. In 1968, ten isogenic lines (each carrying a different gene for crown rust resistance) were blended to produce the appropriate balance of resistance in the line with the natural composition of the crown rust population. Later they found the 2 isolines used in Multiline E68 did not meet their standards and were dropped, so 'Multiline E69' was composed of only 8 isolines. By the end of 1969 three additional isolines were found useful against naturally occurring crown rust races, and were added to produce 'Multiline 70'. Frey, *et al.* (58) feel that the life of a given multiline oat probably will not be ended by crown rust but by development of a superior variety. Breeders' seed of multilines is newly blended each year; each time the isoline composition is changed the new composite is given a new designation. The breeder is faced with the problem, however, of predicting the crown rust resistance that a multiline requires 4 years in advance of its wide commercial use during which time seed stocks are being multiplied.

Walton (186) has stated that some of the existing Canadian spring wheat varieties are multiline strains consisting of chance mixtures of lines with different yield and quality characteristics. Most Canadian spring wheat breeders make their last single plant selections between the F_5 and F_8, and thus it is probable that all the loci controlling yield and quality will not be homozygous. If, for example, 10 loci are concerned, the percentage of homozygous individuals in the population between the F_5 and F_8 will range from 73 to 96 percent, assuming no crossing over (which is not the case). As the generations advance, plants with heterozygous loci will produce segregates that form a mixture of homozygous lines. A multiline strain is thus developed by chance. However, in this case the sub-lines are very closely related and similar in performance. Thus, the multiline represents quite a different situation than as used in an Iowa oat breeding program where it refers to a blend of isogenic lines developed by conventional backcrossing.

Based on Walton's (186) description of multiline spring wheat strains the five peanut varieties released in Florida, since the initiation of an active peanut breeding program in the 1920's, could be classified as multiline strains or as early generation composites. However, as in the case of the Canadian spring wheat varieties, they are generally referred to as pure lines. Each of the Florida varieties, at the time of its release, was a composite of from 4 to 10 sister lines selected in the F_4 to F_8 generation, and the individual lines are still maintained separately by the breeder. The phenotypes of the lines are similar and indistinguishable from each other for seed certification purposes. A few years ago, however, the Florida seed certification agency detected some differences in the inner seed coat color within a few varieties and thought the varieties were contaminated with seed of other varieties. However, the varieties had not been selected for uniformity of inner seed coat color, and as it turned out, certain varieties, especially Florigiant, are quite variable in this regard. The inheritance of the inner seed coat color characteristic turned out to be very complex, with at least 4 loci controlling its expression (166).

In peanuts, where the end product is utilized primarily for human consumption, the trade requirements for chemical and flavor quality are considerably more stringent than in a crop that is utilized primarily for animal food. Thus, it requires many years of evaluation before the peanut breeder has accumulated sufficient data to be reasonably sure that the removal of just one of the lines in the original variety will not detract from its yield, processing or end-use product quality. The Florigiant variety was comprised of ten sister lines when released in 1960 and currently is composed of seven lines. No lines have ever been added to a Florida peanut variety after its release. In oats, however, isolines can and are dropped or added to the multiline variety based on one or two years results (58).

In Florida the objective is to mold the peanut variety to fit the somewhat specific and restrictive marketing system while at the same time making a conscious effort to avoid depleting the variety of its genetic versatility. It may be that this feature of the breeding system incorporates the environmental stability and wide adaptability noted in the Flordia varieties. Elliot (41), in reference to the stability of F_1 hybrids of self-fertilizing genotypes, points out that stability of a phenotypic norm over a series of variable microclimates in a given environment is due not only to obscure features of heterosis, but is probably more directly related to the genic contents of the hybrid. The writer has observed that when continued intensive selection for uniformity or other characteristics is practiced into the late generations of a cross, that the resulting lines had poor seasonal stability and lower average yields than the less highly selected material. Stability in production over a wide area is an important attribute of a peanut variety to be used for commercial production.

Variety Maintenance

Time to develop a new variety

Most of the crosses made do not result in improved varieties. When a cross does result in an improved variety, usually a minimum of from 12 to 15 years have elapsed from the time that the cross was made until the variety developed therefrom begins to make an impact in commercial production. Growing an extra generation of breeding lines in off-season nurseries each year in a tropical environment could reduce this period by 3 to 4 years. Greenhouses also can be utilized for this purpose in the early generations, but they may impose severe limitations on population sizes.

Maintaining seed viability

With this large expenditure of time and effort involved in peanut varietal development, it is proper to place emphasis on the preservation, maintenance and improvement, if possible, of the new variety in order to extend its useful life for as long as posssible. The breeder has the responsibility of maintaining breeders seed indefinitely, so long as the variety is grown. This task is less difficult if adequate seed storage facilities are available. Early studies by Beattie, *et al.* (17) showed that only small losses in germination of Valencia peanut seed occurred when stored for 5 years unshelled in galvanized-iron cans in a dry place at about 70°F. Seed of a Spanish variety under similar storage conditions suffered a distinct loss in germination after three years. They concluded in 1932 that "by proper storage it should be practical to retain a satisfactory viability of peanut seed for about three to six years, depending upon the variety". Most seeds retain their viability best when kept dry and at low temperatures. However, there is very little experimental data available on the optimum storage conditions for maintaining the viability of peanut seeds over long periods.

Ketring (113) in Texas recently conducted short term storage studies with the Starr variety of Spanish peanuts and found that the deleterious effects on germination, vigor, nucleic acids and ethylene production of the seeds was apparently caused by high relative humidity, since a lower relative humidity at the same or a higher temperature did not cause these effects.

