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Peanut Peg Strength: Force Required for Pod Detachment in Relation to Peg Structure[1]

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ABSTRACT

Peanut peg strength, which influences the proportion of peanut pods harvested, was measured as a function of the force required either to detach the peg from the pod or to break the peg. Pegs from 10 commercial cultivars and 30 plant introductions were tested for peg strength with an Instron Test Instrument. The mean peg detachment forces for Florunner, Florigiant, Spantex, Tamnut-74, and Toalson varieties were 10.0, 12.7, 13.0, 17.2, and 22.1 Newtons (N), respectively. Peg detachment forces for Plant Introductions 295210, 393523, 393530, and 393647 were 28.2, 35.2, 35.3, and 37.2 N, respectively. Peg anatomy and the intensity of phloroglucinol staining for lignin were directly correlated with peg detachment forces. Strong pegs had highly developed sclerenchymatous tissue and large crescentshaped, closely spaced, and highly lignified bundle caps. Bundle caps in weaker pegs were small, less compact, and spaced farther apart. Peg detachment forces and peg anatomy are criteria that could be considered in the development of improved peanut varieties.

Key Words: *Arachis hypogaea*, peg anatomy, peanut breeding.

Loss of peanut pods in or on the soil surface during harvest has become a significant problem with the advent of mechanical harvesting. Losses have been attributed to inherently weak pegs; pegs damaged by fungi, nematodes, and insects; and pegs broken by equipment during the digging and combine operations. Beasley (2) reported that pod losses for the cultivars Florigiant, NC-5, and NC-2 ranged from 5-35% in North Carolina fields. In related studies, Duke (4), reported losses for the commercial peanut cultivars Florigiant, NC-17, and VA-61R varied from 10-28% in Virginia. Using a peanut salvager in field plots, Duke was able to recover an additional 519 Kg/ha (579 lbs/A) of peanuts over the yields from field plots when using the conventional digger-combine harvest procedure. These observations point out the need

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to develop peanut cultivars with improved peg strength.

Previous assessments of peg strengths have been determined by measurement of the forces required to separate the peg from either the stem or pod and/or to break the peg itself. In general, less force is required to separate the peg from the pod (12, 15) at the point of pod attachment. The mean peg-pod detachment forces for the commercial cultivars Early Runner, Florunner, and Florigiant have been reported to be (in gms-force) 750 (7.4 Newtons), 1000 (9.8 N), and 1080 (10.6 N) respectively (1). In Japan Ito et al. (6) reported the peg detachment forces for the cultivars Chiba-handachi, Kikuyp, and Java No. 13 to be (in gms-force) 500 (4.9 N), 700 (6.9 N) and 1100 (10.8 N), respectively. The peg detachment for the cultivar Va-61R has been reported to be 1130 gms force (12.7 N) (12), while the peg detachment force for Starr has been reported to be 1500 gms force (14.7 N) (13). These results indicate that the pod detachment force for several commercial cultivars ranges from 4.9 to 14.7 N.

Differences in the forces required to detach peanut pegs from their pods could be related to the structural features of the peg and the manner in which the peg is attached to the pod. The peanut peg (gynophore) exhibits the internal structure of a typical herbaceous dicotyledonous stem (3,7,10,16). In cross section the peg consists of a hollow cylindrical cavity surrounded by pith cells (8), a cambial ring (7), and a ring of 11-18 vascular bundles (11,17). Each vascular bundle is capped by a bundle of extraxylary fibers (3). Fiber caps are 3-5 cell layers across and are polyhedral in cross section. An interfascicular cambium connects the vascular bundles (8, 16). Parenchyma cells form on both sides of the cambium and extend out to the epidermis (8, 10). Following aerial pollination, the peg grows downward in the soil and the ovary enlarges 2-5 cm below the soil surface (8). As the pod forms, the larger vascular bundles within the peg branch into smaller bundles over the pod surface and no abscission zone is formed between the pod and peg (8). The objectives of this study were to identify peanut phenotypes with strong pegs and to determine structural features of the pegs which could be correlated with their strengths.

