# Rhizoma Peanut Yield and Nutritive Value are Influenced by Harvest Technique and Timing

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## ABSTRACT

**Rhizoma peanut (*Arachis glabrata* Benth.) is a warm-season perennial forage legume adapted to the southern USA. The objectives of this study were to evaluate harvest technique and timing on dry matter (DM) yield, crude protein (CP), acid detergent fiber (ADF), and acid detergent lignin (ADL) concentrations of rhizoma peanut. Two experiments (one without irrigation and one with irrigation) each with four replications were conducted during the 2004–2006 growing seasons (April–October) in north-central Texas on a Windthorst fine sandy loam. Treatments consisted of manually clipping all plant material three times throughout the growing season at 5-cm height with a July rest (5-JR) or a September rest (5-SR), four times throughout the season (June, July, September, October) at 10-cm height, or manual harvesting (hand-plucking) all leaves and growing tips to ground level four times throughout the season. Annual rhizoma peanut DM yield for the irrigated experiment (4710 to 10870 kg DM ha$^{-1}$) was greater than the nonirrigated experiment (2750 to 9300 kg ha$^{-1}$). In both experiments, the 5-JR treatment reduced rhizoma peanut DM yield in the third year by 29 to 37% compared with the hand-plucked and the 5-SR treatments. Harvest timing or technique did affect nutritive value although these differences were small, ranging from 186 to 204 g CP kg$^{-1}$, 280 to 313 g ADF kg$^{-1}$, and 57 to 65 g ADL kg$^{-1}$. These data indicate that rhizoma peanut had high nutritive value regardless of treatment and maintained greater DM yield if harvested by hand-plucking or at a 5-cm height with a September rest.**

Rhizoma peanut has relatively high DM yield and nutritive value, similar to that of alfalfa *(Medicago sativa* L.) (Ocumpaugh, 1990; French et al., 1993). In spite of the nutritional value of rhizoma peanut, most producers are not willing to plant it for traditional livestock operations due to the high cost and slow rate of vegetative establishment (Rice et al., 1995). If utilized for the nascent wildlife game market, these costs may not be such a factor. In 2001, it was estimated that 13 million U.S. residents spent $US 20.6 billion on recreational hunting (US Census Bureau, 2003). The wildlife industry would benefit from the use of a long-lived summer perennial legume. Rhizoma peanut may be a viable alternative to planting annual warm-season legumes currently used by game ranches.

Rhizoma peanut is a warm-season perennial forage legume of South American origin, adapted to the southern USA with limited winter hardiness (French and Prine, 2006). Ball et al. (2002) reported that 'Florigraze' rhizoma peanut can survive temperatures as low as −9°C, while Terrill et al. (1996) found that Florigraze survived at −12°C at Fort Valley, GA (32°N 83°W). Newly established PI 262819 and PI 262821 survived temperatures as low as −15°C in December 2005 at Stephenville, TX (32° N, 98° W) and Ardmore, OK (34° N 97° W) (Butler et al., 2006), indicating that these genotypes may be grown farther north than previously recommended (French and Prine, 2006). This increase in survival at northern locations could also be related to warmer climates in recent years. This phenomenon is illustrated by reclassification of Ardmore, OK, Stephenville, TX, and Fort Valley, GA, from climate hardiness zone 7 to zone 8 (average minimum annual temperature, 0–10°C and 10–20°C, respectively; National Arbor Day Foundation, 2006).

One additional opportunity with rhizoma peanut is the development of selections that are better suited to Texas conditions than material released in Florida. In previous work in Texas with rhizoma peanut, Reed and Ocumpaugh (1991) reported that of 23 genotypes evaluated, PI 262819 and PI 262821, originally from Paraguay (French et al., 1993), had agronomic potential, with greater height, spread, and DM production. Butler et al. (2006) reported that PI 262819 and PI 262821 had a greater number of shoots and spread farther than Florigraze and 'Arbrook' rhizoma peanut, especially during the lower rainfall years in south and north-central Texas. Prine et al. (1986b) reported winter kill of rhizoma peanut in southern Georgia that was harvested four times, the second season after establishment, while uncut plots had no winter stand loss. Butler et al. (2006) also reported that PI 262819 and PI 262821 survived 10 yr at a location farther north (Stephenville) than previously tested; however, those plots were not harvested. This raises questions about the relationship between mid-summer (low moisture) and autumn rest periods (for possible carbohydrate accumulation), for rhizoma peanut forage harvest and subsequent stand dynamics, as measured by yield.

