GROWTH AND PRODUCTION OF GROUNDNUTS

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Contents

Summary

The groundnut or peanut is one of the important legume crops of tropical and semiarid tropical countries, where it provides a major source of edible oil and vegetable protein. Groundnut kernels contain 47-53% oil and 25-36% protein. The crop is cultivated between 40ºN to 40ºS of the equator. Groundnut is a self pollinated crop whereby flowers are produced above ground and, after fertilization, pegs move towards the soil, and seed-containing pods are formed and developed underneath the soil.

The productivity of groundnuts varies from 3500 kg/ha in the United States of America to 2500 kg/ha in South America, 1600 kg/ha in Asia, and less than 800 kg/ha in Africa. This is due mainly to various abiotic and biotic constraints. Abiotic stresses of prime importance include temperature extremes, drought stress, soil factors such as alkalinity, poor soil fertility and nutrient deficiencies. Groundnuts grow best in light textured sandy loam soils with neutral pH. Optimum temperature for their growth and development ranges from 28 to 30 ºC; the crop requires about 500-600 mm of well distributed rainfall.

The main yield limiting factors in semiarid regions are drought and high temperature stress. The stages of reproductive development prior to flowering, at flowering and at early pod development, are particularly sensitive to these constraints. Apart from N, P and K, other nutrient deficiencies causing significant yield losses are Ca, Fe and B. Biotic stresses mainly include pests, diseases and weeds. Among insects pests pod borers, aphids and mites are of importance. The most important diseases are leaf spots, rusts and the toxin-producing fungus *Aspergillus*.

1. Origin and Distribution

The cultivated groundnut or peanut (*Arachis hypogaea* L.) originated in South America. The term *Arachis* is derived from the Greek word "arachos", meaning a weed, and *hypogaea*, meaning underground chamber, i.e. in botanical terms, a weed with fruits produced below the soil surface. There are two most common names used for this crop i.e. groundnut or peanut. The term groundnut is used in most countries of Asia, Africa, Europe and Australia, while in North and South America it is commonly referred to as peanut. The term groundnut refers to the pods with seeds that mature underground; the connotation of peanut is because this crop belongs to the leguminous family which includes also other crops such as peas and beans. It is a legume crop and not related to other nuts (e.g. walnut, hazelnut or cashews). The terminology of nut is used due its unusual growing habit where flowers are formed above ground (soil) and after fertilization the gynoecium penetrates the soil and forms pods which contain seeds (kernels). In this manuscript the term groundnut will be used due its wider acceptance.

The earliest archaeological records of groundnuts in cultivation are from Peru, dated 3750-3900 years before present (BP). Groundnuts were widely dispersed through South and Central America by the time Europeans reached the continent, probably by the Arawak Indians. There is archaeological evidence of their existence from Mexico, dated 1300-2200 BP. After European contact, groundnuts were dispersed world-wide. The Peruvian runner type was taken to the Western Pacific, China, Southeast Asia and Madagascar. The Spanish probably introduced the Virginia type to Mexico, via The Philippines, in the sixteenth century. The Portuguese then took it to Africa, and later to India, via Brazil. Virginia types apparently reached the Southeast US with the slave trade. Gibbons *et al*. (1972) noted substantial secondary diversity in Africa and Asia. The types they found and their locations supported these various conjectures regarding dispersal.

2. Taxonomy and Classification

The genus *Arachis* belongs to family *Fabaceae*, subfamily *Papilionaceae*, tribe *Aeschynomeneae*, subtribe *Stylosanthinae*. This genus is morphologically well defined and distinguished from other genera by having a peg and geocarpic reproductive growth. The genus *Arachis* has more than 70 wild species, of which only *Arachis hypogaea* L. is domesticated and commonly cultivated.

