Growth Stages of Peanut (*Arachis hypogaea* L.)[1]

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ABSTRACT

Uniform growth stage descriptions were developed for peanut based on visually observable vegetative (V) and reproductive (R) events. The V stage was determined by counting the number of developed nodes on the main stem, beginning with the cotyledonary node as zero. The last node counted must have its tetrafoliolate leaf sufficiently expanded so the leaflets are unfolded and flat in appearance. The R stages proposed are R1 (beginning bloom), R2 (beginning peg), R3 (beginning pod), R4 (full pod), R5 (beginning seed), R6 (full seed), R7 (beginning maturity), R8 (harvest maturity), and R9 (over mature pod). The V and R stages can be measured separately and concurrently and apply to populations or single plants. For populations, a given stage is reached when 50% of the plants sampled have achieved the specified node number or have one or more flowers, pegs, pods, or seeds exhibiting the specified trait. The stages apply to both Spanish and Virginia type cultivars.

The proposed standard descriptions of peanut plant development should aid in peanut research planning and communication and should assist extension recommendation of timing of cultural practices.

Key Words: Groundnut, Development stages, Vegetative development, Flowering, Pegging, Pod development, Seed development, Maturation, Inner pericarp coloration.

Uniform growth stage descriptions have been developed for several crops and have facilitated better communication among producers, researchers, and educators concerned with crop development. Such stage descriptions have already been used successfully on some crops to better schedule a variety of cultural practices, including irrigation, herbicides, insecticides, fungicides, growth regulators, and harvest. Specific morphological stages are more accurately followed than general descriptive ones, such as "blooming" or "fruiting" or "lapping in the middles". There is a similar need for uniform growth stage descriptions which apply to both the spanish and virginia botanical types of peanuts.

Growth stages have been defined for soybean (*Glycine max* L. Merr.) by Fehr, Caviness, Burmood, and Pennington (7) and Fehr and Caviness (6), for corn (*Zea mays* L.) by Hanway (10), for sorghum (*Sorghum bicolor* L. Moench) by Vanderlip and Reeves (20), for wheat (*Triticum aestivum* L.) by Waldren and Flowerday (21) and Haun (11), and for cotton (*Gossypium hirsutum* L.) by

Elsner, Smith, and Owen (4). Their common objective was to propose precise, objective descriptions of discrete, visual phenological events in the morphological and physiological development of a plant. Hanway (10) suggested that proposed growth stages should relate to important transitional periods in the plant life cycle and should occur regularly throughout the life cycle to permit growth staging at various times during the growing season. Another frequent feature of growth staging is to separately designate vegetative growth stages and reproductive growth stages as was done for soybean (6, 7). This approach is used in this paper.

Research related to peanut plant growth stages include fruit development studies by Schenk (18) and fruit maturation stages described by Pattee et al. (16) and by Williams and Drexler (22). Their research pertains to growth and maturation of individual fruits *per se* and does not relate directly to the progress in the life cycle of the peanut plant. Williams, Hildebrand, and Tattersfield (23), in order to study environmental effects on various peanut growth periods, divided the peanut life cycle into ten arbitrary phases of development. They described growth phases such as germination and emergency, vegetative growth only, vegetative growth and first flowers, etc., but they did not emphasize the precise, visual events (stages) needed to mark the beginning or end of each phase. Many investigators have described methods to predict peanut maturity, but these efforts have ignored plant growth staging (9, 12, 15, 17).

My objective was to design stage of development descriptions for spanish and virginia type peanuts based on visually observable vegetative (V) and reproductive (R) events. The V and R stages were patterned as much as possible after those developed for soybean (6, 7), because that system has been successful and a similar approach would allow a given V or R stage to mean nearly the same for both crops. These growth stage descriptions were first adapted to peanut as proposed by Boote (1).

Materials and Methods

Florunner and Starr peanut cultivars were planted May 8, 1979 in a deep, well-drained Arredondo fine sand at the University of Florida Agronomy Farm, Gainesville, FL. Seeds were hand-planted at 10-cm spacing in 76-cm rows. Recommended cultural practices - deep plowing, fertilization, herbicides, gypsum, fungicides, and insecticides were used, although leafspot control broke down in late season for unknown reasons. Plots were irrigated as needed.

