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Agronomic Aspects of Normal and Abnormal Root Formation in Peanuts (*Arachis hypogaea* L.)

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ABSTRACT

Peanut (*Arachis hypogaea* L.) research in Ontario, Canada has focused on the problems inherent in growing a crop in an area where it had previously not been grown. It had been observed that a significant percentage of germinating seeds developed abnormal root systems. Many of these abnormal seedlings did not emerge; others emerged but failed to produce vigorous plants.

Four peanut cultivars, each from two distinct sources, commercial and hand-harvested seeds were compared on the basis of pod yield, plant stand, and percentage of plants with normal root systems. A normal root system was designated as one which had a long straight tap root with many laterals. Among all cultivars, pod yield, and plant stand from hand-harvested seed exceeded that of commercial seed. In addition, the percentage of plants with normal root systems was greater for hand-harvested seed than for commercial seed with two of the cultivars.

Field grown plants of three peanut genotypes were examined to determine the relative percentages of plants with normal or abnormal root systems. An abnormal root system was classified as having a curvature of the hypocotyl or the hypocotyl and tap root or no main tap root. High percentages (50-60%) of plants with abnormal root systems were found for two genotypes and for each of the three genotypes it was determined that an abnormal plant was capable of producing approximately 50% as many pods as a normal plant.

Four sources of seeds were collected for each of the three genotypes: (a) normal-rooted plants, (b) abnormally-rooted plants, (c) a random selection of plants, and (d) a random selection of plants, combine-harvested. The seeds were grown in a growth cabinet study and in two field trials. In all cases, the data were consistent in that selection for normal-rooted plants did not increase the percentage of normal-rooted plants over the random selection or the abnormal selection in the following generation. Combine-harvesting caused a dramatic reduction in the percentage of plants with normal roots. In two genotypes this reduction led to a significant yield reduction when compared to the hand-harvested selections. Seed from a commercial seed lot for one of the genotypes produced a very low percentage of plants with normal roots, which also resulted in a yield reduction.

The overall results demonstrated that the use of high quality seed was an extremely important facet of peanut production in this environment and that additional research in the area of seed quality is justified.

Key Words: *Arachis hypogaea*, Seed Quality, Seed Damage, Normal and Abnormal Roots.

During several years of peanut research in Ontario, it had been observed that a significant percentage of germinating seeds developed abnormal root systems. Many of these abnormal seedlings did not emerge and thus reduced stands; others emerged but failed to produce vigorous plants.

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Sullivan and Perry (4) examined the performance of normal and abnormal seedlings in the field. They classified abnormal seedlings as those that emerged 7-10 days later than the field average, and stated that 95% of the abnormal seedlings had abnormal root development. Further, they reported that the reduction in yield of plants with abnormal root systems was mainly due to decreased pod set and that a high percentage of these plants in the field population could considerably reduce final yeild, even though some compensation from adjacent normal plants was likely. They hypothesized that the amount of yield reduction associated with plants with abnormal root systems would be inversely related to plant population.

Mechanical injury to the radicle of the seeds caused a dramatic increase in the percentage of plants with abnormally-developed root systems (5). Turner *et. al.* (6) demonstrated similar effects when the hull of a peanut was subjected to various impact velocities. Damage in terms of percent germination and abnormal root development was most prevalent with the apical kernel when the hull was struck on the apical end.

Branch (1) selected normal seedlings that had undergone a chilling stress during germination and compared their progeny to the original population to which no selection pressure had been applied, and stated that there was significantly more normal seedlings from the selections, than from the original population, when both were subjected to a chilling stress. Branch's results indicated that abnormal seedlings were more prevalent under cool germination conditions and variability for the attribute existed, thereby opening the way for selection of cultivars with reduced proportions of abnormal seedlings.

The objectives of this study were (a) to determine whether seed damage associated with harvesting could increase the prevalence of abnormal-rooted plants in the progeny, (b) to determine whether selection of seeds from plants with normal or abnormal root development would increase or decrease, respectively, the percentage of plants with normal roots in the following generation over that of an unselected population, and (c) to determine the extent to which the percentage of normal rooted plants in a population affected final yield.

Materials and Methods

Seed Source Trial (Experiment I)

In 1976, seed of four peanut cultivars ('Comet', 'Tifspan', 'Starr', 'Goldin 1') from two distinct sources was used to compare hand-harvested seed with commercial seed. Seeds for each cultivar were obtained from (a) U.S. commercial seed lots and from (b) seeds originally obtained from U.S. commercial seed lots (1975) but grown for one season in Ontario and harvested by hand.

