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RESEARCH

Establishment, Agronomic Characteristics, and Dry Matter Yield of Rhizoma Peanut Genotypes in Cool Environments

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ABSTRACT

Rhizoma peanut (*Arachis glabrata* Benth.) has potential to provide high quality forage during summer months; however, establishment of the stand is slow and cold tolerance is limited. During the three growing seasons from 2006 to 2010, a randomized complete block design experiment was initiated at four locations, near Tifton, GA (2006, 2007, and 2008), Gene Autry, OK (2006), Burneyville, OK (2007 and 2008), and Vashti, TX (2007 and 2008), evaluating 16 rhizoma peanut genotypes for better establishment characteristics and cold tolerance. At the end of the establishment year, genotype A6 (PI 210555) had the greatest coverage (74%), followed by genotypes A156 and A160 (51 and 56%, respectively), while genotypes A10 and A42 had the least coverage (9 and 13%, respectively). The remaining genotypes were intermediate and generally did not differ from the released cultivars Florigraze, Arbrook, and Latitude 34, which had 25, 25, and 30% coverage, respectively. In the second season after establishment, genotypes Latitude 34 and A160 produced the greatest yields (1000 and 1360 kg ha^{-1}, respectively). In the third season after establishment, Latitude 34 (3630 kg ha^{-1}) outyielded all genotypes except A156 and A160 (2610 and 2260 kg ha^{-1}, respectively). Therefore genotypes A160 and Latitude 34 consistently had the greatest coverage and production and may have greater cold tolerance. However, in the final year (2010), there were no genotypes that survived the winter.

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Abbreviations: CP, crude protein; DM, dry matter.

Rhizoma peanut (*Arachis glabrata* Benth.) is a warm-season perennial forage legume that has relatively high dry matter (DM) yield and nutritive value similar to that of alfalfa (*Medicago sativa* L.) (Ocumpaugh, 1990; French, 1991). In Florida, the DM yield of 'Florigraze' and 'Arbrook' range from 9968 to 11,984 kg ha^{-1} (Prine et al., 1986, 1990). In central Georgia, Florigraze DM yields increased from 5197 kg ha^{-1} the season after establishment to 10,595 kg ha^{-1} the third season after establishment (Terrill et al., 1996). In south Texas (Ocumpaugh, 1990), Florigraze DM yields (8000 to 10,000 kg ha^{-1}) were similar to yields obtained in Florida and Georgia. In north central Texas, rhizoma peanut yields averaged 6038 kg DM ha^{-1} under dryland conditions and 8600 kg DM ha^{-1} under irrigation (Butler et al., 2007). Terrill et al. (1996) reported that alfalfa had greater crude protein (CP) concentrations than rhizoma peanut but in vitro organic matter digestibility (IVOMD) values were similar. Saldivar et al. (1990) reported CP concentrations ranging from 200 to 250 g kg^{-1} in April but declined to 125 g kg^{-1} at the end of the season.

Although rhizoma peanut has potential to provide high quality forage during the summer when forage nutritive value is typically low,

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it requires 2 to 3 yr for complete coverage (Rice et al., 1996; Williams et al., 1997). Another weakness associated with rhizoma peanut is the high cost of planting along with the long grazing-deferment period during establishment (Rice et al., 1995). Defoliation during the year after establishment greatly reduces rhizome production (Saldivar et al., 1992); therefore, utilization should be deferred until stands are completely established. Rhizoma peanut is typically only recommended for sandy soils with a pH ranging from 5.8 to 6.5 (Prine et al., 1990; French and Prine, 2006). However, Reed and Ocumpaugh (1991) identified 23 genotypes tolerant to Fe deficiency chlorosis on high pH calcareous soils from a screening of 69 PIs. Of these 23 genotypes, two (PI 262819 and PI 262821), originally from Paraguay (French et al., 1993), were identified as having agronomic potential with greater height, spread, and estimated DM production (Butler et al., 2006).

Rhizoma peanut releases are currently limited to the extreme southern United States due to poor winter hardiness (French and Prine, 2006). Initial winter conditions and harvest management during the second season after establishment can greatly affect rhizoma peanut survival (Butler et al., 2006). Identifying germplasm that establishes more rapidly, tolerates cold temperatures, and is adapted to a wider range of soils than the currently available genotypes might expand the growing area of rhizoma peanut. Therefore, the objective of this study was to evaluate rhizoma peanut genotypes for better establishment characteristics and cold tolerance on various soils.

