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A Non-Destructive Method for Determining Peanut Pod Maturity

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ABSTRACT

A method of classification based on color and morphological differences of the mesocarp is described for determining the developmental stages of fresh peanut [*Arachis hypogaea* (L) 'Florunner'] pods. Developmental stages are designated as Classes 1-7, with each subsequently numbered class representing progressively greater degrees of maturity. For illustration each class is subdivided into one-quarter increments which are represented pictorially by beginning points. Because various combinations of classes and/or subclasses can be used, the system has inherent flexibility to accomodate the degree of refinement dictated by classification needs.

Maturity determination by this method requires removal of a portion of the exocarp or epidermis to expose the pod mesocarp. The exocarp can be removed by sand blasting, gentle abrasion, or lightly scraping with a knife. Because removal of the exocarp is non-destructive to the remaining pod structure and enclosed seeds, the method has inherent advantages for use in commercial culture and in biological investigations requiring intact pods and/or seed.

Key Words: *Arachis hypogaea* (L.), pericarp, mesocarp, color, morphology, classification, development, maturity.

Several visual characteristics and qualitative attributes exist by which the relative development stages of fresh, individual peanut *Arachis hypogaea* (L.) pods can be determined. Pickett (8) suggested as the simplest and most reliable method a combination of observations of the seed texture, seed coat color, tightness of seed within the hull, amount of fleshy material in the hull, change of inner hull color, and gross appearance of the outside of the hull. Schenk (11) described and presented pictorially the progressive maturation in weekly intervals and expressed maturity-related changes similar to those Pickett reported previously. Pattee et al. (6,7) extended the descriptions of Pickett and Schenk into fifteen developmental stages by further delineating the darkening of the inner hull, recession and cracking of endocarp parachyma tissue, changes in seed coat color, and size and shape of pods and seed. Through compositional studies the fifteen stages were shown to be physiologically distinctive maturity groupings.

In 1973, Drexler (2) observed that the characteristic darkening of the inner pericarp was part of a complex change which is manifest in the mesocarp in vivid colors and various patterns of yellow, orange, brown, and black. Because the various colors had not been previously reported, a study was begun to determine if these and other characteristics of the mesocarp could be used for a more definitive method of determining the developmental stage of individual peanut pods.

Because of the wide variations of terminology in the literature describing the peanut pod, the descriptive terms used in this paper are defined below and illustrated in Figure 1 in a sectional view of a pod in its normal growth orientation.

Apical - Of or pertaining to the pod segment or seed situated farthest from the pod stem.
Basal - Of or pertaining to the pod segment or seed situated nearest the pod stem.
Dorsal - Of or pertaining to the uppermost surface of the pod in its normal growth orientation.
Endocarp - The innermost layer of the pericarp consisting of parenchyma tissue.
Epidermis - The outermost layer of cells of the ovary, distinctive in the initial stages of pod development.
Exocarp (Periderm) - The secondary, protective tissue composed of cork that replaces the epidermis and forms the outermost layer of the pericarp.
Mesocarp - The middle layer consisting of sclerenchyma tissue that forms the mechanical or supportive structure of the pericarp.
Pericarp (hull) - The outer fruit wall consisting of the epidermis or periderm (depending on the stage of development), mesocarp, and endocarp.
Pod (fruit) - The ovary and its contents.
Pod stem (peg) - The stalk of the ovary.
Reticulation - The net-like ridges of the mesocarp supporting the veins.
Seed - The maturing or mature ovule consisting of the embryo, cotyledons, and seed coat.
Seed coat (testa) - The outer coat of the seed derived from the integument or integuments.
Ventral - Of or pertaining to the lowermost surface of the pod in its normal growth orientation.

For further discussion of the anatomy of the fruit of the peanut and other seed plants, see Brennan (1), Esau (3), Smith (12), and Winton (13).

Materials and Methods

Fresh, individual pods from the peanut cultivar Florunner grown under conventional cultural practices were examined in crop years 1973-79. Plants were carefully removed from the soil at selected intervals and washed. Pods were removed and separated by visual assessment of surface appearance into groups of soft, watery pods and pods which had mesocarp sturctures sufficiently advanced to provide some mechanical or supportive structure to the pericarp (fully formed pods).

In 1973-74, mesocarp features of individual moist pods of both groups were exposed by lightly scraping with a pocket knife the epidermis or exocarp from the entire pod. Characteristics of the endocarp and other features were examined after shelling or cutting the pods longitudinally or in cross-sections.