The taxonomy of the genus *Arachis* has been well documented and includes 37 named species and a number of undescribed species. The genus has been divided into nine sections i.e., *Arachis, Caulorrhizae, Erectoides, Extranervosae, Heteranthae, Procumbentes, Rhizomatosae, Trierectoides* and *Triseminalae*. The section Arachis comprises an annual and perennial diploid ($2n = 20$) and two annual tetraploids ($2n = 4x = 40$). The leaves of *Arachis hypogaea* L. are tetrafoliolate, and plants are typically erect or decumbent and pegs penetrate the soil at an angle of approximately 45°. Most of the earlier classifications of *Arachis hypogaea* L. were based on growth habit, presence or absence of seed dormancy and relative time to maturity. In later classifications, characters such as branching pattern and location of reproductive branches have been included.

Cultivated groundnuts are divided into two large botanical groups, Virginia and Spanish-Valencia, on the basis of branching pattern. There are two basic types of branching "alternate" and "sequential", and cultivar groups within the two branching patterns are considered as subspecies. In the Virginia group, the main stem does not have reproductive axes. Alternating pairs of vegetative and reproductive axes are borne on the cotyledonary laterals and on other $n+1$ branches (where `n' is the main axis, and primary, secondary and tertiary branches are $n+1, n+2$ and $n+3$, respectively). This system was termed the `alternate branching pattern'. The first two branches on the $n+1$ laterals are always vegetative and the alternate branching pattern is repeated in the higher order branches.

In the Spanish-Valencia group, reproductive branches are borne in a continuous series on successive nodes of the cotyledonary and other lateral branches, on which the first branch is always reproductive. Reproductive branches are also borne directly on the main axis at higher nodes. Most $n+2$ and $n+3$ nodes are reproductive.

Subdivision of *Arachis hypogaea* L. holds two subspecies: *A. hypogaea subsp. hypogaea* and *A. hypogaea subsp. fastigiata*. Subspecies *hypogaea* has a central axis that never bears inflorescence and has laterals where vegetative branches alternate regularly with reproductive branches. The inflorescence is simple, seeds show dormancy and plants are late maturing (120 to 150 days depending on temperature and crop density). In general, these types branch profusely and have a runner or spreading bunch habit. In runners (prostrate) the stems trails over the ground, while in spreading bunch, the main stem is erect, while branches trails on the ground. The US market types Virginia and Virginia Runner and the distinct variety *hirsuta* belong to this group.

Arachis hypogaea subsp. fastigiata comprises plants that are always erect, with inflorescence on the central axis, and without a regular pattern in the sequence of reproductive and vegetative branches. The inflorescence is simple or compound, pods are concentrated around the central axis, and seeds do not show dormancy; plants are early maturing (90 to 120 days). In general, these types are sparsely branched and have an erect bunch habit. The US market types Valencia and Spanish belong to this group.

3. Groundnut Production and Productivity

The world groundnut (in shell) harvested area in 2007 (FAO, 2007) was 23.4 million ha with a total production of 34.9 million metric tons (Mt). The total harvested area in 2007 increased by 3.7 million ha when compared to 1990, while production increased by 11.7 million Mt. The world's average productivity in 2007 was about 1490 kg/ha. It is cultivated in as many as 90 countries. Groundnut is therefore an oilseed crop on a global scale.

Groundnuts are predominantly grown in developing countries (Asia and Africa), where the crop finds the appropriate climates for optimum production. About 90% of the total world production comes from this region and about 60% of production comes from the semiarid tropics (SAT). Roughly two-thirds of this is used for oil, making it one of the important sources of vegetable oil, along that of soybean, sunflower and palm oil (see also: *Growth and Production of Soybeans* and *Growth and Production of Oil Palm*).

3.1. Asia

Asia has the largest area of groundnut cultivation in the world contributing to 67% of the total production in 2007. India holds the largest acreage (6.7 million ha) followed by China (4.7 million ha), Indonesia, Myanmar, Pakistan and Thailand. There has been an important increase in harvested area in Asia in the last two decades, mainly in China, Hong Kong, Japan, Korea and Taiwan.