The experimental unit consisted of three rows, 7 m long with 40 cm row widths. The design used was a split-plot with locations (Delhi Tobacco Research Station and a nearby farm) as the main plots and cultivar x seed source as subplots. All cultural practices were the same at each location. The fertility program consisted of 448 kg/ha of 3-9-18 analysis fertilizer broadcast and ploughed down on April 13.

All seeds were treated with commercially available seed treatment at the recommended rates for peanuts. The seeds were planted on May 13 at a rate of 13 viable seeds per meter to a depth of approximately four cm by means of hand-operated V-belt seeders. The plots were overseeded to compensate for differences in petri dish germination percentages. A commercial *Rhizobium spp.* peat inoculant was applied with the seeds at planting. Weed control was achieved using 2.24 kg alachlor [2-chloro-2', 6'-diethly-*N*-(methoxymethyl)-acetanilide] active ingredients/ha plus 2.24 kg dinoseb (2-*sec*-butyl-4,6-dinitrophenol) a.i./ha applied at cracking. Leafhoppers (*Empoasca fabae* Harris) were controlled by means of a foliar spray of 1.12 kg carbaryl (1-napthyl *N*-methylcarbamate) a.i./ha on July 9, 17, 30, and August 20. Leafspot (*Cercospora* spp.) was controlled by applying a foliar spray of 0.81 kg chlorothalonil (tetrachloroisophthalonitrile) a.i./ha on June 25, July 9, 17, and 30. On September 30, 6 m of the center row were harvested by hand for yield. After the pods had been pulled from the vine by hand, the roots were examined to determine the number of plants with normal root development. Digging by hand enabled the majority of the root to be examined. A normal-rooted plant was characterized as having a long straight tap root with many laterals.

Seed Sources For Experiments, II, III, IV

To determine if selection for normal-rooted plants was possible three peanut genotypes of the Spanish type (Delhi an introduction of unknown origin, U.S.D.A. P.I. No. 26881, and the commercial cultivar Comet) were grown in 1976. At harvest, the total number of pods on fifty plants with normal roots and on fifty plants with abnormal roots was recorded for each line. The criteria used to determine plants with normal root systems was the same as that used in Experiment I. An abnormal root was defined as having either a curvature of the hypocotyl or the hypocotyl and main tap root or lack of a main tap root.

Seeds were collected from four sources within each of the three genotypes (Delhi, U.S.D.A. P.I. No. 26881, and Comet): (a) from normal-rooted plants, (b) from abnormal-rooted plants, (c) from a random selection of plants from within the field, and (d) from a random selection of plants which had been combine-harvested. The seeds from the first three sources were hand-harvested. The treatments for Experiments II, III, and IV consisted of the above four seed sources for each of the three genotypes making a total of 12 treatments. For the field trials, (Experiments III, and IV) in addition to the above 12 treatments, Comet seed, from a commercial certified seed lot, was included.

Growth Cabinet[1] Study (Experiment II)

Seed from each of the 4 sources for the three peanut genotypes (Delhi, U.S.D.A. P.I. No. 268661 and Comet) was treated with the fungicide Granox PFM (maneb 30% - captan 30% - molybdate 1%). Chipman Chemicals Ltd., Stoney Creek, Ontario, at 142 g/45 kg of seeds. The seeds were planted into a Fox loamy sand in wooden flats (57 cm x 27.5 cm x 14 cm). A 12-hour light and dark photoperiod with a light intensity of 300u Einsteins m^{-2} sec^{-1} and a constant temperature of 25 ± 0.5 C was used. The experimental unit consisted of 20 seeds per plot, planted approximately 2.5 cm apart. There were four treatments within one flat, with three flats per replicate. A randomized complete block design with four replicates was used. The flats were watered regularly to ensure sufficient moisture for normal development. The plants were harvested three weeks after planting and scored as having either a normal or abnormal root system.

Field Trials (Experiments III and IV)

Experiments III and IV were conducted to determine the percentage of normal-rooted plants in each of the thirteen treatments under field conditions. Experiment IV was further used for yield determinations. The fertility program consisted of 330 kg/ha of 10-20-20 analysis fertilizer broadcast and ploughed down on April 26. The plots were overseeded to compensate for differences in germination percentages. The seeds were treated with Granox PFM at 142 g/45 kg of seed, then planted at a rate of 15 viable seeds/m to a depth of approximately 4 cm by means of hand-operated V-belt seeders. A commercial *Rhizobium* spp. granular inoculant was applied with the seed at planting. An early planting date (April 27) was used in both experiments to ensure that the seeds were exposed to a chilling stress.