MATERIALS AND METHODS

During the 2006 to 2010 seasons, a randomized complete block design experiment evaluating 16 rhizoma peanut genotypes was initiated at Tifton, GA (2006, 2007, and 2008, Pelham loamy sand, Loamy-siliceous-thermic Arenic Paleaquults), Gene Autry, OK (2006, Dale silt loam, Fine-silty, mixed, superactive, thermic Pachic Haplustoll), Burneyville, OK (2007, Eufaula loamy sand, Siliceous, thermic Psammentic Paleustalfs; 2008, Ashport clay loam, Fine-silty, mixed, superactive, thermic Fluventic Haplustolls), and Vashti, TX (2007, Anocon loam soil, Fine, mixed, thermic Udic Paleustalfs; 2008, Bonti fine sandy loam, Fine, mixed, active, thermic Ultic Paleustalfs). Genotypes evaluated included A6 (PI 210555), A10 (PI unknown), A20 (PI 162801), A23 (PI 118457), A27 (PI unknown), A42 (PI unknown), A44 (PI 231318), A76 (PI unknown), A156 (PI unknown), A160 (PI unknown), HL335 (PI 338317), and HL410 (PI 338280) (all experimental lines from the USDA-ARS); TX62 (PI 262819) and 'Latitude 34' (Muir et al., 2010) recently released for northern Texas, and two cultivars from Florida (Arbrook and Florigraze; Prine et al., 1986, 1990).

Soil pH values ranged from 4.7 to 8.3 (Table 1). Within each site, individual 15-cm rhizomes were planted in the greenhouse in late winter (February) and then transplanted to the field in April (after the last killing frost). Sites were fertilized one time with P and K according to soil test recommendation before planting. Each plot consisted of five plants spaced 61-cm apart, which resulted in an effective 1.5 by 3 m plot, with 1.5 m alleys between each entry. In each year, two replications per location were used due to limited amount of rhizomes available. During the initial establishment year at each location, the number of shoots that emerged, the length of rhizoma peanut spread, and plant height was recorded for each plant on a monthly interval throughout the growing season (April–October); however, only the measurements taken in October, the end of the season, are reported. Dry matter yield was not estimated during the first season due to higher probability of winter kill (Butler et al., 2006). Weeds were controlled as needed depending on species present: 2,4-DB (Butyrac) 4-(2,4-dichlorophenoxy) butyric acid (Albaugh , Inc. / Agri-Star, Ankeny, IA) was applied at 0.84 kg a.i. ha^{-1} to control broadleaf weeds, clethodim (Select) (±)-2-[(E)-1-[(E)-3-chloroallyloxyimino]propyl]-5-[2-(ethylthio) propyl]-3- hydroxycyclohex-2-enone (Winfield Solutions, LLC, St. Paul, MN) applied at 0.28 kg a.i. ha^{-1} was used to control grass weeds, and imazapic (Plateau) 5-methyl-2-(4-methyl-5-oxo-4-propan-2-yl-1H-imidazol-2-yl)pyridine-3-carboxylic acid (BASF Specialty Products, Research Triangle Park, NC) applied at 0.067 kg a.i. ha^{-1} was used for residual control of grasses, broadleaves, and sedges. In addition, plots were maintained weed-free by hand weeding throughout the season.

During the second season, DM yield and percent ground coverage were estimated once in July, while in the third season, DM yields and percent coverage were estimated in both July and October. Total yield is reported in the third season as the sum of July and October yields. Yields were estimated at the northern locations by clipping the entire plot with a forage harvester (Hege, Colwich, KS) to approximately 2.5-cm height. Dry matter yield at Tifton, GA, was not included, since there was no winter damage or loss of stands at this location. Forage samples were weighed at harvest and dried in a forced draft oven set at 50°C to a constant weight for 3 to 4 d. Dry matter yield was determined from the percent DM and plot yields.

All data were analyzed as mixed models, with replication, year, and location as random effects and rhizoma peanut

Table 1. Site, year of establishment, soil name, texture, pH, and P and K concentrations where rhizoma peanut (*Arachis glabrata* Benth.) were evaluated.

Site	Year	Soil name	pH	P	K
				kg ha^{-1}	
Gene Autry, OK	2006	Dale silt loam	6.8	276	632
Tifton, GA	2006	Pelham loamy sand	5.2	25	103
Burneyville, OK	2007	Eufaula loamy sand	7.9	99	256
Vashti, TX	2007	Anocon loam	6.4	99	576
Burneyville, OK	2008	Ashport clay loam	8.3	41	793
Vashti, TX	2008	Bonti fine sandy loam	4.7	13	233

Table 2. Location, 30-yr average and actual precipitation during the growing season (March–October), absolute low temperatures by year and location, and number of days minimum and maximum temperatures were below freezing.