More than 25% of the groundnut area harvested in the world is in India followed by 20% in China. However, China is the largest producer of groundnut and accounts for 37% of world production, followed by India with 22%. The average productivity of groundnut in Asia is 1739 kg/ha.

In India the important groundnut growing states are Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, and Rajasthan. The crop is grown in all three seasons: rainy, post-rainy, and during summer months. It is mostly cultivated under rain fed conditions; only about 10-15% of the cropping area is irrigated.

3.2. Africa

In Africa, groundnut is grown mainly in Nigeria, Sudan, Senegal, Chad, Ghana, Congo, and Niger. In 2007, the total harvested area in Africa was 9.04 million ha with a total production of 8.7 million Mt. The average productivity in this region is 964 kg/ha, which is poor when compared to the US and other developed countries where it is close to 3500 kg/ha. Average productivity is 1720 kg/ha in Nigeria, 500 kg/ha in Sudan, and close to 700 kg/ha in Senegal. For a long time groundnut was the main export product of Senegal and The Gambia.

3.3. North America

In 2007, the total harvested area in the US was 0.57 million ha, with a total production of 1.6 million Mt. The average productivity of this region is 3508 kg/ha, which is about 2000 kg/ha above the world average. Production is mainly concentrated in three major geographic areas: the Southeast, which includes Alabama, Florida, Georgia, and South Carolina; the Southwest, which includes New Mexico, Oklahoma, Texas; and Virginia-Carolina, which includes North Carolina and Virginia. The largest single area in the US is found in Georgia, followed by North Carolina and Alabama.

3.4. South America

The major countries growing groundnut in South America are Argentina, Brazil, Paraguay, Ecuador and Bolivia. The crop is cultivated over an area of 0.39 million ha, with a total production of 1.02 million Mt in 2007. The average productivity of this region is 2595 kg/ha. Argentina is the major groundnut growing country in the region, contributing to more than 70% of area and production. The SAT growing region in this continent is in Brazil, located between 19° and 25° South.

3.5. Europe

In 2007, the total European production amounted to 8,910 Mt, which comes from a harvest area of 10,506 ha with an average productivity of 843 kg/ha. The major groundnut growing country is Greece, followed by Spain, Portugal, and Hungary. There has been a significant variability in the total groundnut area harvested in this region in the last two decades. It increased from 12,718 ha in 1980 to 17,849 ha in 1990, and then decreased again to 11,080 ha in 2007.

4. Utilization

Groundnut is an important subsistence food crop throughout the tropics. It is mainly grown for the kernels and the edible oil and meal derived from them, and the vegetative residue. Groundnut kernels typically contain 47-53% oil and 25-36% protein; they also contain about 10-15% carbohydrate and are rich in P; they are also a good source of vitamins B and E.

Groundnuts are used in various forms, which include groundnut oil, roasted, and salted groundnut, boiled or raw groundnut or as paste popularly known as groundnut (or peanut) butter. The tender leaves are used in certain parts of West Africa as a vegetable in soups. Groundnut oil is the most important product of the crop, which is used for both domestic and industrial purposes. About 75% of the world groundnut production is used in extraction of edible oil.

Groundnut oil is the cheapest and most extensively used vegetable oil in India. It is used mainly for cooking, for margarine and vegetable ghee, salads, for deep-frying, for shortening in pastries and bread, for pharmaceutical and cosmetic products, as a lubricant and emulsion for insecticides and as a fuel for diesel engines. The press cake containing 40-50% protein is used mainly as a high-protein livestock feed and as a fertilizer.

The dry pericarp of the mature pods (known as shells or husks) is used for fuel, as a soil conditioner, filler in fertilizers and feeds, or is processed as substitute for cork or hardboard or composting with the aid of lignin decomposing bacteria. The foliage of the crop also serves as silage and forage. With the recent thrust on bioenergy, possibilities are being tested for using groundnut as a bio-diesel crop, because groundnut produces more oil per hectare than any other food crop.