Peanut plants were observed approximately three times per week. Vegetative stages were observed on one-plant samples. Peg and fruit development and reproductive stages were observed on 5- to 10-plant samples taken from one contiguous section of row at 3 to 7 day intervals. All samplings were confined to a uniform 6 by 12 m area of peanuts.

Results and Discussion

Vegetative Growth Stages: Determination of the vegetative growth stage (Table 1) is based on the number of developed nodes on the main axis of the peanut plant, beginning with the cotyledonary node as zero. Nodes, rather than leaves, are used for stage determination because they are permanent, whereas early leaves may be lost. When a peanut leaf drops, the node can easily be identified by either the stipules or by the petiole scar or by presence of a branch in the former axil of the leaf. Commonly, two cotyledonary branches develop at the cotyledonary node, one in each axil of the cotyledonary (seed) leaves. In spite of two seed leaves and two cotyledonary branches, this node is considered as one node and is designated node "zero" because it is the site of seed leaves. The first true leaf forms at the next node up, which is designated as node "one". A node is counted as developed when its tetrafoliolate has developed sufficiently so its leaflets are unfolded and flat.

Table 1. Growth stage descriptions for peanut.

Stage No.	Abbreviated stage title	Description
------------------------Vegetative Stages[†]-------------------------		
VE	Emergence	Cotyledons near the soil surface with the seedling showing some part of the plant visible.
VO		Cotyledons are flat and open at or below the soil surface.
V-1 V-(N)	First tetrafoliolate to Nth tetrafoliolate	One to 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 on the plant.
R2	Beginning peg	One elongated peg (gynophore).
R3	Beginning pod	One peg in the soil with turned swollen ovary at least twice the width of the peg.
R4	Full pod	One fully-expanded pod, to dimensions characteristic of the cultivar.
R5	Beginning seed	One fully-expanded pod in which seed cotyledon growth is visible when the fruit is cut in cross-section with a razor blade (Past the liquid endosperm phase).
R6	Full seed	One pod with cavity apparently filled by the seeds when fresh.
R7	Beginning maturity	One pod showing visible natural coloration or blotching of inner pericarp or testa.
R8	Harvest maturity	Two-thirds to three-fourths of all developed pods have testa or pericarp coloration. Fraction is cultivar-dependent, lower for Virginia types.
R9	Over-mature pod	One undamaged pod showing orange-tan coloration of the testa and/or natural peg deterioration.

† For populations, V stages can be averaged if desired. Reproductive stages should not be averaged. An R stage should remain unchanged until the date when 50% of the plants in the sample demonstrate the desired trait of the next R stage. The timing of a reproductive stage for a given plant is set by the first occurrence of the specific trait on the plant without regard to position on the plant.

The vegetative stage "VE" or emergence is defined as cotyledons near the soil surface with some part of the plant visible in half of the seedlings. This stage corresponds closely to the period commonly termed "cracking". The rate of progression from seeding to "VE" is primarily dependent on soil temperature, although modified by soil water and seed dormancy mechanisms. Hypothetically,

there may be a vegetative stage "VO" when cotyledons are flat and open at or slightly below the soil surface, but the time of occurrence is too close to VE to justify distinction.

Vegetative stage V1 is defined as one developed node with one tetrafoliolate leaf unfolded and its leaflets flat. Subsequent V stages up to V_N are based on N developed nodes on the main axis of the plant, counting the uppermost last node having a tetrafoliolate unfolded with its leaflets flat. Rate of node development (V stage progression) is dependent on air and soil temperature, availability of soil water, and plant maturity. Figure 1 shows that the rate of node development of Starr and Florunner was initially rapid, but progressively slowed as the plants matured and set fruit. Further studies on many cultivars are needed before one can suggest any particular relationship of V stage to R stage, i.e. that R1 for a given cultivar occurs on a specific V stage. Nevertheless, this may be a worthy research objective, since both vegetative and reproductive development of peanut responds mainly to temperature with little effect of photoperiod (2, 5, 15, 24).
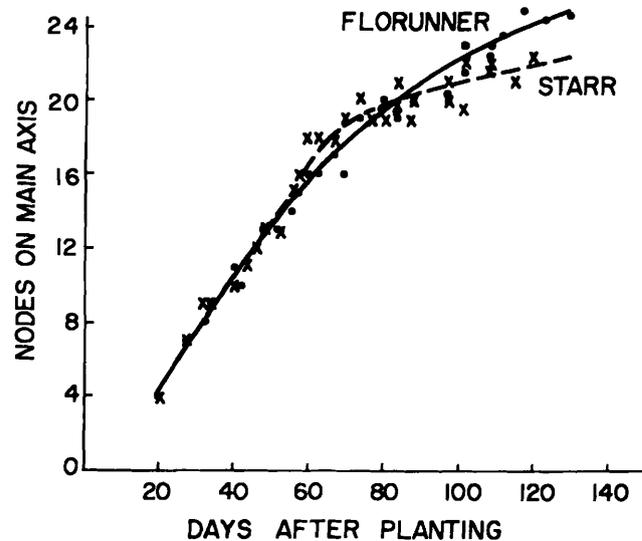