In Flordia, shelled seed of runner and Virginia type varieties has been stored at 65 to 70°F in sealed steel drums (with paradichlorobenzene crystals added) for as long as ten years with many lots maintaining from 50 to 60% germination. Preliminary results from long range peanut seed storage studies indicate that after six years, storing seed at either 25 to 30°F or 35 to 40°F maintains viability better than storage at the 62 to 68°F range, and that storage of seed with very low moisture content (2%) maintains viability better than at 7-9% moisture. Seed stored in a building without any temperature control lost germination very rapidly after one year in storage (A. J. Norden—unpublished data). Unpublished data of S. A. Parham in Georgia showed that small seed lots of Spanish, Early Runner, and Florigiant seed germinated at 99%, 95% and 91% respectively after storage for seven years in sealed containers at about 10°F (R. O. Hammons, personal communication).

When determining vitality of peanut seed, Mixon (142) found that the promptness with which the radicles emerge when the seed are placed in a germinator has predictive value for performance of the seed when planted under field conditions.

Maintaining varietal purity

The end product of peanut varietal improvement programs can be a single pure line, an early generation composite, a blend of isogenic lines (sometimes referred to as a multiline), or a mixture of two or more relatively homozygous but not closely related lines or varieties, referred to as blends or mixtures. Even so-called pure lines may contain physiologic strains which, although morphologically alike, may differ in yielding ability or other characteristics. If too few plants are selected in increasing a pure line variety some of the physiologic types present in the original variety may be omitted, and a shift in the variety base would occur.

To lessen the possibility of a genetic shift in varieties comprised of sub-lines, the various sub-lines are maintained separately by the breeder and blended in equal quantities by weight whenever seed is relayed for increase. In the initial years following release of a new variety, breeders' seed is supplied on an annual basis. At times it is

possible to refine the original lot of breeders' seed by dropping one or two lines from the variety. This is not done, however, without several years of evaluation and generally the refinements are not of great enough significance to have justified holding up the initial release.

Natural cross-pollination has been detected at levels ranging from 0 to 2.56% depending on the season, variety, and location (37, 62, 83, 84). In the breeding nurseries at Tifton, Georgia, natural outcrossing ranged from 0.25% to 6.16% (R. O. Hammons, personal communication). Thus, it is important that there be adequate isolation between varieties in seed production fields to help prevent both mechanical mixtures and the transfer of pollen from other varieties. In Florida and Georgia, a peanut field, to be eligible for certification, must not be closer than 15 m to other peanut fields. Georgia has a 30 m isolation requirement for foundation seed fields. Florida certified peanut seed standards require a minimum of 96.0% pure seed and allow a maximum of 0.5% of other varieties. The tolerance of other varieties in Florida Foundation and Registered seed is 0.2%. All states do not have the same standards for certifying peanut seed. Georgia, for example, has zero tolerance for other varieties in the field. This can create problems at times for certified seed producers due to the chance occurrence of mutations, which is often higher than people realize, or to outcrosses; and also, if Registered or Foundation seed is purchased from states with different tolerances. Jensen (111) is of the opinion that the 'purity concept' has been carried to unnecessary lengths in small grains and that it may be antagonistic to the attainment of highest production.

Deterioration of new varieties

Gregory, *et al.* (79) pointed out that pure lines of peanuts tend to break down if selection pressure is relaxed and noted that the instability may be due to accidental seed mixture, natural outcrossing or chromosomal instability. The evidence collected since 1950 and discussed earlier in this chapter concerning the amount of natural outcrossing and the occurrence of mutations in cultivated strains continue to support this statement. The techniques of the plant breeder has also been mentioned as a factor in varietal deterioration (41).

In many peanut varieties a very limited amount of genetic diversity is present, since they may contain only one or a limited number of homozygous genotypes and selection for uniformity has been continually practiced. A number of older peanut varieties, however, including those released in Florida, were not replaced due to declining yields but rather because the new variety was higher yielding or had better quality. It is important to continually renew breeders' seed if a variety continues in commercial production. Selection pressures exerted by the seed industry or by the breeder can alter the life of a peanut variety. Seed sizing, for example, proved detrimental to the longevity of the NC 2 variety in North Carolina (77). Coffelt and Hammons (35) found recently that seed sizing influenced the genetic ratios they obtained in an inheritance study concerning albino seedlings. They obtained significantly more albino mutants than expected in the smaller seed sizes and less than expected in the large seed sizes. Although sized seed may be important in precision planting, these results indicate that such practices should be kept to a minimum in the seed industry.