Location	Growing season				
	30-yr avg.	2006	2007	2008	2009
	Precipitation (mm)				
Gene Autry, OK	737	305	533	432	635
Tifton, GA	838	457	610	838	1168
Burneyville, OK	737	–	813	533	1143
Vashti, TX	610	–	406	483	533
	Low temperature† (°C)				
Gene Autry, OK	–	–11	–10	–12	–14
Tifton, GA	–	–5	–6	–6	–7
Burneyville, OK	–	–	–11	–11	–16
Vashti, TX	–	–	–17	–11	–14
	No. days minimum temperature below 0°C				
Gene Autry, OK	–	47	59	61	69
Tifton, GA		12	11	19	23
Burneyville, OK	–	–	70	72	74
Vashti, TX		–	68	67	70
	No. days max temperature below 0°C				
Gene Autry, OK	–	9	0	5	5
Tifton, GA		0	0	0	0
Burneyville, OK	–	–	0	5	1
Vashti, TX		–	1	3	5

†Absolute minimum temperature reached in the winter following the growing season listed.

genotype as fixed effect, using the PROC MIXED procedure of SAS (SAS Institute, 1999). Significance was determined at the $p < 0.05$ level. The PDIFF feature of the LSMEANS procedure was used to compare means. Coverage data were subjected to arcsine transformation before statistical analysis and back-transformed for data presentation.

RESULTS AND DISCUSSION

Weather

Precipitation varied across years and locations but was generally less than the 30-yr average (Table 2). At Gene Autry, OK, precipitation ranged from 15 to 60% less than average and at Vashti, TX, precipitation ranged from 15 to 34% less than average. At the Burneyville, OK, location, precipitation ranged from 28% less than average in 2008 to greater than 60% above average in 2009. At Tifton, GA, precipitation ranged from 45% below average in 2006 to 39% above average in 2009. The absolute low temperature recorded the winter after establishment was similar across the Oklahoma and Texas locations, ranging from –12 to –10°C in 2006 to 2008 seasons. In the winter of 2009–2010, temperatures were slightly colder, reaching –16 to –14°C. However, temperatures at Tifton, GA, were considerably milder with low temperatures reaching –7 to –5°C.

Table 3. Rhizoma peanut (*Arachis glabrata* Benth.) genotypes evaluated for distance of lateral spread, percent coverage, and shoot emergence in October of the establishment year averaged across the Gene Autry, OK, Burneyville, OK, Vashti, TX, and Tifton, GA, locations.

Entry	PI identifier	Lateral spread†	Coverage	Shoot
		cm	%	No. plant^{-1}
A6	210555	111 cd‡	74 e	117 e
A10	–	59 a	9 a	6 a
A20	162801	92 c	29 c	30 bc
A23	118457	99 c	28 c	36 bc
A27	–	90 bc	23 abc	47 cd
A42	–	95 c	13 a	36 bc
A44	231318	99 c	32 c	35 bc
A76	–	73 ab	16 ab	21 ab
A156	–	106 c	51 d	59 d
A160	–	99 c	56 d	65 d
Arbrook	–	73 ab	25 bc	28 bc
Florigraze	–	70 a	25 bc	23 ab
HL335	338317	106 c	27 c	34 bc
HL410	338280	121 d	36 c	34 bc
Latitude 34	–	91 c	30 c	31 bc
TX62	262819	92 c	25 bc	33 bc
SE		12.5	1.3	9.9

†The average distance that an individual plant spread laterally at the end of the establishment year.

‡Means followed by the same letter within column do not differ by the LSMEANS test ($p > 0.05$).

Percent Coverage at the End of the Establishment Year

Averaged across years and locations, percent coverage at the end of the establishment year (7 mo after planting) ranged from 9 to 74% (Table 3). Others have reported similar variation (5 to 100%) for percent coverage of Florigraze and Arbrook 8 mo after planting in Florida, depending on year and location (Williams, 1993; Williams et al., 1997). Greater coverage ratings indicates quicker establishment, which is important to reduce competition from weeds and could result in more rapid utilization (Butler et al., 2006). Genotype A6 (PI 210555) had the greatest coverage (74%), followed by genotypes A156 and A160 (51 and 56%, respectively), while genotypes A10 and A42 had lesser coverage (9 and 13%, respectively) than all genotypes except A27 and A76. The remaining genotypes were intermediate and generally did not differ from the released cultivars Florigraze, Arbrook, and Latitude 34, which had 25, 25, and 30% coverage, respectively.