It is unknown how much Texas-adapted rhizoma peanut will produce and persist under a different management, particularly where selective grazers are utilized. It is also unknown how the choice of harvest intensity or method may affect the trade-offs between forage yield, apparent nutritive value, and subsequent stand productivity. Harvest techniques that more closely mimic selective grazers/browsers may provide more accurate information as to the potential production and nutritive value of rhizoma peanut or other rhizomatous forbs. Although hand-plucking has proven accurate in predicting forage nutritive value in grasses vis-à-vis bovine

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**Abbreviations:** ADF, acid detergent fiber; ADL, acid detergent lignin; CP, crude protein; DM, dry matter; 5-JR, 5-cm height with July rest; 5-SR, 5-cm height with September rest.

esophageal extrusa (Wallis de Vries, 1995) and mechanical clipping (Pires Silveira et al., 2005), no similar relationships have been established for nutritive value and yields of legumes or other forbs. In addition, these relationships may change with ruminant species such as sheep (Edlefsen, 1960) and are unknown for browsers or mixed selective grazers/browsers. Selective grazers/browsers are more likely to leave nutrient reserves in unpalatable/less digestible stems than do bulk grazers or mechanical harvests such as hay production systems. Forage utilization depends on the type of animal and its grazing behavior. Bulk grazers (like cattle, *Bos taurus*) will harvest plant material indiscriminately compared with selective grazers or browsers (like white-tailed deer, *Odocoileus virginianus*) (Ellis and Travis, 1975). If results do indicate differences in harvest methods, knowing which yield and nutritive value data sets to apply to different production systems such as white-tailed deer browsing versus hay production should be very useful. It is hypothesized that hand-plucked defoliation may result in lower total DM yield, but greater nutritive value.

The objective of this study was to evaluate the effect of harvest technique and timing on Texas-adapted rhizoma peanut (PI 262821) DM yield, CP, ADF, and ADL concentrations. One experiment looked at these factors under irrigation while the other, without irrigation, more closely reflects production and nutritive value under the vagaries of uneven rainfall distribution typical of sub-humid climates.

## MATERIALS AND METHODS

Two adjacent and contemporary experiments were conducted, one nonirrigated and the other receiving irrigation. Both experiments were randomized complete block designs with four replications and were conducted during the 2004 to 2006 growing seasons at the Texas Agricultural Research and Extension Center near Stephenville, TX (32° 15′ N, 98° 12′ W, altitude 395 m). In the irrigated experiment, water was supplied via sprinklers from May to September each year to meet the difference between actual precipitation and long-term average precipitation for each month (Fig. 1), if needed, on a weekly basis with a maximum 25 mm wk$^{-1}$. The irrigated experiment received 63, 215, and 134 mm water for 2004, 2005, and 2006, respectively. This resulted in rainfall and irrigation totals (December to October) of 915 mm in 2004, 721 in 2005, and 666 in 2006. In both experiments, treatments were applied to a 3-yr-old stand of rhizoma peanut (PI 262821), which had no previous defoliation. Rhizoma peanut typically requires 2 to 3 yr to develop full canopy (Rice et al., 1996; Williams et al., 1997). The soil in the experiment area was a Windthorst fine sandy loam (fine, mixed, thermic, Udic Paleustalf) (pH 6.6, 11 mg P kg$^{-1}$, 196 mg K kg$^{-1}$, 902 mg Ca kg$^{-1}$, and 168 mg kg$^{-1}$ using the TAMU-EDTA extractant method, Hons et al., 1990). Weeds were controlled by applying 0.56 kg a.i. ha$^{-1}$ 2,4-DB, 4-(2,4-dichlorophenoxy)butyric acid, dimethyl amine plus 0.14 kg a.i. ha$^{-1}$ clethodim ((E,E)(±)-2-[1[[3chloro-2-propenyl)oxy]imino]propyl]-5-[2-ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one) in the spring of all three growing seasons, and plots were maintained weed-free by hand-weeding throughout the season.