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LITERATURE CITED

1. Alexander, M. W. and A. H. Allison. 1970. Registration of Virginia 56R peanuts. Crop Sci. 10(6):727.
2. Alexander, M. W. and A. H. Allison. 1970. Registration of Virginia 61R peanuts. Crop Sci. 10(6):728.
3. Alexander, M. W. and R. W. Mozingo. 1972. Registration of Virginia 72R peanuts. Crop Sci. 12(1):127.
4. Allard, R. W. 1960. Principles of plant breeding. John Wiley and Sons, Inc., New York. 485 p.
5. Ashri, A. and E. Goldin. 1964. Vegetative propagation in peanut breeding. Crop Sci. 4:110-111.
6. Ashri, A. and E. Goldin. 1965. The mutagenic activity of diethyl sulfate in peanuts. Radiat. Bot. 5:431-441.
7. Asoka Raj, P. C. 1969. Genotypic variability in some quantitative characters of groundnut. Sci. and Cult. 35:408-409. (Cited from Plant Breeding Abst. 40(4):1088).
8. Aulakh, K. S. and R. S. Sandhu. 1970. Reaction of groundnut varieties against *Aspergillus niger*. Plant Dis. Reptr. 54:337-338.
9. Avadhani, K. K. and B. V. Ramana Rao. 1968. Studies on the effects of diethyl sulphate on TMV 2 groundnut (*Arachis hypogaea* L.). Indian J. Sci. Ind. 2:77-82. (Cited from Plant Breeding Abstr. 39(3):737).
10. Badami, V. K. 1923. Hybridization work on groundnut. India, Mysore, Agr. Dept., for 1922-23. p. 29-30.
11. Bailey, W. K. 1962. Evaluation of new peanut introductions. Second Nat. Peanut Res. Conf., Proc. p. 12-15.
12. Bailey, W. K. 1968. Peanut variety improvement in the USA. Fifth Nat. Peanut Res. Conf., Proc. p. 1-5.
13. Banks, D. J. 1969. Breeding for northern root-knot nematode, *Meloidogyne hapla*, resistance in peanuts. J. Amer. Peanut Res. Educ. Ass. 1(1):23-28.
14. Banks, D. J. 1970. In-the-furrow application of root-knot larvae in field plots. Agron. J. 62:503-504.
15. Banks, D. J. 1971. Flowering and pollen sterility responses of peanut plants to foliar applications of maleic hydrazide. Okla. Acad. Sci., Proc. 51:44-46.
16. Baumann, R. W. and A. J. Norden. 1971. Effect of growth regulators on vegetative and reproductive characteristics of six peanut genotypes. J. Amer. Peanut Res. Educ. Ass. 3(1):75-81.
17. Beattie, J. H., A. M. Jackson and R. E. Currin. 1932. Effect of cold storage and age of seed on germination and yield of peanuts. USDA Circ. 233.
18. Benson, J. A. 1967. A greenhouse crossing bench for peanuts. Agron. J. 59:383-384.
19. Bolhuis, G. G. 1954. Hybridation artificielle de l'Arachide. Oleagineux 9(6):417-419.
20. Briggs, F. N. and P. F. Knowles. 1967. Introduction to plant breeding. Reinhold Publ. Corp., New York. 426 p.
21. Bromfield, K. R. 1971. Peanut rust: A review of literature. J. Amer. Peanut Res. Educ. Ass. 3(1):111-121.
22. Bromfield, K. R. and S. J. Cevario. 1970. Greenhouse screening of peanut (*Arachis hypogaea*) for resistance to peanut rust (*Puccinia arachidis*). Plant Dis. Reptr. 54:381-383.
23. Browning, J. A. and K. J. Frey. 1969. Multiline cultivars as a means of disease control. Ann. Review of Phytopathol. 7:355:382.

24. Campbell, W. V., D. A. Emery and W. C. Gregory. 1971. Registration of GP-NC343 peanut germplasm. Crop Sci. 11(4):605.

25. Carver, W. A. 1953. The Florispan Runner peanut variety. Fla. Agr. Exp. Sta. Circ. S-62.

26. Carver, W. A. 1959. Peanut breeding in Florida. Soil Crop Sci. of Fla., Proc. 19:115-118.

27. Carver, W. A. 1961. Florigiant — a jumbo runner peanut. Fla. Agr. Exp. Sta. Circ. S-129.

28. Carver, W. A. and F. H. Hull. 1939. Peanut Improvement. Fla. Agr. Exp. Sta. Ann. Rept. p. 39.

29. Carver, W. A. and F. H. Hull. 1950. Dixie Runner peanuts. Fla. Agr. Exp. Sta. Circ. S-16.

30. Carver, W. A., F. H. Hull and F. Clark. 1952. The Early Runner peanut variety. Fla. Agr. Exp. Sta. Circ. S-52.

31. Chalfant, R. B. and E. R. Mitchell. 1970. Resistance of peanut varieties to the southern corn rootworm in the field. J. Econ. Entomol. 63:1825-1827.

32. Cheng, C. F. and H. Lin. 1961. Breeding for resistance to *Sclerotium* wilt in peanuts. Crop and Seed Improvement in Taiwan, China. July, p. 134-146.

33. Chohan, J. S., R. S. Sandhu and J. L. Dalal. 1969. Screening of world collection of groundnut (*Arachis hypogaea* L.) germplasm for resistance to collar rot disease caused by *Aspergillus niger* van Tiegham in Punjab. Indian J. Agr. Sci. 40(6):546-551.

34. Chopra, A. K. and I. S. Bhatia. 1970. The influence of habit of growth and environment on the protein quality of groundnut (*Arachis hypogaea* L.). J. Res. Punjab Agr. Univ., Ludhiana. 7(1):69-74. (Cited from Plant Breeding Abstr. 41(3):762).

35. Coffelt, T. A. and R. O. Hammons. 1972. The variable occurrence of albino seedling in different seed size populations of an infraspecific peanut hybrid. Georgia Agro. Abstr. 15:2.

36. Cooper, W. E. and W. C. Gregory. 1960. Radiation-induced leafspot resistant mutants in the peanut (*Arachis hypogaea* L.). Agron. J. 52:1-4.

37. Culp, T. W., W. K. Bailey and R. O. Hammons. 1968. Natural hybridization of peanuts, *Arachis hypogaea L.,* in Virginia. Crop Sci. 8:109-111.

38. Culp, T. W. and J. L. Troutman. 1968. Varietal reaction of peanuts, *Arachis hypogaea,* to stunt virus disease. Plant Dis. Reptr. 52:914-918.