Materials and Methods

Preliminary peg strength studies were conducted with mature pods from ten commercial cultivars. One hundred pods with straight pegs were hand harvested immediately following digging and transported to the laboratory on ice. These pods were stored at 5C for no more than 4 days previous to measuring the peg detachment forces. Five healthy sound pods with good pegs were initially examined from each cultivar. These tests were repeated with both fresh pods and dried pods.

Peg detachment forces were measured with an Instron Universal Testing Instrument Model 1122 (Instron Corp., 2500 Washington St., Canton, MA 02021) (5) which consisted of a tension load cell, electronic drive mechanism, chart recorder and associated computer connection. Test pods were held below a hole in a 8 cm^2 metal plate so that the peg projected up through the hole. The peg was held in a spring tension clamping device attached to the load cell. The load cell was moved upward at a constant cross-head speed of 100 mm/min and the load detected and recorded at a chart speed of 500 mm/min.

The major peg detachment studies were conducted with mature pods from 30 plant introductions (PIs). These 30 PIs chosen for instrumental tests were selected from a planting of 180 PIs grown at Stephenville, Texas. Fifteen healthy pods with straight pegs were removed from windrowed peanuts immediately after digging and the pegs removed by hand pulling. Using this subjective peg strength test the pods were grouped as having strongly, intermediately, or weakly attached pegs. Pods with attached pegs of ten PIs were chosen from each of the three pod groups and transported to the laboratory on ice. Fifteen pods of each PI were selected to determine the mean detachment force with the tension load cell.

Based on the detachment forces obtained, pegs from 12 PIs were chosen for the anatomical studies: four from each grouping of strong, intermediate, and weak features. Six pegs from each of 12 PIs were preserved in formalin-acetic acid-alcohol (FAA) and dehydrated in a tertiary butyl alcohol series. The pegs were embedded in Tissue Prep (MP 56.5C) (Fisher Scientific Co.), cut in 10 um sections on a Spencer 820 rotary microtome, and stained with safranin and fast green (9). Cross sections were photographed with an Olympus automatic camera attached to a Leitz Ortholux microscope. The number of vascular bundle caps, fiber cap cells per vascular bundle and peg diameter were recorded for each peg examined. Lignin depositions in free-hand sections were stained with acidified phloroglucinol for 2 minutes and photographed with a dissecting microscope and a Leitz camera.

Results and Discussion

Peg Strength

Representative peg detachment forces (load-newtons), as recorded by the Instron Test instrument, are illustrated in Fig. 1. Peg detachment curves for 4 pegs of PI

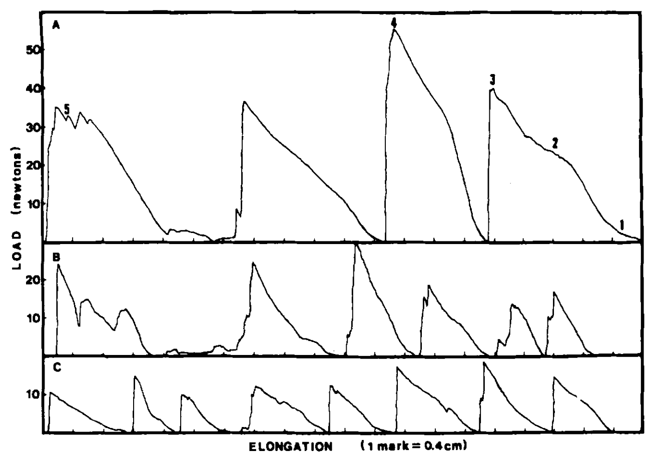

Fig. 1. Peg detachment curves as recorded by the Instron test instrument. A) Curves from pegs of cultivar PI 393647 (strong group); B) Curves from pegs of cultivar PI 306228 (moderate group); C) Curves from pegs of cultivar PI 365553 (weak group).