The experimental unit for Experiment III consisted of a single row, 7 m long, with 40 cm row widths, using a randomized complete block design. Weed control was achieved with 3.36 kg alachlor a.i./ha plus 2.24 kg dinoseb a.i./ha applied at cracking on May 13. The mean number of days from planting to emergence was recorded for each treatment. On June 16 (50 days after planting) each row was hand-dug, the root system washed to remove excess soil, and examined. The roots were classified as either normal, intermediate, or abnormal. An intermediate category consisted of plants with roots that had a slightly to moderately curved hypocotyl.

The experimental unit for Experiment IV consisted of three rows, 7 m long with 40 cm row widths. A randomized complete block design was used. Weed control was achieved with 3.36 kg alachlor a.i./ha plus 2.24 kg dinoseb a.i./ha applied at cracking on May 13. Leafhoppers were controlled by means of 3.4 kg granular disulfoton (0, 0-diethyl S-2-(ethylthio) ethyl phosphorodithiioate) a.i./ha banded over the row on June 10 and a foliar spray of 1.12 kg carbaryl a.i./ha on July 12, 29 and August 9. Leafspot was controlled by applying a foliar spray of 0.81 kg chlorothalonil a.i./ha on July 29. On October 3, 6 m of the center row were harvested by hand for yield. After the pods had been removed by hand, the roots were examined and classified as either normal, intermediate, or abnormal.

In all experiments, the percentage of plants in each of the categories was determined. For purposes of analysis the percentages were transformed into arcsin square root values.

Pods from all experiments were cured in an ambient temperature dryer to 10% moisture and later shelled in a U.S. Federal Inspection Sheller. Sound Mature kernels (SMK) were graded over a 0.60 x 1.90 cm screen. In Experiment IV, an analysis of covariance (3) was used to adjust pod weight, kernel weight, and SMK weight to compensate for differences in plant population.

[1]Model E8M, Controlled Environments Ltd.

Results and Discussion

For each of the four cultivars in Experiment I, plants from the hand-harvested seed dramatically outyielded plants from the commercial seed (Table 1). Reduction in

Table 1. Effect of seed source on yield, stand and percentage of plants with normal roots systems for four peanut cultivars.

Cultivar	Seed source	Pod yield[+]	Normal roots[+]	Population[+]
		kg/ha	%	plants/ha
Comet	Ontario grown hand-harvested	2210 a*	80.2 ab	232813 a
	U.S. commercial seed	841 e	57.7 d	58333 d
Starr	Ontario grown hand-harvested	1998 ab	81.2 ab	234375 a
	U.S. commercial seed	903 de	68.4 bcd	58854 d
Tifspan	Ontario grown hand-harvested	1908 b	78.2 ab	200521 b
	U.S. commercial seed	1165 cd	61.5 cd	86979 c
Goldin I	Ontario grown hand-harvested	1284 c	83.1 a	189583 b
	U.S. commercial seed	886 de	71.7 abc	91667 c
C.V., %		28.0	21.2	17.5

[+]Data represent the mean of two locations, the effect of locations and the interaction of locations x cultivar-seed source was not significant.

*All means within a column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test (MNRT) at the 5% level.

yield of plants from commercial seeds would appear to be a product of two factors (a) the reduced plant population, and (b) the lower percentage of plants with normal root systems (Table 1). As the same population of viable seeds was planted in both groups, the lower population of the commercial seeds must have been due to seed damage which was not detectable using petri plate germinations. Teter and Miller (5) and Moore (2) reported that, although germination of mechanically injured seed may not be significantly lowered, the emergence and early development of the seedlings was retarded.

For each line (Delhi, U.S.D.A. P.I. No. 268661, and Comet) harvested in the fall of 1976, (seed source for Experiments II, III, IV), there were approximately twice the number of pods on plants with normal roots as were obtained from plants with abnormal roots (Table 2). The dramatic reduction of pod numbers on plants with abnormal roots plus the high percentage of these plants in the field populations of Delhi and Comet emphasize the adverse affect of abnormal roots on final yield.

Table 2. Percentage of plants with normal or abnormal root systems and the total number of pods/plant of each type for three peanut genotypes.

Line	Root system		Number of mature pods/plant+	
	Normal	Abnormal	Normal	Abnormal
	%			
Delhi	40.0	60.0	11.3	6.7
U.S.D.A. P.I. No. 268661	78.3	21.7	24.8	12.3
Comet	49.8	50.2	17.0	8.2

+Mean of fifty plants for each genotype and each root type.