39. Dickens, J. W. 1961. Shelling equipment for samples of peanuts. USDA Marketing Res. Rept. 528. 11 p.

40. Ducker, H. C. 1962. The characteristics, classification, and nomenclature of cultivated groundnuts in the Rhodesias and Nyasaland. Rhodesia Agr. J. 59:24-27.

41. Elliot, F. C. 1958. Plant breeding and cytogenetics. McGraw-Hill Book Co., Inc., New York. 395 p.

42. Emery, D. A. 1962. A peanut breeder looks at marketing. Second Nat. Peanut Res. Conf., Proc. p. 90-91.

43. Emery, D. A. 1963. Reproductive efficiency in Virginia type peanuts I. Differences among varieties. Peanut Improvement Working Group, Proc. p. 107-135.

44. Emery, D. A. 1965. The peanut, the predictable legume. Peanut Farmer 1(1):14.

45. Emery, D. A. 1966. The varietal booster. Peanut Farmer 2(3):10.

46. Emery, D. A. 1970. Registration of NC 17 peanuts. Crop Sci. 10:460.

47. Emery, D. A., J. A. Benson and J. C. Wynne. 1970. Four empirical experiments with Virginia peanut seed mixtures. Oleagineux 25(5):275-278.

48. Emery, D. A. and W. C. Gregory. 1970. Registration of NC 5 peanuts. Crop Sci. 10:460.

49. Emery, D. A., W. C. Gregory and P. J. Loesch, Jr. 1965. Breeding value of the radiation-induced macro-mutant II. Effect of mutant expression and associated backgrounds on selection potential in *Arachis hypogaea* L. The use of induced mutations in plant breeding. Suppl. to Radiat. Bot. 5:339-353. Pergamon Press, London.

50. Emery, D. A. and C. L. Gupton. 1968. Reproductive efficiency of Virginia type peanuts II. The influence of variety and seasonal growth period upon fruit and kernel mutation. Oleagineux 23:99-104.

51. Emery, D. A., C. L. Gupton and R. O. Hexem. 1966. Indexing the maturation of varietal and segregating populations of Virginia type peanuts. Fourth Nat. Peanut Res. Conf., Proc. p. 25-30.

52. Farrior, J. W. 1941. Improvement of Virginia type peanuts by mass selection. Unpubl. M. S. thesis. North Carolina State Coll.

53. Frank, Z. R. 1967. Notes on late leafspot of groundnuts. Phytopathol. mediterr. 6(1-2): 48-50. (Cited from Plant Breeding Abstr. 39(3):738).

54. Frank, Z. R. and J. Krikun. 1969. Evaluation of peanut *(Arachis hypogaea)* varieties for *Verticillium* wilt resistance. Plant Dis. Reptr. 53:744-746.

55. French, R. B. 1962. Analyses of pecan, peanut and other oils by gas-liquid chromatography and ultra-violet spectrophotometry. J. of Amer. Oil Chemists Soc. 39(3):414-415.

56. Frey, K. J. 1964. Adaptation reaction of oat strains selected under stress and non-stress environmental conditions. Crop Sci. 4:55-58.

57. Frey, K. J. 1965. The utility of hill plots in oat research. Euphytica 14:196-208.

58. Frey, K. J., J. A. Browning and R. L. Grindeland. 1970. New multiline oats. Iowa Farm Sci. 24(8):3-6.

59. Frey, K. J. and U. Maldonado. 1967. Relative productivity of homogeneous and heterogeneous oat cultivars in optimum and sub-optimum environments. Crop Sci. 7:532-535.

60. Gautreau, J. 1970. Etude comparative de la transpiration relative chez deux varietes d'arachide. Oleagineux 25(1):23-28.

61. Gibbons, R. W. 1969. Groundnut rosette research in Malawi. Third East African Cereals Conf., Zambia and Malawi. Processed Rep. 8 p.

62. Gibbons, R. W. and J. R. Tattersfield. 1969. Out-crossing trials with groundnuts (*Arachis hypogaea* L.) Rhodesia J. Agr. Res. 7(1):71-85.

63. Gillier, P. and P. Silvestre. 1969. Genetique et amelioration, p. 70-87. *In* l'Arachide. G.-P. Maisonneuve and Larose, Paris.

64. Goldin, E. 1970. New early-maturing Virginia-type groundnuts. World Crops 22:220-224.

65. Gopani, D. D., M. M. Kabaria and N. L. Vaishani. 1970. Size and shape of plots in field experiment on groundnut. Indian J. Agr. Sci. 40(11):1004-1010.

66. Gopani, D. D. and N. L. Vaishnani. 1970. Two mutant forms of groundnut (*Arachis hypogaea* L.). Indian J. Agr. Sci. 40:431-437.

67. Gregory, W. C. 1955. X-ray breeding of peanuts (*Arachis hypogaea* L.). Agron. J. 47(9):396-399.

68. Gregory, W. C. 1956. Radiosensitivity studies in peanuts (*Arachis hypogaea* L.). Int. Genetics Symp., Proc. p. 243-247. Suppl. Vol. Cytologia, July 30, 1957.

69. Gregory, W. C. 1956. Induction of useful mutations in the peanut. Genetics in Plant Breeding. Brookhaven Symp. in Biol. 9:177-190.

70. Gregory, W. C. 1957. Progress in establishing the effectiveness of radiation in breeding peanuts. Ninth Oak Ridge Regional Symp., Proc.: Radiation in Plant Breeding. p. 36-47.

71. Gregory, W. C. 1960. The peanut NC4X, a milestone in crop breeding. Crops and Soils 12(8):12-13.

72. Gregory, W. C. 1961. The efficacy of mutation breeding. Mutation and Plant Breeding. Nat. Acad. Sci. — Nat. Res. Council publ. 891:461-486.