Fig. 1. Development of nodes on main axis of Starr (X) and Florunner (●) peanut during the 1979 season at Gainesville, FL.

Reproductive Stages: Determination of reproductive stages is based upon visually observable events related to flowering, pegging, fruit growth, seed growth, and maturity (Stages are defined in Table 1). Reproductive stages are similar to those developed for soybean by Fehr and Caviness (6), except that R2 was re-defined as "beginning peg" and R9 stage was added to denote "over-mature pods". Days from planting to specific R stages are given in Table 2 for Starr and Florunner, but observations represent only one warm, irrigated environment at Gainesville, FL; therefore, no particular significance should be attached to absolute number of days. In fact, the purpose of V and R staging is to get away from a calendar date approach. To assist readers in visualizing the growth stages defined in Table 1, the photographs in Figure 2 show identifying traits associated with the reproductive stages for Florunner. Florunner plants at R1, R2, R3, and R4 growth stages are shown in Figure 3. Appearance of reproductive stages for Starr are not shown, but are very

similar except for smaller fruit size and erect plant type.

Reproductive stage R1, beginning bloom, is defined as the date when 50% of the plants have or have had one open flower (Table 1, Fig. 3). The number of days to R1 is primarily influenced by temperature (2, 5). Florunner and Starr planted 8 May at Gainesville reached R1 at 31 days after planting (Table 2). The flowering date of peanuts is nearly insensitive to photoperiod although short photoperiods increase the reproductive to vegetative ratio (24).

Table 2. Days from planting to specific reproductive growth stages for Starr and Florunner peanut cultivars at Gainesville, FL in 1979.

Reproductive	Elapsed Time from Planting	
Stage	Starr	Florunner
	----days----	
R1	31	31
R2	39	42
R3	46	51
R4	52	60
R5	57	62
R6	67	74
R7	80	93
R8	119	129
R9	NA	123

Stage R2, beginning peg, is defined as the date when 50% of the plants have at least one elongated peg without reference to soil penetration (Figs. 2. and 3). R2 of Starr and Florunner occurred 8 and 11 days, respectively, after R1. Smith (19) reported 5 to 7 days from flower fertilization until the base of the fertilized ovary (gynophore) began to elongate geotropically. The elongation process itself only requires 1 to 2 days.

Stage R3, beginning pod, is defined as the date when 50% of the plants have an elongated peg with ovary tip beginning to swell to at least twice the peg diameter (Figs. 2 and 3). R3 occurred 7 and 9 days after R2 for Starr and Florunner, respectively. A fruit at this time would correspond to stage 1 of Pattee et al. (16) and to stage 1.00 of Williams and Drexler (22). R3 marks the beginning of active pegging and fruit development. According to McCloud (13) and McGraw (14), peanuts at this stage (51 days after planting) have achieved a constant and maximum rate of dry matter accumulation, although the canopy may not be fully closed or at its maximum leaf area index.

The R4 reproductive stage, full pod, employs the characteristic fruit size of the cultivar and is attained when 50% of the plants have a fully-expanded fruit (Figs. 2 and 3). A fully-expanded pod at this stage corresponds to stage 3 reported by Pattee et al. (16) and to stage 2.00 of Williams and Drexler (22). Starr and Florunner reached R4 at 52 and 60 days, respectively, after planting (Table 2). At this stage, vegetative growth rate remains at its maximum (14), but the plant is just beginning to add significant pod numbers and weight.

The R5 stage, beginning seed, follows shortly after the R4 stage. The best way to observe this stage is to cut the fruits in cross section. R5 is defined arbitrarily when 50% of the plants have at least one fruit in which the seed cotyledons are sufficiently grown that they show easily visible cotyledon sections when cut with a sharp knife (Fig. 2). First fruits on plants at R5 correspond to stage 5 fruits of Pattee et al. (16). At stages prior to R5, the testa appears nearly hollow with seed in a "liquid" endosperm

condition and the cotyledons easily displaced, similar to Pattee's stage 4 where kernels are mainly seed coat.