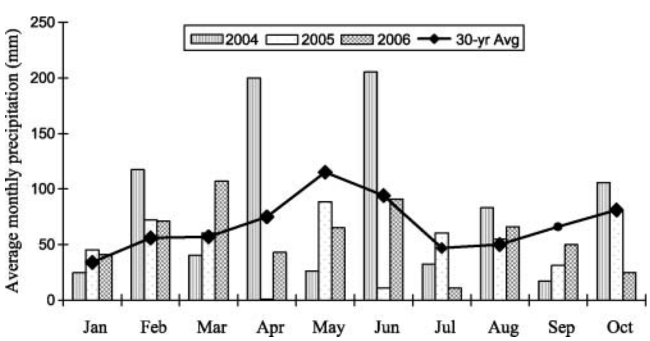


**Fig. 1. Monthly rainfall for the 2004, 2005, and 2006 growing seasons at Stephenville, TX, compared with the 30-yr average.**

Harvest treatments consisted of manually clipping all plant material three times throughout the harvest season (June to October) at 5-cm height with a July rest (5-JR) or September rest (5-SR), harvesting four times (June, July, September, and October) throughout the season at 10-cm height, or hand-plucking all leaves and growing tips to ground level four times (June, July, September, and October) each season. The maximum number of harvests (four) was determined during the first year of the trial when plots were harvested whenever canopy closure occurred in the 10-cm height treatment. Cutting four times to 5-cm height was not included as a treatment since previous experience has shown that this combination of high frequency and intensity resulted in poor stand persistence (W.R. Ocumpaugh, personal communication, 2002). A July rest was considered a mid-season low-rainfall rest, while the September rest was chosen because plants cease growing shortly after this time as night temperature and/or photoperiod decline. Leaves were hand-plucked in an attempt to mimic how a selective grazer such as white-tailed deer might utilize rhizoma peanut by removing leaves and tender shoots while leaving behind less palatable lignified stems. This resulted in a uniform harvest in plots with complete leaf removal throughout the canopy.

Harvest techniques and timing were applied to 2.25-m$^2$ plots of which the inner 1 m$^2$ were used for determining DM yield to reduce the border effect. All DM measurements were made after drying a subsample for 72 h at 55°C in a forced-air oven and adjusting the total plot weight to report DM yield on a per hectare basis. Dried samples were ground through a sheer mill (Wiley Co., Philadelphia, PA) fitted with a 1-mm screen. Total N concentrations were measured in the forage by using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Sample weight was 1.0 g, digest used was 5 g of 33:1:1 $K_2SO_4$:$CuSO_4$:$TiO_2$, and digestion was conducted for 2 h at 400°C using 17 mL of $H_2SO_4$. Nitrogen concentration in the digestate was determined by semi-automated colorimetry (Hambleton, 1977) using a Technicon Autoanalyzer II (Technicon Industrial Systems, Tarrytown, NY). Nitrogen was reported as CP concentration by multiplying N concentrations by 6.25. Acid detergent fiber and ADL were determined utilizing the method described by Van Soest and Robertson (1980).

Each experiment was analyzed separately, and dependent variables (yield and nutritive values) from each experiment were subjected to analysis of variance using PROC GLM (SAS Institute, 1999) with treatment differences having $P < 0.05$ reported as significant. Year and harvest treatments were considered fixed effects, while replication was considered random. Means were separated using Fisher's Protected LSD test at $P = 0.05$ level of significance.

## RESULTS AND DISCUSSION

### Yield

Year × harvest intensity interaction was significant for DM yield in both experiments, so DM means were reported by year. This interaction may be only partially related to rainfall amount and distribution each year (Fig. 1) and total combined rainfall and irrigation moisture (79 and 73% combined rainfall and irrigation moisture the second and third years compared with the first year). Stored plant nutrient depletion may also have accumulated with each additional year of harvest. Rainfall during the growing season (April–October) in 2004 was 25% greater than the 30-yr average, while years 2005 and 2006 were approximately 35 to 39% below average. These ranges were considered normal for the subhumid climate and were useful in comparing harvest technique and timing during years of high and low rainfall in the no-irrigation treatment.