73. Gregory, W. C. 1962. Peanut breeding resources. Second Nat. Peanut Res. Conf., Proc. p. 11-12.

74. Gregory, W. C. 1964. Mutation frequency, magnitude of change and the probability of improvement in adaption, p. 429-441. *In:* The use of induced mutations in plant breeding. Pergamon Press, London.

75. Gregory, W. C. 1966. Mutation breeding, p. 189-218. *In:* Plant breeding. Iowa State University Press, Ames, Iowa.

76. Gregory, W. C. (Ed.). 1968. Review paper: A radiation breeding experiment with peanuts. Radiat. Bot. 8:81-147.

77. Gregory, W. C. 1970. Registration of NC 2 peanuts. Crop Sci. 10:459-460.

78. Gregory, W. C. and M. P. Gregory. 1967. Induced mutation and species hybridization in the de-speciation of *Arachis* L. Ciencia e Cultura 19(1):166-174.

79. Gregory W. C., B. W. Smith and J. A. Yarbrough. 1951. Morphology, genetics and breeding, p. 28-88. *In:* The peanut — the unpredictable legume. The Nat. Fertilizer Ass., Washington, D. C.

80. Gupton, C. L. and D. A. Emery. 1970. Heritability estimates of the maturity of fruit from specific growth periods in Virginia type peanuts (*Arachis hypogaea* L.). Crop Sci. 10:127-129.

81. Gustafsson, A. and T. Gadd. 1965. Mutations and crop improvement V. *Arachis hypogaea* L. (Leguminosae). Hereditas 53:143-164.

82. Hammons, R. O. 1963. Artificial cross-pollination of the peanut with bee-collected pollen. Crop Sci. 3:562-563.

83. Hammons, R. O. 1964. Krinkle, a dominant leaf marker in the peanut, *Arachis hypogaea* L. Crop Sci. 4:22-24.

84. Hammons, R. O. 1964. Pedigreed natural crossing — a new genetic technique. Third Nat. Peanut Res. Conf., Proc. p. 49-53.

85. Hammons, R. O. 1970. Registration of Spancross peanuts. Crop Sci. 10(4):459.

86. Hammons, R. O. 1970. Registration of Tifspan peanuts. Crop Sci. 10(4):459.

87. Hammons, R. O. 1970. Registration of Virginia Bunch 67 peanuts. Crop Sci. 10(4): 460-461.

88. Hammons, R. O. 1970. Registration of Southeastern Runner 56-15 peanuts. Crop Sci. 10(6):727.

89. Hammons, R. O. 1970. Registration of Georgia 119-20 peanuts. Crop Sci. 11(2):313.

90. Hammons, R. O. and D. B. Leuck. 1966. Natural cross-pollination of the peanut, *Arachis hypogaea* L. in the presence of bees and thrips. Agron. J. 58:396.

91. Harrison, A. L. 1971. Peanut leafspot and rust control on peanuts. J. Amer. Peanut Res. Educ. Ass. 3(1):96-101.

92. Harvey, J. E. 1969. A first: Commercial peanut breeding. Peanut Farmer 5(3):24-25.

93. Harvey, P. H. and E. F. Schultz. 1943. Multiplying peanut hybrids by vegetative propagation. J. Amer. Soc. Agron. 35:637-639.

94. Hassan, M. A. and D. P. Srivastava. 1966. Floral biology of the groundnut, *Arachis hypogaea* L. J. of Indian Bot. Sci. 45:93-102.

95. Hayes, H. K., F. R. Immer and D. C. Smith. 1955. Methods of plant breeding. McGraw-Hill Book Co., Inc., New York. 551 p.

96. Hayes, T. R. 1933. The classification of groundnut varieties. Trop. Agr. 10(11):318-327.

97. Heinis, J. L. 1971. Methionine content of 25 peanut selections and effect of molybdenum on methionine and nitrogen in peanut plants. J. Amer. Peanut Res. Educ. Ass. 3(1):52-56.

98. Higgins, B. B. 1957. Relation of breeding and varieties to quality for specific uses. Peanut Res. Conf., Proc. p. 13-20.

99. Higgins, B. B. and W. K. Bailey. 1955. New varieties and selected strains of peanuts. Georgia Agr. Exp. Sta. Bull. N.S.11. 35 p.

100. Higgins, B. B., K. T. Holley, T. A. Pickett and C. D. Wheeler. 1941. I. Peanut breeding and characteristics of some new strains. Georgia Agr. Exp. Sta. Bull. 213. p. 3-11.

101. Holaday, C. E. *(Chairman)*. 1971. Report of the peanut quality committee. J. Amer. Peanut Res. Educ. Ass. 3(1):238-247.

102. Holley, K. T. and R. O. Hammons. 1968. Strain and seasonal effects on peanut characteristics. Georgia Agr. Exp. Sta. Res. Bull. 32. 27 p.

103. Hsi, D. C. H. 1970. An evaluation of host reactions of Valencia peanut accessions grown at two locations to the blackhull disease fungus in vitro. Phytopathology 60:1297.

104. Hsi, D. C. H. and R. E. Finkner. 1972. Registration of New Mexico Valencia A peanut variety. Crop Sci. 12(2):256.

105. Hull, F. H. 1937. Inheritance of rest period of seeds and certain other characters in the peanut. Fla. Agr. Exp. Sta. Tech. Bull. 314. 46 p.