The R6 stage, full seed, occurred at 67 and 74 days after planting for Starr and Florunner, respectively (Table 2). This stage is somewhat more subjective than others, requiring half the plants to have a fruit with seed appearing to fill the pod cavity when fresh (Fig. 2). The fresh, spongy endocarp that typically fills up the remaining pod volume should appear to be gone or comprise a small cottony layer inside the pod wall. For Florunner, dry weight per R6 seed was less than half as much (43%) as mature seed and the seed shriveled to half size upon drying. Thus, R6 stage certainly does not mark the end of seed growth, even for the first fruits. In fact, this stage appears to occur prior to achievement of a full pod load. Data of McGraw (14) and Boote (unpublished data) show that the pod addition period continues from R4 until about 1 and 2 weeks after R6 for Starr and Florunner, respectively.

Stage R7, beginning maturity, occurs when 50% of the plants have at least one pod which has exhibited inner pericarp coloration (IPC) (Fig. 2). While not given a stage designation, visible seed compression on the inner pericarp was observed 4 and 6 days prior to R7 on at least one pod on 50% of the Starr and Florunner plants, respectively. Thus, for these cultivars, compression marks were a good indication of the approach of stage R7. The 4 to 6 day sequence of compression followed by the IPC suggests that seed and testa compression into the pericarp may be related to development of IPC in these two cultivars. First fruits on plants at R7 stage are comparable to stage 9 fruits of Pattee et al. (16) and to stage 5.0-5.5 fruits of Williams and Drexler (22). First fruits (exhibiting IPC) on plants achieving R7 stage were 86 and 91% of their maximum mature dry weight per fruit for Starr and Florunner, respectively. Thus the end of pod fill for the first fruits was only slowly being approached at the R7 stage. Although R7 is defined as "beginning maturity", the crop as a whole is really in the middle of its active seed fill phase at that time.

Harvest maturity, R8, for Florunner and Starr is defined as the date when 70 to 75% of the fruits demonstrate inner pericarp coloration or testa color change (Fig. 2). The exact percentage of mature fruits at harvest maturity is cultivar and location dependent, with 70% for virginia market type cultivars, 75% for Florunner and Early Bunch, and up to 80% for spanish cultivars in Florida. Producers should use percentages commonly recommended for their cultivars in their production areas. The method used to observe the approach of harvest maturity (R8) requires considerable opening, observation, and counting of pods. As suggested by Drexler and Williams (3), I observed that pods with IPC almost always had a brown mesocarp visible upon scraping away the outer pericarp with a knife. Their approach would save time required to open pods, although pod counting will still be necessary.

The concept of an overmature stage, R9, was a fortunate happenstance of poor late season leafspot control, which caused an earlier than normal weakening of pegs and loss of pods for Florunner. The Starr cultivar was not evaluated for the R9 stage. At 129 days, a few weak pegs and several dropped pods were evident. All seeds from
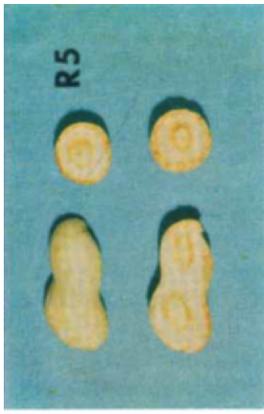
R5, Beginning seed

R4, Full pod
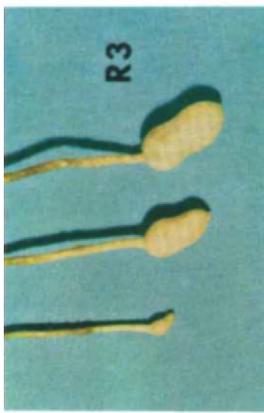
R3, Beginning pod
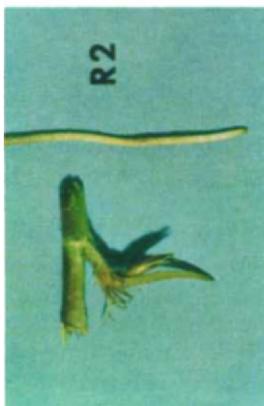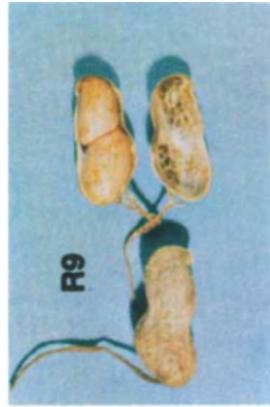
R2, Beginning peg