In 1975, individual moist pods of both groups from the cultivars Florunner, Florigiant, and Starr were examined after lightly scraping the exocarp or epidermis on either side of the dorsal midline suture. Samples consisted of all pods from three, five-plant replicates of each cultivar for six weekly harvests.

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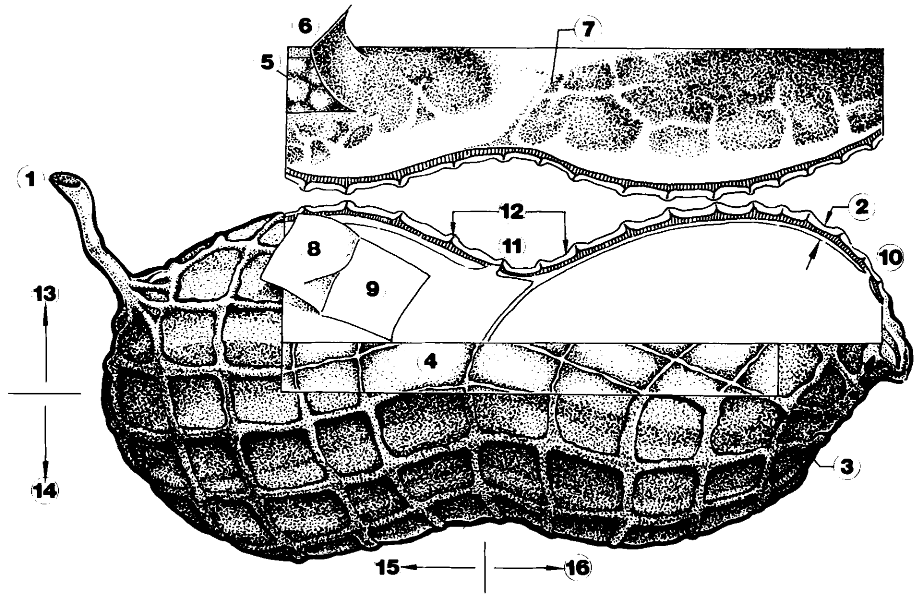

Fig. 1. Sectional view of a peanut pod in its normal growth orientaion.

In 1976-77, and in subsequent years for the soft, watery pod group, individual moist pods were examined after lightly scraping the exocarp or epidermis from the dorsal surface of the basal segment on either side of the midline suture. In 1976, samples consisted of all pods in four replicates of 0.51 m of row harvested at eight weekly intervals. In 1977, pods were sampled from two fields. Samples consisted of, respectively, all pods in two replicates of 0.76 m of row harvested at five weekly intervals, and all pods in four replicates of 0.76 m of row harvested at four ten-day intervals.

In 1978, moist, fully formed pods were examined after the exocarp had been removed from the entire pod by gentle abrasion. Groups of up to 250 pods were placed between oscillating and stationary surfaces consisting of an artificial turf material. Pods of pregressively greater maturity were removed after 0.5,2,3, and 5 minutes of abrasion (unpublished work). Samples were obtained from four plantings which were planted at ten-day intervals, and two plantings of individually, spaced plants with thirty days difference in planting dates. For each planting, samples consisted of, respectively, all pods in four replicates of 0.76 m of row, and all pods from each of eight plants. Sampling commenced when the first pegs began to enlarge and continued weekly until substantial pod loss occurred with senescence. In addition, pods of the cultivars Florigiant, Early Bunch, GK-3, Starr, Tamnut, and Tifrun were selectively examined.

In 1979, moist, fully formed pods were examined after sand blasting the entire pod or its dorsal portion. The exocarp was removed from the entire pod by varying the pod orientation mechanically or by hand relative to the blasting nozzle. The exocarp was removed from the dorsal portion after orienting up to 200 pods in resilient rubber mounts (unpublished work). Samples were obtained from two plantings with thirty days difference in planting dates. For each planting, samples consisted of all pods in six replicates of 0.76 m of row. Sampling commenced when the first pegs began to enlarge and continued until substantial pod loss had occurred.

During each year color, structure, shape, size, and any other characteristics which appeared related to pod maturity were recorded. In 1978-79, the most advanced mesocarp characteristics were determined in weekly samples. Mesocarp characteristics which could be used to designate stages of development were categorized into groups by distinctiveness of characteristic and ease of recognition. Within these constraints, groups were further combined or subdivided for uniformity in time intervals of development for the first formed pods. Photographs of the mesocarp of pods illustrative of group differences were taken, and group characteristics were summarized. Descriptive color terminology used conforms to ISCC-NBS standards for color nomenclature (5).