106. Hull, F. H. 1945. Recurrent selection for specific combining ability in corn. J. Amer. Soc. of Agron. 37:134-145.

107. Hull, F. H. and W. A. Carver. 1936. Peanut improvement. Fla. Agr. Exp. Sta. Agron. Mimeo Rept., April 7.

108. Hull, F. H. and W. A. Carver. 1938. Peanut improvement. Fla. Agr. Exp. Sta. Ann. Rept., June 30.

109. Husted, L. 1936. Cytological studies on the peanut, *Arachis* II. Chromosome number, morphology and behavior, and their application to the problem of the origin of the cultivated forms. Cytologia 7(3):396-423.

110. Jensen, N. F. 1952. Intra-varietal diversification in oat breeding. Agron. J. 44:30-34.

111. Jensen, N. F. 1965. Population variability in small grains. Agron. J. 57:153-162.

112. Johansen, E. L. and B. W. Smith. 1956. *Arachis hypogaea* x *A. diogoi.* Embryo and seed failure. Amer. J. of Bot. 43(4):250-258.

113. Ketring, D. L. 1971. Physiology of oil seeds III. Response of initially high and low germinating Spanish-type peanut seed to three storage environments. Agron. J. 63:435-438.

114. Krapovickas, A. 1968. Origen, variabilidad y difusion del mani *(Arachis hypogaea).* Actas y Memorias del XXXVII Cong. Int. de Americanistas 2:517-534.

115. Krapovickas, A., H. M. Cenoz and H. R. Ojeda. 1968. Memoria de la II Reunion Tecnica Nacional de Mani, Corrientes 3 y 4 de Agosta de 1967. (Rept. of the Second Nat. Tech. Meeting on Groundnut, Corrientes, 3 and 4 August, 1967). Bot. Cat. Genet. Fitotec., Corrientes 5:96. (Cited from Plant Breeding Abstr. 41(3):762).

116. Kubicek, J. M. and D. J. Banks. 1971. Endosperm studies in peanuts. Oklahoma Acad. Sci., Proc. 51:51.

117. Kushman, L. J. and J. H. Beattie. 1946. Natural hybridization in peanuts. J. Amer. Soc. Agron. 38:755-756.

118. Lal, S. and N. Mehrotra. 1968. Effect of colchicine on some characters of groundnut (*Arachis hypogaea* L.). Madras Agr. J. 55:549-551. (Cited from Plant Breeding Abstr. 40(3):773-774).

119. Langley, B. C. 1962. Starr Spanish peanuts. Texas Agr. Exp. Sta. Circ. L-562.

120. Leuck, D. B. and R. O. Hammons. 1968. Resistance of wild peanut plants to the mite *Tetranychus tumidellus.* J. of Econ. Entomol. 61(3):687-688.

121. Leuck, D. B. and R. O. Hammons. 1969. Occurrence of atypical flowers and some associated bees *(Apoidea)* in the peanut, *Arachis hypogaea* L. Agron. J. 61:958-960.

122. Leuck, D. B., R. O. Hammons, L. W. Morgan and J. E. Harvey. 1967. Insect preference to peanut varieties. J. Econ. Entomol. 60:1546-1549.

123. Leuck, D. B. and J. L. Skinner. 1971. Resistance in peanut foliage influencing fall armyworm control. J. of Econ. Entomol. 64(1):148-150.

124. Lin, H. 1959. Observations on wilt disease resistance of peanut. J. of Agr. Ass. of China 26:44-48.

125. Lin, H. 1960. The influences of thermal neutrons and X-ray irradiation on peanut in the first generation. J. of Agr. Ass. of China 32:27-37.

126. Lin, H. 1966. Studies of the genetic behavior of quantitative characters in the hybrid progenies of Virginia and Spanish peanut. J. of Agr. Ass. of China 53:1-7.

127. Lin, H. and C. C. Chen. 1967. Studies on the yield components of peanut I. The path coefficient of yield components in different types of peanut. J. of Agr. Ass. of China 57:35-48.

128. Lin, H. and C. C. Chen. 1969. Studies on the seed dormancy of peanut I. Studies on seed dormancy of different varieties of peanut. Taiwan Agr. Quart. 6(1):1-10.

129. Lin, H., C. C. Chen and C. Y. Lin. 1969. Studies on the yield components of peanut. II. The path coefficient of yield components in different crops of peanut. J. of Agr. Ass. of China 65:22-31.

130. Lin, H., C. C. Chen and C. Y. Lin. 1971. Studies on the effect of selection for yield of

pod at different planting densities in F_5 bulk population of peanut. J. of Agr. Ass. of China 47:27-35.

131. Lin, H. and C. Y. Lin. 1971. Studies on the seed dormancy of peanuts II. The effect of seed maturity on dormancy and sprouting of peanuts. J. of Taiwan Agr. Res. 20(3):42-48.

132. Majumdar, P. K., R. Prakash and F. Hague, M. D. 1969. Genotypic and phenotypic variability in quantitative characters in groundnut. Indian J. Genet. 29:291-296. (Cited from Plant Breeding Abstr. 40(4):1088.)

133. Martin, J. P. 1968. Evolution de la richesse en huile dans la descendance d'arachides irradiees. Oleagineux 23(2):105-108.

134. Martin, J. P. 1968. Differences de richesse en huile des graines d'arachide selon leur position dans la gousse. Oleagineux 23(7):453-460.

135. Martin, J. P. 1969. Contribution a l'etude de certains caracteres d'importance agronomique chez l'arachide. Cah. Orstom: Ser. Biol. 7:3-53. (Cited from Plant Breeding Abstr. 40(1):190.)