Experiment II

There were no significant differences in the percentage of plants with normal roots among the progeny of normal, abnormal or random seed sources for any genotype when the seeds were hand-harvested (Table 3). However, the combine-harvested treatments produced a significantly lower percentage of plants with normal root systems than the other treatments.

Table 3. Effect of seed source on the percentage of plants with normal root systems for three peanut genotypes when grown in controlled environment at 25 C (winter 1977).

Seed source+	Peanut genotypes		
	Delhi	U.S.D.A. P.I. No. 268661	Comet
	% normal roots		
Normal-rooted plants	78.9 a*	77.2 a	77.4 a
Abnormal-rooted plants	76.7 a	80.9 a	77.6 a
Random selection of plants (original population)	83.3 a	81.4 a	85.9 a
Random selection of plants (combine-harvested)	48.6 b	30.2 b	43.9 b
C.V., %		14.2	

+Seeds from the first three seed sources were hand-harvested.

*Values followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at the 5% level.

For each genotype in each of the hand-harvested populations, approximately 80% of the plants had a normal root system. It was not known what caused approximately 20% of the progeny to have abnormal root systems, although mechanical damage incurred during shelling may have been a contributing factor.

Field Trials

In Experiment III, the rate of emergence was more rapid from hand-harvested seeds than from combine-harvested seeds for Comet and U.S.D.A. P.I. No. 268661 (Table 4). A numerical reduction in emergence rate for combine-harvested seeds when compared with hand-harvested seeds was noted for Delhi (Table 4). Several authors have noted a decrease in the rate of seedling emergence for plants with abnormal root development (2, 4, 5). The logical extension of this observation is that the lower the percentage of potentially normal-rooted plants in any given population, the slower the mean rate of emergence. The lower percentage of normal-rooted plants from the combine-harvested seeds of Comet and U.S.D.A. P.I. No. 268661 and the commercial Comet seeds agrees with the delay in emergence (Table 4).

Selection for normal-rooted or abnormal-rooted plants resulted in no significant increase or decrease, respectively, in the percentage of plants with normal roots, over the original (random seed source) population (Table 4). During the period from planting to emergence, the minimum air temperature dropped below 5 C 16 times and on four occasions it was 0 C or below, ranging down to -5 C. The average maximum temperature during this period was 20.8 C. The low temperatures should have simulated the experimental conditions employed by Branch (1) and, therefore, exposed differences among the progenies of the hand-harvested seed sources.

The combine-harvested seed for Comet and P.I. No. 268661 was significantly lower in the percentage of normal-rooted plants than the hand-harvested seed (Table 4). A numerical decrease, which approached significance, was also observed for Delhi. The commercial Comet seed produced significantly fewer plants with normal root systems than the hand-harvested Comet treatments, but was not significantly different from the combine-harvested Comet.

In Experiment IV, the results, when the roots were evaluated at harvest, were similar to those obtained in Experiments I, II, and III (Table 5).

From the data presented in Table 2, and from that of Sullivan and Perry (4), it can be concluded that a plant with an abnormal root system was only capable of producing, on the average, 40-50% of the yield of a plant with a normal root system. Pod, total kernels (TK) and SMK weights were used to derive mean squares for seed source comparisons among the three genotypes. The mean squares indicated that the significantly lower yield of pods, TK and SMK for the combine-harvested seeds for the Delhi and Comet (Table 6), when compared to the hand-harvested seeds, can be directly attributed to the

Table 4. Effects of seed source on rates of field emergence and the percentage of plants with normal, intermediate, or abnormal root systems for three peanut genotypes (field, summer 1977).

Genotype	Seed source+	Emergence	Root types‡ Normal	Intermediate	Abnormal
		days	%		
Delhi	Normal-rooted plants	23.3 abc*	51.4 bcd	33.8 bcd	14.7 abc
	Abnormal-rooted plants	23.0 abcd	50.7 bcd	37.3 bc	12.0 abc
	Random selection of plants	23.4 ab	46.0 cd	32.2 bcd	21.8 a
	Random selection of plants combine-harvested	24.0 a	39.0 de	42.4 ab	18.7 ab
U.S.D.A. P.I. No. 268661	Normal-rooted plants	21.3 ef	68.2 a	24.6 cd	7.2 c
	Abnormal-rooted plants	21.0 f	74.7 a	20.8 d	4.5 c
	Random selection of plants	21.1 f	64.3 ab	27.5 bcd	8.2 c
	Random selection of plants combine-harvested	22.9 bcd	43.0 d	36.4 bc	20.6 a
Comet	Normal-rooted plants	22.1 def*	64.0 ab	29.2 bcd	6.8 c
	Abnormal-rooted plants	22.2 cde	60.8 abc	30.5 bcd	8.6 bc
	Random selection of plants	22.0 def	71.4 a	23.2 cd	5.4 c
	Random selection of plants combine-harvested	23.9 ab	37.2 de	42.2 ab	20.6 a
	Commercial seed	23.7 ab	26.8 e	53.2 a	20.0 a
C.V., %		3.3	11.9	16.5	27.0

+Seeds from the first three seed sources within each genotype were hand-harvested.