## Experiment I—Nonirrigated

Dry matter yield varied by harvest each year; however, only cumulative DM yields are discussed since these were of primary importance. Cumulative DM yields ranged from 2750 to 9300 kg ha$^{-1}$ yr$^{-1}$ (Table 1), and were greatest in the first year (2004) and declined each year thereafter. In 2004, rhizoma peanut DM yields were similar for both the 5-cm height treatments harvested three times and the hand-plucked treatment harvested four times, which were 15 to 17% greater than the 10-cm height treatment. In 2005, yield of both the 5-cm height treatments were greater than the 10-cm height and hand-plucked yield harvested four times throughout the season, which did not differ. Harvesting at taller heights typically results in lower yield (Sheaffer et al., 1988), but it was unclear why the hand-plucked yield was lower in the drier year (2005) but not the higher rainfall year (2004).

By 2006, both the hand-plucked (4340 kg ha$^{-1}$) and 5-SR treatment (4240 kg ha$^{-1}$) yields were 38 to 41% greater than plots harvested at 10-cm height four times throughout the season (3080 kg ha$^{-1}$) and 54 to 58% greater than the 5-JR treatment (2750 kg ha$^{-1}$). Previous research had indicated that the severity and the greater frequency of defoliation reduce the total nonstructural carbohydrates of rhizoma peanut (Saldivar et al., 1992; Rice et al., 1995). A late-summer rest allows rhizoma peanut to translocate greater carbohydrates to the root system, which may be important for winter survival and subsequent spring production. Sheaffer et al. (1988) found that alfalfa stands could decline following a fall harvest (September to October); however, in one study a late-summer rest (August) improved alfalfa production and persistence under grazing (Sledge et al., 2006). These data suggest that a September rest may benefit rhizoma peanut production compared to a July rest, especially long term, at this northern location.

The third harvest of the 5-JR treatment did not produce significant amounts of forage in October (100 to 440 kg ha$^{-1}$) suggesting that two-cut systems may be suitable for this northern location. Terrill et al. (1996) also concluded that a two-cut system would work well in central Georgia; however, a three-cut harvest schedule was not evaluated in that study.

## Experiment II—Irrigation

Rhizoma peanut cumulative DM yield from plots receiving irrigation ranged from 4710 to 10870 kg DM ha$^{-1}$ (Table 2), which was greater than those measured in the nonirrigated experiment. These irrigated yields were similar to nonirrigated yields for rhizoma peanut reported elsewhere. This difference is probably due to the greater annual rainfall received at these other locations. In Florida, DM yield of Florigraze and Arbrook ranged from 10,000 to 12000 kg DM ha$^{-1}$ yr$^{-1}$ (Prine et al. (1986a, 1990). In central Georgia, Florigraze yield increased from 5200 kg ha$^{-1}$ the season after establishment to 10600 kg ha$^{-1}$ the third season after establishment (Terrill et al., 1996). In south Texas, Florigraze and PI

**Table 1. Dry matter (DM) yield of PI 262821 rhizoma peanut in the 2004, 2005, and 2006 growing seasons in the nonirrigated experiment at Stephenville, TX.**

| Harvest regime | June | July | September | October | Total |
|---|---|---|---|---|---|
| | kg DM ha$^{-1}$ | | | | |
| **2004** | | | | | |
| Hand-plucked | 3490 b† | 3250 a | 1360 b | 860 b | 8960 a |
| 5-cm height, with July rest | 4690 a | – | 4510 a | 100 c | 9300 a |
| 5-cm height, September rest | 4380 a | 3190 a | – | 1520 a | 9090 a |
| 10-cm height | 4090 ab | 2970 a | 470 c | 240 c | 7770 b |
| **2005** | | | | | |
| Hand-plucked | 2830 a | 360 a | 2180 a | 880 b | 6250 b |
| 5-cm height, with July rest | 4280 a | – | 2630 a | 440 c | 7350 a |
| 5-cm height, September rest | 4210 a | 350 a | – | 3340 a | 7900 a |
| 10-cm height | 3320 a | 130 a | 1800 a | 420 c | 5670 b |
| **2006** | | | | | |
| Hand-plucked | 2720 a | 710 a | 710 a | 200 b | 4340 a |
| 5-cm height, with July rest | 1870 a | – | 770 a | 110 b | 2750 b |
| 5-cm height, September rest | 2350 a | 650 a | – | 1240 a | 4240 a |
| 10-cm height | 2350 a | 250 b | 440 b | 40 c | 3080 b |

† Means within year and column followed by the same letter do not differ at the $P = 0.05$ level of significance.