Results and Discussion

A method was derived for classifying individual Florunner peanut pods into distinctive stages of development based on observable color and morphological differences of the mesocarp. The method evolved over seven years as part of a study of the relationship between pod maturity distribution and time of harvest (unpublished work). The system reported in this paper was not the only means of classification used, but is the result of study and experience with classification to date.

Classes were defined as seven discrete pod groups designated as Classes 1-7, each representing progressively more advanced stages of development. Characteristics associated with class beginnings and midpoints are summarized in Table 1. The progressive changes which occur within a class are represented by four pods of each class as shown in Figure 2. The first pod in each class depicts the class beginning, with the remaining three pods representing the beginning points of developmental stages one-fourth, one-half, and three-fourths through the development within class. Although divisions of one-fourth class were used and are shown for illustration, subdivisions of less than one-half class were impractical in most classes for routine sampling. In subsequent discussion, stages within classes are assigned numerical values, e.g. Stage 5.5 defines the beginning of the stage one-half way through Class 5. Because colors sometimes photographed differently from those observed, color illustrations were used to develop the concept of class divisions rather than to illustrate absolute standards of class identity.

Transitions of the mesocarp

The various colors are the most easily recognized characteristics of the developing pod mesocarp. They occur over more successive developmental stages (Classes 3-7) than any other visual characteristic and form the primary basis for class division.

To appreciate class divisions, it is necessary to understand the concept of color replacement and its transitional nature. Colors of the mesocarp are not composed of single colors which suddenly develop, but can be conceptually thought of as a progressive change; as one color replaces another and generates combinations of a dominant or replacing color and a background color which is being replaced. In normally developing pods the replacing color originates at or near the attachment point of the basal seed to the pericarp, then progresses distally toward the pod stem, while at the same time progressing around the pod toward the ventral surface of the basal segment. Though normally slightly delayed, the replacing color then appears at the attachment point of the apical seed to the pericarp and progresses distally toward the pod constriction, while at the same time progressing around the pod toward the ventral surface of the apical segment. The color of the pod constriction and a small portion of the immediately adjacent apical surface appears to be associated with basal segment development.

Depending on the class, it is either the distinctive change in hue or a change in value and degree of saturation of the replacing color that forms the basis for class division. Progressively in the mesocarp, white advances to very pale yellow (Class 3), to deep yellow (Class 4), to orange or brownish-orange (Class 5), to reddish-brown or brown (Class 6), and to black (Class 7). The pattern formed by a given color as it replaces the background color was the basis for subdividing classes into incremental stages of development. The range of colors described as orange or brownish-orange and reddish-brown account for inherent color variation.

Although color and color pattern change are the dominant classification criteria for Classes 3-7, structural differences were also important. As with color, structural differences are transitional as the mesocarp develops from a soft, watery beginning and advances through successive stages of softness (Classes 1-2), resiliency (Class 3), and rigidity (Classes 4-7). Although structural changes occurred throughout the entire progression of color and color pattern change, differences are most evident in the developmental stages where very pale yellow replaced white (Class 3) and where deep yellow replaced very pale yellow (Class 4). In Class 3, the mesocarp changes from its soft, watery beginning to become somewhat resilient. In Class 4, structural rigidity supplants structural resiliency. Because subtle differences in yellows were accompanied by striking differences in structure, structural characteristics are extremely important in identifying diffrences associated with these stages.

Perceptive differences in vein development are most evident in soft, watery pods where the distinctive epidermal layer is removed to exposed veins that are deeply embedded within the pericarp. The distinctive appearance of longitudinal veins on the basal segment delineates the beginning of Class 2 from Class 1, while various degrees of venation determines the incremental divisions within classes. Initially, veins are indistinctive in appearance (Stages 1.0). Longitudinal veins appear (Stage 1.5), then become distinctive in appearance (Stage 2.0). Netted (reticulate) veins appear between the longitudinal veins on the basal segment (Stage 2.5), followed by an appearance on the apical segment.

Pods of Class 3 have a transitional nature in that the distinctive epidermal layer is replaced by the developing exocarp. As the exocarp and/or epidermis is removed, veins often partially break away leaving the mesocarp with a stringy appearance. In Class 4, veins are easily broken away with removal of the exocarp.