393647 (Fig. 1A) were recorded from right to left with the initial adjustment in tension recorded below point 1. As additional force was applied to the first peg, the peg became taut, stretched, and the increased tension was recorded as the portion of the sloping curve along and on each side of point 2. Peg detachment (break) was recorded at the peak (point 3). Breaks for most pods occurred at the junction of the peg and the pod or along the peg; however sometimes the pegs broke at a constriction where the vascular tissues flare out over the pod surface. When the vascular strands broke as a group a single peak was recorded (test pod #2, point 4, Fig. 1A). When the vascular strands broke in sequence a series of peaks was recorded, (test pod #4, point 5, Fig. 1A). The six peg detachment curves for PI 295749 (Fig. 1B) illustrate the types of variability encountered in some of the moderately strong pegs. The second peg detached in this sequence required 14 N while the fourth peg required 31 N. The sixth peg in this sequence broke with three major peaks, each the result of a vascular strand breaking from the surface of the pod. Peg detachment forces of eight weak pegs of PI 365553 are illustrated by the curves in Fig. 1C.

The mean peg detachment force for each of the 10 commercial cultivars ranged from 8.3 N (UF 70115) to 22.1 N (Toalson cultivar) (Table 1). The Toalson cultivar has previously been reported to exhibit tolerance to peg rot pathogens (14). Detachment forces of Starr and Florunner cultivars were between these values and in general agreement with the values obtained by Troeger et al. (15) and Bauman and Norden (1).

Table 1. Forces required to detach peanut pegs from pods of ten commercial cultivars.

Cultivar	Detachment force [a/] (Newtons)
Toalson	22.1 ± 4.57
Comet	19.5 ± 3.45
Tamnut-74	17.2 ± 2.90
Starr	15.3 ± 4.28
Spancross	14.7 ± 3.88
Spantex	13.0 ± 3.03
Florigiant	12.7 ± 1.97
GK-19	10.7 ± 2.22
Florunner	10.0 ± 2.99
UF-70115	8.3 ± 1.88

[a/] Force is the mean of five replicate samples of each cultivar

Pegs with greater strength were discovered in several of the plant introductions. The greatest peg detachment forces and largest standard deviation in peg strength were recorded for pods of PI 393647, 393530, and 393523 (Table 2). Weakest pegs were noted on pods of PI 311003, 298849, 365553, 298878, 295239, and 341885. Smaller standard deviations in peg strength were noted for the weak pegs.

Peg Anatomy

Microscopic examination of peanut peg cross sections of pegs classified as weak, moderate, and strong revealed that there are structural and biochemical differences between peg groups. Obvious similarities also exist. Stelar pith cells in all pegs gradually disintegrate with maturity, forming a hollow stele; the vascular bundles and associated fiber caps are arranged in a ring; and some have epidermal hairs. Differences between pegs were related to the size and shape of the fiber caps, degree of lignification, and the number of cambial and parenchymatous cells between the vascular bundles.

Vascular bundles of two weak pegs, PI 311003 and PI 365553 (Fig. 2A and 2B), were smaller than those in the moderate (Fig. 2C and 2D) and strong pegs (Fig. 2E and 2F). The weak pegs contained 13-15 well defined vascular bundles in the ring and the fiber caps contained a mean of 1095 and 1226 cells per peg, respectively (Table 3). Between the vascular bundles, 3-5 rows of interfascicular cambium and parenchyma cells were evident.

Table 2. Forces required to detach peanut pegs from pods of thirty plant introductions.

Cultivar	Peg detachment force [a/]	
	Mean (Newtons)	Standard deviation
PI 393647	37.2 a	13.08
PI 393530	35.3 a	7.09
PI 393523	35.2 a	9.90
PI 295210	28.2 b	4.62
PI 393532	27.4 bc	8.41
PI 306361	26.9 bc	5.94
PI 295737	24.0 bcd	7.99
PI 393518	23.0 bcd	4.66
PI 295215	22.6 cd	5.91
PI 393521	22.6 cd	4.38
PI 295171	22.5 cd	6.39
PI 295731	22.5 cd	4.37
PI 299471	22.2 cd	4.40
PI 292596	22.2 cd	5.47
PI 393527	21.7 cd	5.22
PI 306228	20.9 de	5.58
PI 295749	19.9 de	6.62
PI 294646	19.8 de	3.45
PI 313118	19.8 de	4.49
PI 259311	19.7 de	8.04
PI 295743	18.7 de	4.56
PI 295230	18.5 de	3.91
PI 313178	18.5 de	3.21
PI 298873	18.5 de	4.12
PI 341885	15.6 f	4.08
PI 295239	15.5 f	5.02
PI 298878	13.2 f	3.66
PI 365553	12.8 f	3.40
PI 298849	12.6 f	3.42
PI 311003	12.1 f	4.09

[a/] Peg detachment force is reported as the mean of fifteen replicate samples. Mean followed by a common letter are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test.