5. Growth and Development of Groundnut

5.1. Growth Stages

The growth stages of groundnut plants based on visual observations of vegetative and reproductive growth have been described and defined by Boote (1982). This widely adopted system describes a series of vegetative (V) and reproductive stages (R), and all stages are discrete population-based events which are mostly determined by field observations (Table 1). Different reproductive stages of groundnut are shown in Figure 1.

Stage	**Stage Title**	**Description**
Vegetative Stages		
VE	Emergence	Cotyledons near the soil surface with the seedling partly visible
V0		Cotyledons are flat and open at or below the soil surface
V1	First tetrafoliolate	One of n developed nodes on the main axis, a node is counted when its tetrafoliolate is unfolded and its leaflets are flat
Reproductive Stages		
R1	Beginning bloom	One open flower at any node
R2	Beginning peg	One elongated peg (gynophore)
R3	Beginning pod	One peg in soil with swollen ovary at least twice the weight of the peg

R4	Full pod	One pod fully expanded to dimensions characteristic for the cultivar
R5	Beginning seed	One fully expanded pod with which seed cotyledon growth is visible when the fruit is cur in cross-section
R6	Full seed	One pod with cavity apparently filled by the seed when fresh
R7	Beginning maturity	One pod showing visible natural coloration or blotching of inner pericarp or testa
R8	Harvest maturity	66 – 75% of all developed pods have testa or pericarp coloration
R9	Over-mature pod	One undamaged pod showing orange-tan coloration of tests and/or natural peg deterioration

Table 1. Growth stage descriptors for groundnut (Boote, 1982).

5.2. Seedling and Vegetative Growth

The groundnut seed consists of two cotyledons, a hypocotyl, epicotyl, and radicle. All primordial leaves, which the seedling will develop within the first few days after germination, are present in the seed. There may be 4-5 leaf primordia in the embryo of seed; five are well developed in large seeds and four in small ones. Germination is epigeal, the cotyledons become green soon after emergence. The seedling consists of cotyledons, vegetative axes, and the main axis. The hypocotyl is white and is easily distinguished during the early stages of growth, but becomes indistinguishable from the root as the plant matures.

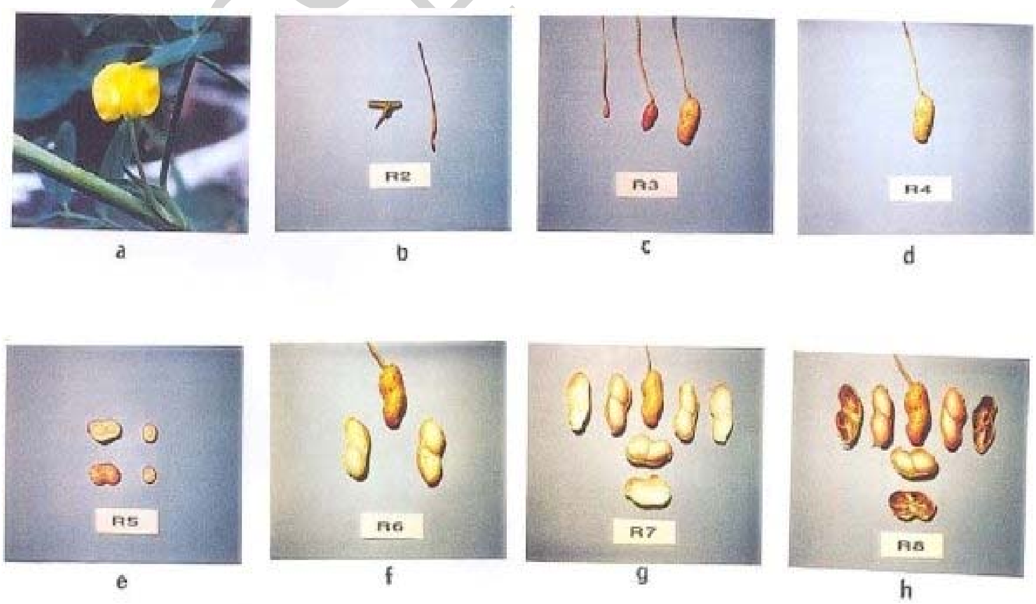

Figure 1. Reproductive stages of groundnut showing (a) appearance of first flower, R1; (b) pegging, R2; (c) podding, R3; (d) full pod, R4; (e) starting of seeding, R5;