Mesocarp surface texture and degree of reticulation are also transitional. Although not totally definitive, these features are involved in the perception of the vein system and are useful when paired with other characteristics of class identity. Surface texture and the degree of reticulation are interrelated because the texture changes progressively from smooth to rough with the ridge development. Reticulations become distinctive in Class 3, and coincided with the textural transition of smooth to slightly rough. The more distinctive ridge development of Class 4 partially account for the transition from structural resiliency to structural rigidity.

Separation of pods into discrete groups is somewhat opposed to the gradual changes that occur in the mesocarp. Although differences between the same stages in adjacent classes are easily determined, the difficulty of separation increased with refinement. For example, there is little difficulty in determining that a pod at Stage 5.5 is considerably different from a pod at Stage 6.5. It is somewhat more difficult, however, to determine small differences in pods that are near the juncture of Classes 5 and 6. Further, the degree of recognizable difference between the end of one class and the beginning of the next varies among classes. Whereas the beginning of Class 5 is distincively different from the end of Class 4, differences at the juncture of Classes 3 and 4 are less distinct. Although in routine classification, pods were occasionally placed incorrectly in adjacent classes, mistakes in identity of over one-half class division were not detected. Refined separations were aided by sorting pods with similar characteristics relative to each other, then determining class divisions by commonality of characteristics.

Table 1. Characteristics of Florunner pods by class beginnings and midpoints.

Stage	Mesocarp Color		Physical Size	Vein System	Surface Texture	Mesocarp Structure	Reticulations
	Dominant or Replacing	Being Replaced					
1.0	White		Initial Development	Indistinct	Smooth	Soft, watery	Not present
1.5				Longitudinal Apparent but Indistinct	Smooth	Soft, watery	Not present
2.0	White			Longitudinal Distinct	Smooth	Soft, watery	Not present
2.5			Maximum	Net venation begins on basal segment	Smooth	Soft, watery	Indistinct
3.0	Very pale Yellow	White	Maximum	Net venation nearly complete or complete	Slightly rough	Somewhat soft Somewhat Resilient	Becoming distinct
3.5				Net venation complete	Slightly rough	Resilient	Distinct
4.0	Deep Yellow	Very Pale Yellow	Maximum	Net venation complete	Moderately rough	Somewhat rigid	Distinct
4.5					Rough	Rigid	Very distinct
5.0	Orange to Brownish-orange	Deep Yellow	Maximum	Net venation complete	Rough	Rigid	Very distinct
5.5						Very rigid	
6.0	Reddish-brown to brown	Orange to brownish-orange	Maximum	Net venation complete	Very rough	Very rigid	Very distinct
6.5							
7.0	Black	Reddish-brown to brown	Maximum	Net venation complete	Very rough	Very rigid	Very distinct
7.5							

Fig. 2. Florunner mesocarps (exocarp removed) of seven maturity classes subdivided into incremental stages.

Time of Development

Table 2 shows the week of appearance of pods of the most advanced class. The most advanced pods were considered to be the first pods which the plant set. They normally included the first pod on the first reproductive branch and the first pod on the first two vegetative branches arising from the cotyledonary laterals. These pods were among those reported in the first pegging group by Gupton et al. (4).

Table 2. Week of appearance of pods of each maturity class.

TEST	MATURITY CLASS						
	1	2	3	4	5	6	7
1	1st	2nd	3rd	5th	7th	9th	10th
2	1st	2nd	3rd	4th	7th	8th	9th
3	1st	2nd	3rd	5th	7th	9th	10th
4	1st	2nd	4th	5th	7th	9th	10th
5	1st	2nd	4th	6th	7th	8th	10th
6	1st	2nd	4th	6th	8th	9th	10th
7	1st	2nd	3rd	5th	7th	8th	9th
8	1st	2nd	3rd	5th	6th	8th	10th

The week in which the first pegs began to enlarge was designated as the first week (Class 1). The appearance of pods with other class characteristics were designated the subsequent week in which they were observed. Because pod observations were to the nearest week, greater variations in times to class appearance would be expected than may actually exist. Pods appeared in Class 7, however, in the ninth or tenth week though tests were conducted over a broad range of environmental conditions.

Growth environments could not be disregarded as having influenced time. Environmental influences, however, appeared insignificant unless extreme enough to cause cessation of pod development. Evaluation of these data and other data from studies of pod maturity distribution indicate that class times of development for the first pods fell consistently within 10-14 day intervals (unpublished data).