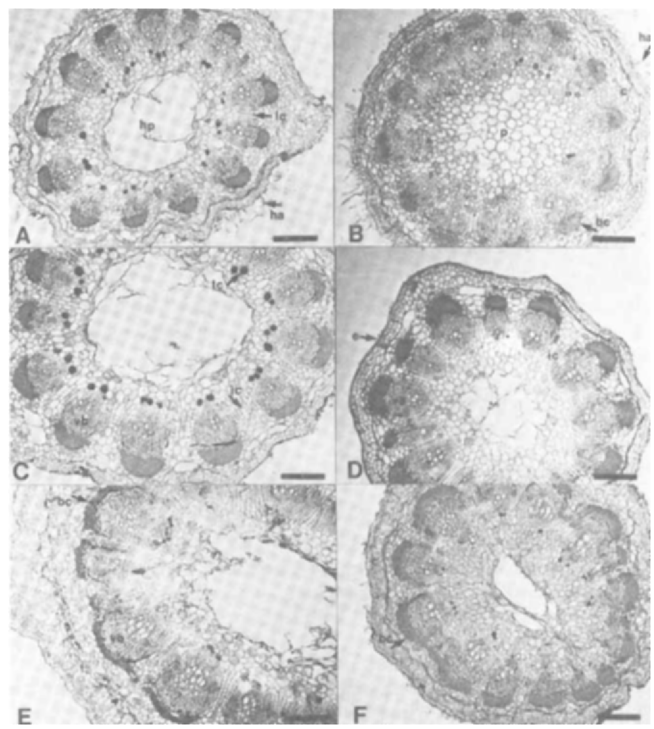

Fig. 2. Peanut peg cross sections illustrating the anatomical features of pegs from 6 cultivars. A) PI 311003 (weak group); B) PI 365553 (weak group); C) PI 295749 (moderate group); D) PI 306228 (moderate group); E) PI 393530 (strong group); F) PI 393647 (strong group). bc = bundle cap; c = cortex; ha = epidermal hairs; e = epidermis; hp = hollow pith; ic = interfascicular cambium; p = pith; tc = tannin cell; vb = vascular bundle. Bars indicate 0.2 mm.

Table 3. Number of vascular bundles and fibers for select plant introductions.[a]

Plant Introduction	Strength category	Vascular bundles No.	Cells within fiber caps No.
393647	Strong	14	1740
393530	Strong	18	1827
306228	Moderate	14	1698
295749	Moderate	13	1462
365553	Weak	15	1226
311003	Weak	13	1095

[a]Vascular bundle number and fiber cap number are reported as the means of six replicate cross sections.

The moderately strong pegs, PI 295749 and PI 306228 (Fig. 2C and 2D), contained 13 and 14 vascular bundles, respectively, and the associated bundle caps contained a mean of 200-600 more cap cells than in the weak pegs. The vascular ring and associated fiber cells were more uniformly arranged and closer together with 1-4 rows of interfascicular cambium and parenchyma cells separating the vascular bundles. The moderately strong pegs of PI 295749 (Fig. 2C) contained large tannin cells and the pegs of PI 306228 (Fig. 2D) contained a continuous band of smaller, thick-walled cells exterior and adjacent to the vascular bundle ring.

The strongest pegs examined from PI 393530 and PI 393647 (Fig. 2E and 2F) contained 18 and 14 vascular bundles, respectively (Table 3). The fiber caps contained a mean of 500 to 700 more cells than observed in the weak pegs. Fiber caps were more crescent shaped compared to those in the weaker pegs and only 2-4 rows of interfascicular cambial cells interrupted the continuity of the ring. Pegs of PI 393647 were also observed to have tolerance to peg rotting fungi (13).