Lateral Spread at the End of the Establishment Year

The average distance that an individual plant spread laterally at the end of the establishment year ranged from 59 to 121 cm (Table 3). This parameter gives an indication of how far the rhizomes spread during the establishment year, which could be useful in determining the population density needed for successful establishment. Genotypes that spread farther could compensate for lower densities or could establish more quickly. Genotypes HL410 (PI 338280) and A6 (PI 210555) tended to have the greatest spread, while genotypes A10 and Florigraze had lesser spread than all genotypes except A76 and Arbrook. The remaining genotypes were intermediate and similar to the released cultivar Latitude 34 (91 cm). Butler et al. (2006) reported that Arbrook and Florigraze spread from 142 to 191 cm when planted using similar methodology; however, their report was for 14 mo after planting, instead of 7 mo in this study.

Number of Shoots at the End of the Establishment Year

The number or density of shoots ranged from 6 to 117 shoots plant^{-1} when planted on 61-cm intervals (Table 3). Genotypes with increased density establish more quickly and may have greater rhizome mass that improves winter survival. Genotype A6 (PI 210555) had the greatest average shoot count per plant (117), followed by genotypes A156 and A160 (59 and 65 shoots plant^{-1}, respectively). Genotype A10 had lesser shoot density than all genotypes except A76 and Florigraze, with only six shoots per plant. The remaining genotypes were intermediate and similar to Arbrook and Latitude 34 (28 and 31 shoots plant^{-1}, respectively). It is difficult to compare results to other published data due to differences in establishment methods, but Butler et al. (2006) reported total shoot counts ranging from 119 to 380 shoots m^{-2} and Williams (1993) reported 2 to 65 shoots m^{-2} depending on year and establishment method.

Combining all three parameters for establishment, genotype A6 (PI 210555) was superior to all other genotypes followed by genotype A156 and A160. Therefore, these genotypes have better establishment characteristics and should be better adapted to compete with weeds and may have better winter survival due to increased rhizome growth.

Lateral Spread in the Second Season

Distance of lateral spread per plant in July of the second season after planting ranged from 52 to 182 cm for all genotypes (Table 4). These results are similar to those reported elsewhere. For example, Butler et al. (2006) reported that Arbrook, Florigraze, and Latitude 34 spread ranged from 140 to 198 cm 14 mo after planting in south Texas. Genotype A20 (PI 162801) exhibited less lateral spread than all genotypes except A27, A76, Florigraze, and HL335 (PI 338317). Genotypes A6 (PI 210555), A23 (PI 118457), A42, A44 (PI 231318), A156, A160, HL410 (PI 338280), Arbrook, and Latitude 34 had the greatest spread and did not differ from each other.

Percent Ground Coverage in the Second Season

Percent ground coverage ranged from 4 to 86% in July of the second season after planting (Table 4), which was generally similar to the values reported at the end of the first season, except for genotypes A160 and Latitude 34, for which coverage was approximately 1.5 and twofold greater than the first season, respectively. This indicates

Table 4. Rhizoma peanut (*Arachis glabrata* Benth.) genotypes evaluated for distance of lateral spread, coverage, and dry matter (DM) yield in July of the second season after planting and for total DM yield in the third season after planting, averaged across the Gene Autry, OK, Burneyville, OK, and Vashti, TX, locations.

Entry	PI identifier	July of second season after planting			Third season after planting
		Spread diameter	Coverage	Yield	Total yield
		cm	%	kg DM ha^{-1}	kg DM ha^{-1}
A6	210555	134 cde†	43 defg	510 d	2160 c
A10	–	107 bcd	16 abcd	0 a	550 ab
A20	162801	52 a	4 a	2 a	80 a
A23	118457	145 de	39 cdef	150 ab	1400 bc
A27	–	68 ab	15 abc	0 a	100 ab
A42	–	149 de	24 bcdef	100 ab	1340 abc
A44	231318	182 e	45 efg	190 abcd	900 ab
A76	–	101 abcd	16 abcd	490 cd	1290 abc
A156	–	120 bcde	46 fg	470 cd	2610 cd
A160	–	122 bcde	86 h	1360 e	2260 cd
Arbrook	–	109 bcde	29 bcdef	370 bcd	1680 bc
Florigraze	–	70 ab	10 ab	40 ab	30 a
HL335	338317	89 abc	21 bcde	240 abcd	330 ab
HL410	338280	130 cde	34 cdef	370 bcd	560 ab
Latitude 34	–	155 de	69 gh	1000 e	3630 d
TX62	262819	107 bcd	27 bcdef	170 abc	320 ab
SE		32.1	3.2	196.7	759.7

†Means followed by the same lowercase letters within column do not differ by the LSMEANS test ($p > 0.05$).

that these two genotypes may be better adapted and may have superior winter survival compared to other entries.