Adjustment of class boundaries to approximate uniform time intervals resulted in recognizable class differences varying among and within classes. Many classes used originally were combined into larger groups, but remain subdividable for more precise needs. For example, Class 5 is easily subdivided by the extent of orange to brownish-orange replacement of deep yellow. Classes 1 and 2 may be readily subdivided by pod size, shape, and vein system differences. Classes 3 and 4, however, are not combined despite their similarity of yellows.

Relationship of Mesocarp to Inner Pericarp and Seeds

Figure 3 shows inner pericarp and seeds of typical maturity class midpoints determined by mesocarp characteristics (Classes 2-7). The parenchyma closely surrounds the seed at Stage 2.5. At Stage 3.5 the endocarp noticeably receded as seed enlarged. The seed coat turned light pink at Stage 4.5, while the endocarp receded to the point of showing the reticulate appearance of the mesocarp. In Classes 5-7, however, color transitions of the mesocarp appear as the source of the gradual darkening of the inner pericarp. The dominant mesocarp colors advanced and became increasingly visible through the endocarp. At the same time the parenchyma of the endocarp was grandually stained with time and the extent of progression of the replacing colors. From Stage 5.5 - 7.5 the inner pericarp became progressively darker while seed coats normally changed to darker pink in late stages of development or became brownish-pink with senescence. As with the endocarp, seed coats were normally stained in an irregular pattern to the extent that the reticulate structure of the mesocarp was partially imprinted on the seed.

While parallels exist between transitions of the mesocarp, inner pericarp, and seed development, examination of seed coat texture of pods previously classified by mesocarp characteristics suggested slight variations between pods of different crops and pods set early and late within the same crop. See Sanders (9) for characterization of inner pericarp within mesocarp classes using the Physiological Maturity Index(6), and Schenk (10) for further discussion of factors affecting inner pericarp brown color.

Abnormalities

Abnormal mesocarp developmental patterns were sometimes observed in routine pod examination. These patterns generally related directly to the development of the seed. For example, Figure 4 shows a severe apical lag of two sequential colors which was reflected in the apical seed. Basal lags occurred, but were infrequent.

Abortion of the apical seed was often reflected in cessation of color or structural development in the apical segment of the mesocarp, while at the same time the basal segment developed normally. When a basal seed aborted, the mesocarp of the entire pod progressed through normal color and structural transitions and the apical seed filled both apical and basal cavities. The origin of the mesocarp transitional color was in the vicinity of the apical seed attachment to the pericarp.

Pods subjected to severe soil moisture deficiencies formed highly irregular mesocarp color patterns or distinctive lines of color demarcation at longitudinal veins as shown in Figure 5. Irregular patterns of the mesocarp resulted in substantially less darkening of the inner pericarp (> Stage 5.5). Seed coats became brownish-pink similar to normally developing pods in late developmental stages. Very severe moisture deficiencies resulted in irreversible cessations of mesocarp color and structural changes. Stresses caused by root knot nematodes, *Meloidogyne arenaria,* were observed to cause color patterns in the mesocarp similar to those of moisture stress. Developmental stages in such instances were determined by the most advanced color.

In general, the most reliable portions of the mesocarp for determining the developmental stage was the dorsal surface on either side of the midline suture. Sources of confusion in routine classification were eliminated by removing the exocarp from the dorsal surface only.