R9, Over-mature pod
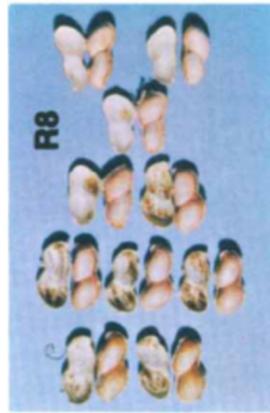
R8, Harvest maturity

R7, Beginning maturity

R6, Full seed

Fig. 2. Appearance of "first" fruiting structures on Florunner plants achieving specific reproductive growth stages.

R4, Full pod

R3, Beginning pod

R2, Beginning peg

R1, Beginning bloom

Fig. 3. Appearance of Florunner plants at R1, R2, R3, and R4 growth stages, respectively.

dropped pods or those with deteriorating pegs demonstrated orangish-tan or brownish coloration of the testa, which was more pronounced in the terminal seed (Fig. 2). The development of brownish color in the seed coat has been previously associated with overmature pods (15, 16). This testa coloration probably means loss of physiological integrity or vascular attachment to the plant, because it also occurred in obviously immature, insect-damaged pods. This coloration was apparent in 4% of the seeds at 123 days, when dropped pods were not evident. Thus the R9 stage, first development of overmature pods, may be a sign for producers to harvest promptly or risk loss of pods.

Reproductive stages R1 to R8 must occur in order in the peanut plant's life cycle although plants may fail to achieve R8 harvest maturity in poor environments. In as much as the R9 stage can precede the R8 stage "R9" is not a "true" growth stage. Nevertheless, the observation of overmature pods and/or deteriorating pegs on a plant is of practical consequence to producers and is therefore worth retaining as a stage.

Sampling For Growth Stages: Plants should be concurrently described for both vegetative and reproductive development as evident in Figure 3. While V and R stage observations can be made on a single plant basis, it is best to rate a representative number of plants in a field population. The V stage of population can be a simple average of node number from many plants to give a decimal such as V8.5. Reproductive stages should not be averaged. The date of a given reproductive stage is the date when 50% of the plants in the sample demonstrate the desired trait. The stage remains unchanged until 50% of the plants exhibit the trait of the next stage. Experienced observers may know approximately where the peanut crop is between stages, but no precise descriptions or phenological traits exist between these R stages, except for determining percent mature pods between stage R7 and R8. The latter may be useful for identifying the approach of harvest maturity.

Staging a peanut field requires sampling and averaging results over three or more representative locations depending on field size and variability. Within a sampling site, a 10-plant sample should be used, preferable 10 consecutive plants in the row to avoid selecting the most vigorous plants. On the other hand, a very weak plant could be discarded if it will contribute nothing to yield. A shortcut for sampling for R5, R6, and R7 stages is to look only at the first two fruits on the first and second reproductive branches on both coyledonary laterals. Gupton, Emery, and Benson (8) found these eight fruit locations to consistently be the earliest fruits. The easiest way to observe the R7 and R8 stages is to scrape the outside of each pod to reveal brown mesocarp coloration indicative of IPC and mature pods (3, 22).

Conclusions

Vegetative and reproductive growth stages were proposed and developed for peanut which can be used to describe the life cycle of both spanish and virginia botanical types of peanuts. The proposed uniform growth stage descriptions should be beneficial in several ways. First, be-

cause they are based on discrete, objective, and visually-identifiable events in the plant's life cycle, they will provide a more precise basis for scheduling cultural practices than use of general descriptors such as "flowering" or "pegging". Secondly, because they describe the entire life cycle of vegetative growth and early to late reproductive growth in terms of the whole plant, they supplement the numerous descriptions of growth and maturation of individual fruits.

Further research and experience will prove the utility of this growth staging system. Nevertheless, these growth stage descriptions are potentially useful to facilitate a common understanding among researchers and extension personnel when considering the peanut crop in terms of its entire life cycle.

Acknowledgement

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