Dry Matter Yield in the Second Season

Dry matter yield ranged from 0 to 1360 kg ha^{-1} (Table 4) in July of the second season after planting, which is substantially lower than values reported by others in warmer latitudes (Butler et al., 2006, 2007; Terrill et al., 1996), illustrating the winter loss at these northern locations. Genotypes Latitude 34 and A160 yielded 1000 and 1360 kg DM ha^{-1}, respectively, which was greater than the yields of all other genotypes. Therefore, these two genotypes may have greater cold tolerance since they recovered more quickly and produced more DM compared to other genotypes at these northern locations.

Total Dry Matter Yield in the Third Season

Distance of lateral spread and coverage exhibited similar trends among genotypes as the data reported for end of establishment year and second season after planting. These data are not shown in an attempt to reduce the presentation of redundant data. Rhizoma peanut genotypes were harvested twice (July and October), and both harvests were summed and reported as total DM yield. Total DM yield ranged from 30 to 3630 kg ha^{-1} (Table 4), which is considerably lower than total DM yields reported by Butler et al. (2006, 2007) and Terrill et al. (1996) at more southern latitudes, most likely a result of significant winter kill at these northern locations. In the third season after establishment, Latitude 34 produced greater total DM yield (3630 kg ha^{-1}) than all genotypes except A156 and A160 (2610 and 2260 kg DM ha^{-1}, respectively). Florigraze was among the lesser yielding genotypes, producing only 30 kg DM ha^{-1} for the entire growing season. Therefore, genotypes A160 and Latitude 34 consistently had the greatest coverage and DM production and may have greater cold tolerance, which would allow for greater utilization of rhizoma peanut.

Winter Survival

Winter survival as indicated by DM yield and percent ground coverage the seasons following the establishment year varied by genotype. Low temperatures during these years ranged from –12 to –10°C at the Oklahoma and Texas locations. Latitude 34 and genotype A160 appear to be slightly more winter hardy than the other genotypes in the study. However, following the 2009–2010 winter season when temperatures ranged from –16 to –14°C, none of the rhizoma peanuts survived at the southern Oklahoma or north Texas locations regardless of location, soil type, or establishment year (data not shown). Ball et al. (2002) reported that Florigraze rhizoma peanut survived temperatures as low as –9°C, while Terrill et al. (1996) found that Florigraze survived –12°C temperatures at Fort Valley, GA (32° N 83° W). However, Butler et al. (2006) reported that newly established Latitude 34 survived sustained freezing temperatures as low as –14°C in December 2005 at Stephenville, TX (32° N, 98° W), and Ardmore, OK (34° N, 97° W). The winter of 2009–2010 was unique in that these locations received two greater-than-254-mm snow events and above-normal winter precipitation compared to the below-average precipitation the previous years. Therefore, the increased soil moisture in combination with temperatures below –12°C could have limited rhizoma peanut production and adaptation. Andrews (1987) describes several ways in which low temperature stress may contribute to plant death, including cell membrane disorganization during freezing exposure, dessication stress, anaerobic stress due to restriction of gas exchange by flooding and ice encasement, soil heaving, and low-temperature diseases. Further research is needed to determine the physiological effects of freezing temperatures on rhizoma peanut in these cool environments.

CONCLUSIONS

Although rhizoma peanut genotypes were slow to establish in this study, two genotypes (A156 and A160) exhibited greater establishment (coverage and spread) than current commercial cultivars. Rhizoma peanuts were also low yielding at the northern locations, but genotypes A160 and Latitude 34 consistently produced the greatest DM yield across locations, which suggests these two genotypes may have greater cold tolerance than traditional commercial cultivars Florigraze and Arbrook. Utilizing new genotypes adapted to colder climates could slightly expand the current area of rhizoma peanut adaption. However, there are definite northern limitations to the adaptation of even A160 and Latitude 34 since these did not survive in the final year of the study. There are, therefore, risks to recommending or growing rhizoma peanut much beyond the current region of where it is presently grown until better genotypes are identified.

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