**Table 2. Dry matter (DM) yield of PI 262821 rhizoma peanut in the 2004, 2005, and 2006 growing seasons in the irrigated experiment at Stephenville, TX.**

| Harvest regime | June | July | September | October | Total |
|---|---|---|---|---|---|
| | kg DM ha$^{-1}$ | | | | |
| **2004** | | | | | |
| Hand-plucked | 3840 b† | 3170 a | 1230 b | 1620 a | 9860 a |
| 5-cm height, with July rest | 5570 a | – | 3680 a | 160 c | 9400 a |
| 5-cm height, September rest | 5420 a | 2600 b | – | 1910 a | 9930 a |
| 10-cm height | 4360 b | 2410 b | 510 c | 590 b | 7870 b |
| **2005** | | | | | |
| Hand-plucked | 3920 b | 1040 a | 2570 c | 2020 b | 9550 a |
| 5-cm height, with July rest | 4780 a | – | 4810 a | 1280 c | 10870 a |
| 5-cm height, September rest | 5090 a | 580 b | – | 4630 a | 10300 a |
| 10-cm height | 4680 a | 430 b | 3910 b | 1150 c | 10170 a |
| **2006** | | | | | |
| Hand-plucked | 3060 ab | 1570 a | 2310 a | 590 b | 7530 a |
| 5-cm height, with July rest | 2120 c | – | 2420 a | 170 b | 4710 c |
| 5-cm height, September rest | 2740 bc | 1310 a | – | 2580 a | 6630 ab |
| 10-cm height | 3500 a | 530 b | 1950 a | 400 b | 6380 b |

† Means within year and column followed by the same letter do not differ at the $P = 0.05$ level of significance.

262821 rhizoma peanut DM yields ranged from 7800 to 13900 kg ha$^{-1}$ (Butler et al., 2006), which were similar to yields obtained in this study.

The yield of the irrigation experiment generally followed the same trends as the nonirrigated experiment. Plots harvested at 10-cm height produced less DM yield in the first season, and the hand-plucked treatment and the 5-SR treatment produced the greatest DM yield in the third season. The main difference between the two experiments was that the harvest treatments had no effect on rhizoma peanut DM yield in 2005. In 2006, the 5-JR treatment produced the least DM yield (4710 kg ha$^{-1}$), again suggesting that carbohydrate reserves may be an important factor determining rhizoma peanut yield and proper utilization. Accumulating pathogen pressures (Blount et al., 2002; Stanley et al., 1996) and pest pressures (Macchia et al., 2003) may also have been a factor, although none were observed during the trial.

## Nutritive Value

Rhizoma peanut nutritive values were similar between the two experiments (nonirrigated and irrigated); mean nutritive values were therefore pooled across the two experiments to avoid redundancy. Means were pooled across the three growing years, because year × harvest treatment interactions were not significant for CP, ADF, and ADL.

### Crude Protein

Crude protein concentrations (Table 3) were all above those considered minimum for adequate nutrition of ruminants (Ball et al., 2002). Values ranged from 179 to 220 g kg$^{-1}$, similar to those reported in other rhizoma peanut studies with similar harvest timings. For example, Saldivar et al. (1990) reported CP concentrations ranging from 200 to 250 g kg$^{-1}$ in April, but declining to 125 g kg$^{-1}$ at the end of the season when left uncut. Terrill et al. (1996) reported that CP concentrations of rhizoma peanut from a two-cut system ranged from 127 to 152 g kg$^{-1}$, lower than values reported in this study. This difference could have been attributed to harvest regimes as there were differences in CP across the growing season for the harvest intensity treatments. Differences occurred primarily with the hand-plucked treatment, which was greater in June during the first harvest, and the 5-cm height harvest treatments, which were lower after each rest period (July or September rest). Similar results were reported by Redfearn et al. (2001), who found that rhizoma peanut CP concentrations ranged from 171 to 237 g kg$^{-1}$ when harvested on a 30-d interval and from 138 to 180 g kg$^{-1}$ when harvested on a 60-d interval. The hand-plucked harvest had greater season-long weighted average CP concentration (204 g kg$^{-1}$) followed by the 10-cm harvest (192 g kg$^{-1}$), while both 5-cm harvests had the lowest concentrations (186 to 187 g kg$^{-1}$). The differences in CP concentration in this study were not as great as expected, which could be explained by the high proportion of leaves in each harvest, regardless of the treatment. Ocumpaugh (1990) summarized that rhizoma peanut leaf CP concentration was 1.7 to 2.3 times greater than stem CP concentrations, while Saldivar et al. (1990) reported that leaves constituted 60 to 80% of the shoot component.