Bundle cap cell walls in the strongest pegs were more highly lignified than those in the weak pegs, as evidenced by the intensity of phloroglucinol staining. A comparison of the weak pegs of PI 311003 (Fig. 3A) and one of the strong pegs, PI 393647 (Fig. 3B), illustrated the differences in bundle cap tissue structure, the relative size of these tissues, and the increased cell wall thickness of the cells within the vascular ring of the stronger peg. Cells of the stronger peg were more compact, contained a higher concentration of lignin, and had a more even distribution of lignin throughout the fiber cap tissues (Fig. 3B) than did those in the weaker peg.

Differences in peg diameter were noted in these studies; however, peg diameter and the number of vascular bundles per peg were not related to peg strength. Pegs with larger diameters could be found in all three peg strength categories. In general, pegs with the strongest peg-detachment forces had somewhat larger diameters. Major differences were noted in the number of cells making up the bundle cap tissues. Bundle caps of the weakest pegs contained approximately 80-90 fiber cells per cap compared to 100-120 cells for the stronger pegs. Secondary cell wall development, especially lignin deposition, was also considered to be a key difference between pegs.

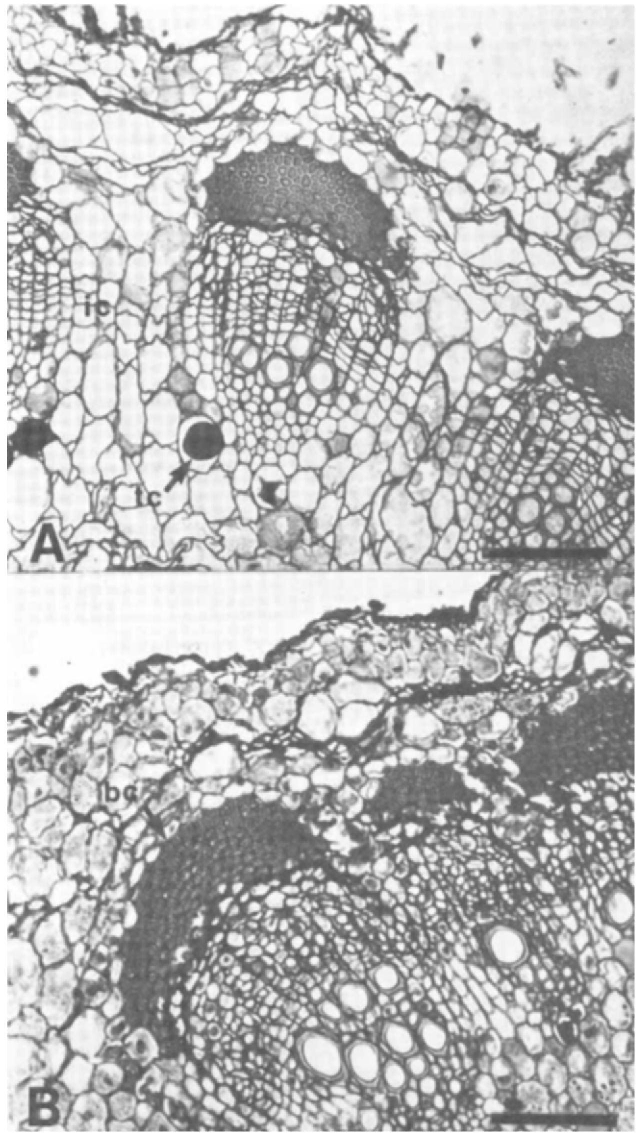

Fig. 3. Peanut peg cross sections illustrating the anatomical features of the bundle caps of a strong and weak peg. A) PI 311003 (weak group); B) PI 393647 (strong group). bc = bundle cap; ic = interfascicular cambium; tc = tannin cell. Bars indicate 0.1 mm.

Conclusions

Considerable variability exists in the strength and anatomical features of pegs from different peanut cultivars. Three of the cultivars examined, PI 393647, PI 393530, and PI 393523, had stronger pegs (35.2 to 37.2 N) than the 14.7 N previously reported for other cultivars. Plants of PI 393530 were found to be the most promising for use in a breeding program because of peg structure and desirable agronomic traits. These results have revealed that there are several sources of genetic material available for the development of peanut cultivars with improved peg strength.

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