136. Martin, J. P. 1970. Culture in vitro d'ovules d'arachide. Oleagineux 25(3):155-156.

137. Matlock, R. S. 1969. Research on peanut quality. Fifth Nat. Peanut Res. Conf., Proc. p. 41-54.

138. McGill, J. F. 1963. Peanut varieties. Georgia Coop. Ext. Service Circ. 518.

139. Meikle, J. O. 1965. A survey of Africa-grown groundnut varieties in Rhodesia. Rhodesia Agr. J. Nov.-Dec., p. 2-6.

140. Minton, N. A., R. O. Hammons and S. A. Parham. 1970. Infection of shell and peg tissues of six peanut cultivars by *Pratylenchus brachyurus*. Phytopathology 60:472-474.

141. Mittelholzer, A. S. 1969. Breeding for resistance to *Mychosphaerella* leafspots of groundnuts (*Arachis hypogaea* L.). Third Eastern African Cereals Conf., Zambia and Malawi. Processed Rept. 2 p.

142. Mixon, A. C. 1971. Promptness of radicle emergence as a measure of peanut seed vitality. Agron. J. 63(2):248-250.

143. Morris, N. J. and A. F. Freeman. 1954. Peanut butter VI. The effect of roasting on the palatability of peanut butter. Food Technol. 8:377-380.

144. Mozingo, R. W. 1970. Peanuts: From breeding line to variety in Virginia and North Carolina. J. Amer. Peanut Res. Educ. Ass. 2(1):18-21.

145. Mozingo, R. W. 1971. Peanut variety and quality evaluation in Virginia and North Carolina 1968-1970 results. Southern Coop. Ser. Bull. 166. 51 p.

146. Nicholaides, J. J., F. R. Cox and D. A. Emery. 1969. Relation between environmental factors and flowering periodicity of Virginia type peanuts. Oleagineux 24:681-683.

147. Norden, A. J. 1968. Peanut breeding. Sunshine State Agr. Res. Rept. Jan., p. 14-16.

148. Norden, A. J. and D. H. Block. 1968. Variety blends: A consideration in peanut oil improvement and production. Oleagineux 23(10):583-586.

149. Norden, A. J. and R. W. Lipscomb. 1968. Relationship between growth habit and genetic background in peanuts at different row spacings. Agron. Abstr., Amer. Soc. of Agron. p. 16.

150. Norden, A. J., R. W. Lipscomb and W. A. Carver. 1969. Florunner — a new peanut variety. Fla. Agr. Expt. Sta. Circ. S-196.

151. Norden, A. J. and V. A. Rodriquez. 1971. Artificial hybridization of peanuts. Oleagineux 26(3):159-162.

152. Nuchowicz, A. 1955. Recherches sur la culture d'embryons et de fragments d'embryons d'*Arachis hypogaea* L. (Research on the culture of (excised) embryos and of sections of embryos of *A. hypogaea.*) Agr., Louvain 3(1):3-37, bibl. 21, illus. (Univ. Louvain, Belgium). (Cited from Field Crop Abstr. 9(3):162-163.)

153. Oakes, A. J. 1958. Pollen behavior in the peanut, *Arachis hypogaea.* Agron. J. 50(7): 387-389.

154. Ojomo, O. A. and B. O. Adelana. 1970. Variety x environment interactions in groundnut variety test in western Nigeria. J. Agr. Sci., Cambridge, England 75:419-420.

155. Ollagnier, M. 1951. Forme, dimension des parcelles et nombre de repetitions dans les essais culturaux sur arachide et sur palmier a huile. Oleagineux 6:707-710, bibl. 6. (Cited from Field Crop Abstr. 5(3):148.)

156. Parker, R. C., J. C. Wynne, and D. A. Emery. 1970. Combining ability estimates in *Arachis hypogaea* L. I. F_1 seedling responses in a controlled environment. Crop Sci. 10:429-432.

157. Patel, J. S., C. M. John and C. R. Seshadri. 1936. The inheritance of characters in the groundnut *Arachis hypogaea.* Indian Acad. of Sci., Proc. 3(3):214-233.

158. Pfahler, P. L. 1965. Environmental variability and genetic diversity within populations of oats (Cultivated species of *Avena*) and rye (*Secale cereale* L.). Crop Sci. 5:271-275.

159. Quader, M. A. 1966. Cytological studies in colchicine induced polyploids in groundnut (*Arachis hypogaea* L.). Ann. Agr. Res. Abstr. post-grad. Res. Wk. 1960-1965: Nagpur Agr. Coll. Mag.: Spec. Res. No. 119-120. (Cited from Plant Breeding Abstr. 39(1):171.)

160. Ramachandran, M., N. S. Loganathan, C. S. Sridharan, N. R. Chandrasekharan, and P. Krishnaswami. 1967. Evolution of dormant bunch groundnut strains by hybridization. Indian J. Agr. Sci. 37:429-436.

161. Ramage, R. T. 1968. Hybrid barley — a breakthrough. Agr. Res. Sept., p. 4.

162. Raman, V. S. and S. R. Sree Rangasamy. 1970. Genetic variability of quantitative attributes in the progenies of the hybrid, *Arachis hypogaea* x *A. monticola.* Madras Agr. J. 57(11):570-577.

163. Ramanathan, T., B. W. X. Ponnaiya and V. S. Raman. 1969. Studies on the breeding behavior of interspecific hybrid derivatives in the genus *Arachis* L. Madras Agr. J. 56:691-698. (Cited from Plant Breeding Abstr. 41(1):187.)

164. Ramanathan, T. and V. S. Raman. 1968. Studies on the relation of certain genetic characters in hybrid populations of groundnut (*Arachis hypogaea* L.) J. Indian Bot. Soc. 47(1-2):113-116.