‡The roots were evaluated 50 days after planting.

*Values within a column followed by the same letter do not differ significantly according to Duncan's New Multiple Range Test at the 5% level.

lower percentage of normal-rooted plants. The yield difference between the progenies of hand-harvested Comet and commerical Comet, and between combine-harvested Comet and commercial Comet can also be attributed to differences in the percentage of normal-rooted plants. There was no significant yield reduction associated with combine-harvested seed of P.I. No. 268661 when compared with the hand-harvested seed.

In all of the experiments, the data were consistent in that selection for normal-rooted plants was not successful.

Comparison of commercial seed sources with hand-harvested seed sources suggests that damage to seeds was occurring with commercial seed production. Combining and shelling may both be contributing to this seed damage. In all experiments, commercial seeds were representative of seeds from only one seed lot, and thus extrapolation to the entire peanut seed industry is obviously not justified. However, the consistently poor performance of the commercial seeds relative to the hand-harvested seeds does suggest that somewhere in the commercial seed production system damage to the seeds was occurring and that more research in the seed quality is justified.

Table 5. Effects of seed source on the percentage of plants with normal, intermediate, or abnormal root systems for three peanut genotypes (field, summer 1977).

Line	Seed source+	Root types§		
		Normal	Intermediate	Abnormal
		%		
Delhi	Normal-rooted plants	73.6 ab*	20.2 de	6.2 cd
	Abnormal-rooted plants	67.2 ab	23.3 de	8.1 cd
	Random selection of plants‡	60.0 b	31.2 bcd	8.1 bcd
	Random selection of plants combine-harvested‡	39.5 c	38.4 ab	21.4 ab
U.S.D.A. P.I. No. 268661	Normal-rooted plants	66.5 ab	23.9 cde	9.6 bcd
	Abnormal-rooted plants	71.8 ab	20.7 de	7.5 cd
	Random selection of plants	73.7 ab	15.3 e	11.0 abcd
	Random selection of plants combine-harvested	39.5 c	34.6 abc	25.9 a
Comet	Normal-rooted plants	73.0 ab*	21.8 de	5.1 cd
	Abnormal-rooted plants	75.6 a	21.4 de	3.2 cd
	Random selection of plants	71.0 ab	25.5 cde	3.5 d
	Random selection of plants combine-harvested	39.8 c	45.9 a	14.2 abc
	Commercial seed	22.2 d	45.8 a	24.5 a
C.V., %		10.3	14.3	39.0

+The first three seed sources within each line were hand-harvested.

*All values within a column followed by the same letter do not differ significantly according to Duncan's New Multiple Range Test at the 5% level.

‡One plot estimated by missing plot technique for a Randomized Complete Block design.

§The roots were evaluated at harvest.

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Table 6. Mean squares of eleven single degree of freedom comparisons among the progeny of four seed sources (normal-rooted plants, abnormal-rooted plants, random selection of plants, and random selection of plants combine-harvested) for pod, kernel, and sound mature kernel yield for three peanut genotypes.

Genotype	Seed source comparison	Mean squares		
		Pods	Kernels	SMK
Delhi	Normal vs. abnormal	221,379	78,021	60,890
	Normal vs. random	108,206	35,078	25,429
	Normal, abnormal, random vs. combine-harvested	529,284*	282,747*	202,904*
U.S.D.A. P.I. No. 268661	Normal vs. abnormal	34,954	20,800	31,786
	Normal vs. random	65,305	18,723	20,967
	Normal, abnormal, random vs. combine-harvested	199,589	108,224	77,538
Comet	Normal vs. abnormal	2,903	2,165	867
	Normal vs. random	20,160	10,585	12,545
	Normal, abnormal, random vs. combine-harvested	337,614*	204,572*	195,126*
	Normal, abnormal, random vs. commercial seed	2,157,651**	1,270,362**	1,197,640**
	Combine-harvested vs. commercial seed	350,354*	202,384*	189,304*

*, ** Indicates significance at the 5% level and the 1% level respectively.

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