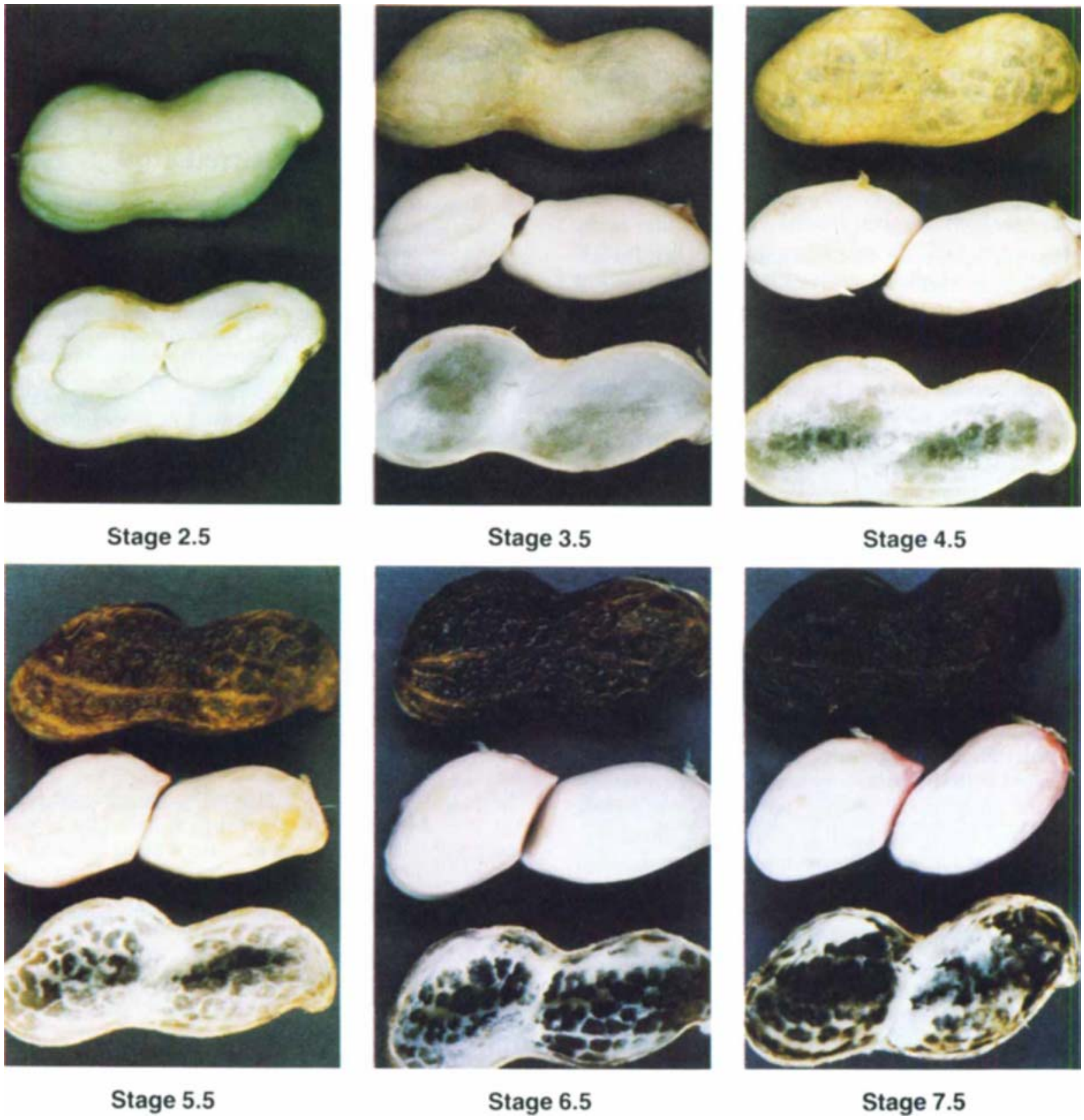

Fig. 3. Inner pericarps and seed of typical maturity class midpoints determined by mesocarp characteristics.

Fig. 4. Mesocarp, inner pericarp, and seed of pod with severe lag in apical segment development.

Fig. 5. Mesocarp, inner pericarp, and seed of pod subjected to soil moisture deficiency.

Conclusions

The system of classification is adapted to determining pod maturity profiles for characterization of overall pod maturity distribution at any plant age. For this use, color and structural transitions of the mesocarp provide definitive criteria for pod maturity assessments throughout all stages of development.

Although the system of classification may be used advantageously in methods of determining optimum time of harvest and in the application of agronomic practices, the ease and speed with which classifications can be accomplished relative to examining inner pericarps and seed coats is advantageous in many applications. The inherent advantages of removing only a portion of the exocarp or epidermis for classification can be useful in various qualitative studies and in other physiological and biological studies pertaining to stages of pod development. The distributional approach to characterizing overall pod maturity at any plant age has useful application in mathematical modeling of maturation processes and in assessing relative differences in genotypes or other factors affecting composite maturity.

While emphasis has been placed on the entire pod, the system may be used to determine maturity of apical and basal seed individually. Because class beginnings are associated with different colors and color change is normally first associated with the basal segment, the stage of development of the entire pod normally reflects more precisely that of the basal segment. Each pod segment, however, may be evaluated individually by applying classification criteria.

Although the classification system was developed from studies of Florunner, other cultivars of subspecies *hypogaea* and *fastigiata* had the same patterns of mesocarp color and structural change. Cultivars examined included those with different thicknesses of endocarp and other associated characteristics which exhibit less tendency toward darkening of the inner pericarp. It appears that with only minor modifications the same classes described for Florunner will be adaptable to other cultivars.

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