165. Robinson, H. F., J. A. Rigney and P. H. Harvey. 1948. Investigations in peanut plot technique. N. C. Agr. Exp. Sta. Tech. Bull. 86. 19 p.

166. Rodriquez, V. A. and A. J. Norden. 1970. Inheritance of inner seed-color in peanuts. J. of Hered. 61(4):161-163.

167. Seshadri, C. R. 1962. Breeding procedures on groundnut p. 108-129. *In:* Groundnut. Indian Central Oilseeds Comm., Hyderabad, India.

168. Sharma, K. D. 1964. An improved crossing technique in groundnut. Indian Central Oilseeds Comm., Third Conf., Oilseed Res. Wkrs. in India, p. 36-37.

169. Shear, G. M. and L. I. Miller. 1960. Influence of plant spacing of the jumbo runner peanut on fruit development, yield and border effect. Agron. J. 52:125-127.

170. Smartt, J. 1964. Interspecific hybridization in relation to peanut improvement. Third Nat. Peanut Res. Conf., Proc. p. 53-56.

171. Smartt, J. 1965. Cross-compatability relationships between the cultivated peanut *Arachis hypogaea* L. and other species of the genus *Arachis.* Ph.D. thesis. North Carolina State Univ. 83 p. Ann Arbor, Mich., Univ. Microfilms No. 65-8968.

172. Smartt, J. and W. C. Gregory. 1967. Interspecific cross-compatability between the cultivated peanut *Arachis hypogaea* L. and other members of the genus *Arachis.* Oleagineux 22(7):455-459.

173. Smith, J. C. and D. M. Porter. 1971. Evaluation of selected peanut lines for resistance to the southern corn rootworm in the greenhouse. J. of Econ. Entomol. 64(1):245-246.

174. Stokes, W. E. and F. H. Hull. 1930. Peanut breeding. J. Amer. Soc. of Agron. 22:1004-1019.

175. Stone, E. G. 1968. Genetic, agronomic, botanical, physical, chemical and organoleptic evaluation of peanuts, *Arachis hypogaea* L. Ph.D. thesis, Oklahoma State Univ., 149 p.

176. Syakudo, K. and S. Kawabata. 1963. Studies on peanut breeding with reference to the combinations of some main characters I. On pod-setting percentage in the crossing among varieties and characteristics of F_1 plants. Japanese J. of Breeding 13(3):137-142.

177. Takeuchi, S. 1969. Breeding of the peanut in Japan. Japan Agr. Res. Quart. 4(4):11-14.

178. Tattersfield, J. R. 1966. Groundnuts in Rhodesia. Rhodesian Farmer. Aug., p. 12-13.

179. Tattersfield, J. R. 1967. Release of a new groundnut variety: Valencia RI. Rhodesia Agr. J. 64(4):1.

180. Toole, V. K., W. K. Bailey and E. H. Toole. Factors influencing dormancy of peanut seeds. Plant Physiol. 39(5):822-832.

181. Tripp, L. D. 1968. Germplasm evaluation and inheritance studies in peanuts, Ph.D. thesis, Oklahoma State Univ., 57 p. Ann. Arbor, Mich., Univ. Microfilms (Diss. Abstr. Int. 30(3):916B, 1969).

182. Tsui, J. G. C. 1968. Studies to aid peanut breeding techniques. Unpubl. M. S. thesis, Oklahoma State Univ., 39 p.

183. Umen, D. P. 1933. (What has been done in groundnut breeding). (Technique of artificial hybridization in *Arachis*.) (Biology of peanut flowering.) Lenin Acad. Agr. Sci., Inst. Sci. Res. Oil Cult. Krasnoda, No. 5:8-12, 29-33; No. 6:1-57. (Cited from Plant Breeding Abstr. 5:60.)

184. Van der Stok, J. E. 1910. Onderzoekingen omtrent, *Arachis hypogaea* L. (Katang-Tanah). Med. van het Dept. Land. 12:176-221. (Cited from Hull, 1937.)

185. Van der Stok, J. E. 1923. Erdnuss, *Arachis hypogaea* L. In Fruwith, C. Hanbuch der landwirtschaftenlichen Pflanzen zuchtung 5:202-205. (Translated into English by Mrs. Elke Humpries and Dr. R. O. Hammons.)

186. Walton, P. D. 1969. Multiline strains of spring wheat. J. of Hered. 60(4):205.

187. Watson, S. A. 1966. What is peanut quality? Peanut farmer 2(8):18-19.

188. Woodroof, J. G. 1966. Peanuts: Production, processing, products. Avi Publ. Co., Westport, Connecticut. 291 p.

189. Worthington, R. E. and R. O. Hammons. 1971. Genotypic variation in fatty acid composition and stability of *Arachis hypogaea* L. oil. Oleagineux 26(11):695-700.

190. Wynne, J. C., D. A. Emery and P. W. Rice. 1970. Combining ability estimates in *Arachis hypogaea* L. II. Field performance of F_1 hybrids. Crop Sci. 10:713-715.

191. Young, S. C. 1969. Field and laboratory tests for genetic resistance of peanuts to the tobacco thrips, *Franklinella fusca*. Ph.D. thesis, Oklahoma State Univ. 113 p.

192. Zamotajlov, S. S. 1969. (Fertilization in the groundnut and the effect of temperature on this process.) Trud. Kuban. sel'skohoz. Inst. (Trans. Kuban. Agr. Inst.) 1968 (17) (45):134-142; from Ref. Z. (Ref. J.) 1969. Abstr. 4V363. (Russian.) (Cited from Plant Breeding Abstr. 40(3):774.)