(f) full seed, R6; (g) mature seed, R7; and (h) harvest maturity, R8.

Groundnuts take about 3-5 days for germination and emergence from the soil at 30° C. The radicle emerges within 24 h or earlier for vigorous Spanish types and within 36 to 48 h in Virginia types. The primary root system is tap-rooted but many lateral roots also appear about 3 days after germination. Roots are concentrated in the 5 to 35 cm zone below the soil surface, but penetrate the profile to a depth of 135 cm. Groundnut roots do not have typical root hairs, but rather tufts of hair, which are produced in the root axils.

During the first few days the developing seedlings are dependent on assimilates stored in cotyledons. After 5-10 days, depending upon cultivar and environmental conditions, the seedling grows autotrophically and is capable of absorbing minerals via the roots whilst the epicotyl is exposed to light and capable of photosynthesis. Stems are angular, green or pigmented and are initially solid, but as the plants grow they tend to become somewhat hollow. The main stem develops from a terminal bud of the epicotyl and two opposite cotyledonary laterals grow at soil level. The main stem can be upright or prostrate and from 12 to 35 cm long or may exceed 1m in runner types.

The early vegetative growth stage is mainly concerned with mainstem elongation and leaf production, whereas the formation of lateral branches dominates later growth. Mainstem leaves account for >50% of the leaf area of plants for the first 35 days, but at 90 days they account only for 10%. After flowering, dry matter accumulation is mainly in the reproductive structures.

The growth and branching patterns differ between subspecies and botanical types. Subspecies *hypogaea* has alternating pairs of vegetative and reproductive nodes, while subspecies *fastigiata* has a sequential pattern of reproductive nodes.

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Biographical Sketches

P.V. Vara Prasad is an Associate Professor of Crop Ecophysiology in the Department of Agronomy at Kansas State University. He holds a PhD in Agriculture from The University of Reading, UK. His research mainly focuses on stress physiology of food crops and developing crop management strategies for efficient use of inputs and improving productivity. He teaches graduate level courses in Crop Physiology and Advanced Crop Ecology. He has on-going international research programs in West Africa and India. He has published 50 peer reviewed journal articles and book chapters in reputed journals of books. Dr. Prasad served as a reviewer for more 20 different international journals. He was an editor of Communications in Biometry and Crop Science and currently serves in the editorial board of the African Journal of Agricultural Research. He is an active member of the American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, American Society of Plant Biology, and the International Society for Agricultural Meteorology.

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Hari D. Upadhyaya is a Principal Scientist and Head of Gene Bank at International Crops Research Institute for the Semi Arid Tropics in Patancheru, India; and Adjunct Professor in the Department of Agronomy at Kansas State University. He holds a PhD from GB Pant University of Agriculture and Technology in India. He started his career as a groundnut breeder at University of Agricultural Science in Dhaward, India, and later moved to ICRISAT and served in Crop Improvement and Management Program. Dr. Upadhyaya is a well recognized scientist in the area of plant breeding and genetic resource management. He has developed an innovative method of developing mini core collection and utilizing them for crop improvement. He has used this method for several crops including sorghum, peanut, chickpea and finger millet. He has published more than 100 journals article and book chapters. He has been a reviewer for several international journals and currently serves in the editorial board of Field Crops Research. He received several national and international awards and was nominated a fellow of the American Society of Agronomy, and Crop Science Society of America.