**Table 3. Crude protein (CP), acid detergent fiber (ADF), and acid detergent lignin (ADL) values of PI 262821 rhizoma peanut pooled across three growing seasons and irrigated and nonirrigated plots at Stephenville, TX.**

| Harvest regime | June | July | September | October | Average‡ |
|---|---|---|---|---|---|
| | g kg$^{-1}$ | | | | |
| **CP** | | | | | |
| Hand-plucked | 194 a† | 220 a | 219 a | 208 a | 204 a |
| 5-cm height, with July rest | 179 b | – | 197 b | 207 a | 186 c |
| 5-cm height, September rest | 181 b | 215 a | – | 189 b | 187 c |
| 10-cm height | 184 b | 206 a | 212 a | 206 a | 192 b |
| **ADF** | | | | | |
| Hand-plucked | 306 b | 247 a | 273 b | 246 b | 280 c |
| 5-cm height, with July rest | 329 a | – | 299 a | 249 b | 313 a |
| 5-cm height, September rest | 327 a | 267 a | – | 257 a | 291 b |
| 10-cm height | 323 a | 254 a | 272 b | 245 b | 300 b |
| **ADL** | | | | | |
| Hand-plucked | 65 a | 44 b | 56 b | 59 a | 58 b |
| 5-cm height, with July rest | 66 a | – | 64 a | 59 a | 65 a |
| 5-cm height, September rest | 65 a | 50 a | – | 56 a | 58 b |
| 10-cm height | 64 a | 49 a | 49 c | 50 b | 57 b |

† Means within column and nutritive value followed by the same letter do not differ at the $P = 0.05$ level of significance.
‡ Averages reported as season-long weighted averages.

### Acid Detergent Fiber and Lignin

Acid detergent fiber and ADL followed a similar trend and ranged from 247 to 329 g ADF kg$^{-1}$ and 44 to 66 g ADL kg$^{-1}$ (Table 3). These values fell within the range of those reported by others. For example, Terrill et al. (1996) reported ADF concentrations of Florigraze in Georgia ranging from 332 to 500 g kg$^{-1}$ and ADL concentrations ranging from 68 to 73 g kg$^{-1}$. The primary difference in ADF and ADL followed a pattern similar to CP in that the plots harvested at 5-cm heights had greater concentrations than the other harvest treatments within that harvest timing, which affected the season-long weighted average. The hand-plucked harvest treatment had the lowest ADF concentration and among the lowest ADL concentrations, while the 5-cm harvest with a July rest had the greatest fiber concentrations due to the greater proportion of DM produced in the summer. These data indicate that, as previously reported, rhizoma peanut has a relatively high nutritive value similar to that of alfalfa, and could provide high quality forage during the summer months.

## CONCLUSIONS

At this north-Texas location, PI 262821 rhizoma peanut consistently produced high nutritive value forage during three summer growing seasons. Harvest technique and timing over three consecutive years appeared to be cumulative and affected rhizoma peanut DM production. By the third year, the importance of deferring late-season harvests when clipping to 5-cm height or not removing stems in the hand-plucked harvests became evident. The consistent productivity of hand-plucked plots harvested throughout the season, including September, to simulate grazing of selective browsers, suggests that rhizoma peanut management, when selective grazing is allowed, may be different than under mechanical harvest at this location. This Texas selection of rhizoma peanut was sufficiently productive, persistent, and of sufficiently high nutritive value over 3 yr to merit further study, especially grazing trials in north Texas. Future grazing research evaluating rhizoma peanut quality and stand persistence should include both selective grazers (small ruminants) and bulk grazers to differentiate the effects of grazing habits.

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