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Research article

Improved *Arachis hypogeae* variety effect on grain yield, fodder quality and livestock growth

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Abstract

The hypothesis that improved groundnut (*Arachis hypogea*) varieties could improve seed and fodder yield and livestock growth performance was evaluated in two experiments: 1) an agronomic trial to determine the yield and yield component of groundnut varieties; and 2) fodder quality of groundnut varieties and its effect on growth performance of sheep. Four improved groundnut varieties (early-maturing: Yenyawoso, late-maturing: Azivivi, Obolo and Mani pinta) were evaluated for 2 yr in a randomized complete block design with four replications in the agronomic and livestock feeding trials. The results from the agronomic trial showed that the late-maturing varieties had significantly higher pods/plant, pod size, seed and fodder yields than Yenyawoso. Obolo had significantly higher seed yield whilst Azivivi had significantly higher fodder yield among the late-maturing varieties. The fodder quality and feeding trial showed that Yenyawoso had significantly higher dry matter, crude protein and resulted in significantly higher live weight gain of Djallonké rams than the other varieties. The Mani pinta variety had significantly higher live weight gain among the late-maturing varieties. Smallholder crop-livestock farmers interested in both seed and livestock growth could use Mani pinta, those interested in only seed yield could use Obolo and those interested in quality fodder for fattening of small ruminants could use Yenyawoso. Thus, groundnut breeding programs could consider fodder quality in addition to seed and fodder yield as selection criteria to develop varieties that best fit into crop-livestock farming systems.

Introduction

Groundnut (*Arachis hypogea*) is the most widespread legume and is an important oil seed in developing countries due to its adaptation to climatic conditions as well as having only limited field pest problems (Prasad et al., 2010). Groundnut is a valuable cash crop and staple food with bulk production in the dry Savanna agro-ecological zone (MoFA, 2011). The grains are a good source of protein (25–34%), cooking oil (48–50%) and vitamins (Ajeigbe et al., 2015) and the fodder is nutritious for livestock feed (Larbi et al., 1999). It is produced by smallholder farmers the majority of whom are women (Gladwin et al., 2001; Ajeigbe et al., 2015).

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Despite the importance of groundnut, the average yield in developing countries is very low (965 kg/ha) compared to developed countries (3,333 kg/ha) according to Food and Agriculture Organization (2017). This has been attributed to the use of poor and low yielding varieties and other biotic, abiotic and socio-economic factors (Craufurd et al., 2002; Naab et al., 2009). Improved groundnut varieties are considered superior to local varieties in terms of pest and disease resistance and seed and fodder yields (Singh et al., 2003; Bala et al., 2011). However, in West Africa, fodder yield and quality are not considered as part of the selection criteria in groundnut improvement programs (Larbi et al., 1999). In Ghana, the National Agricultural Research System has released some improved groundnut varieties in the northern savanna agro-ecological zones based on grain yields, maturity days and pest or diseases resistance over the past years (Oteng-Frimpong et al., 2017). The potential of these improved groundnut varieties for smallholder crop-livestock system has not been fully exploited in these agro-ecological zones.

Dry season feed shortage is a threat to livestock production in the dry savanna regions of West Africa and the utilization of groundnut fodder as feed during this period is a necessary resource for smallholder crop-livestock farmers (Njie and Reed, 1995; Akapali et al., 2018). The current study tested the hypothesis that groundnut varieties may affect the grain and fodder yields, fodder quality and live weight gain of sheep. The results are presented on the effect of improved groundnut varieties on seed and fodder yields, fodder quality and growth of sheep in a crop-livestock system in Northern Ghana.

Materials and Methods

Site description

Agronomic trial

The experiment was conducted in the Guinea Savanna agro-ecology zone of Ghana at the Tamale Airforce farm. The area lies between 009.55420°N and 000.85455° W with a mean daily temperature of 26°C and a mono-modal rainfall pattern with an annual average of 800–1,100 mm as shown in Fig. 1 (Ghana Meteorological Agency, 2015). Composite soil samples from the surface to 20 cm depth in the experimental field were taken to determine the soil chemical properties before planting using the standard procedures of Motsara and Roy (2008). The chemical properties of the soil were pH (4.9; 1:2.5 for soil: H_2O), organic carbon (8.4 g/kg), total nitrogen (1.3 g/kg), available phosphorus (7.3 mg/kg) and exchangeable cations (potassium: 0.2 cmol/kg, calcium 5.5 cmol/kg and magnesium 0.9 cmol/kg).

Livestock feeding trial

The fodder quality and feeding study was conducted at the Department of Animal Science, Faculty of Agriculture, University for Development Studies at Nyankpala, Ghana. The trial area lies between 09.2541°N and 000.5824°W with similar climatic conditions as the experimental site for the agronomic study.

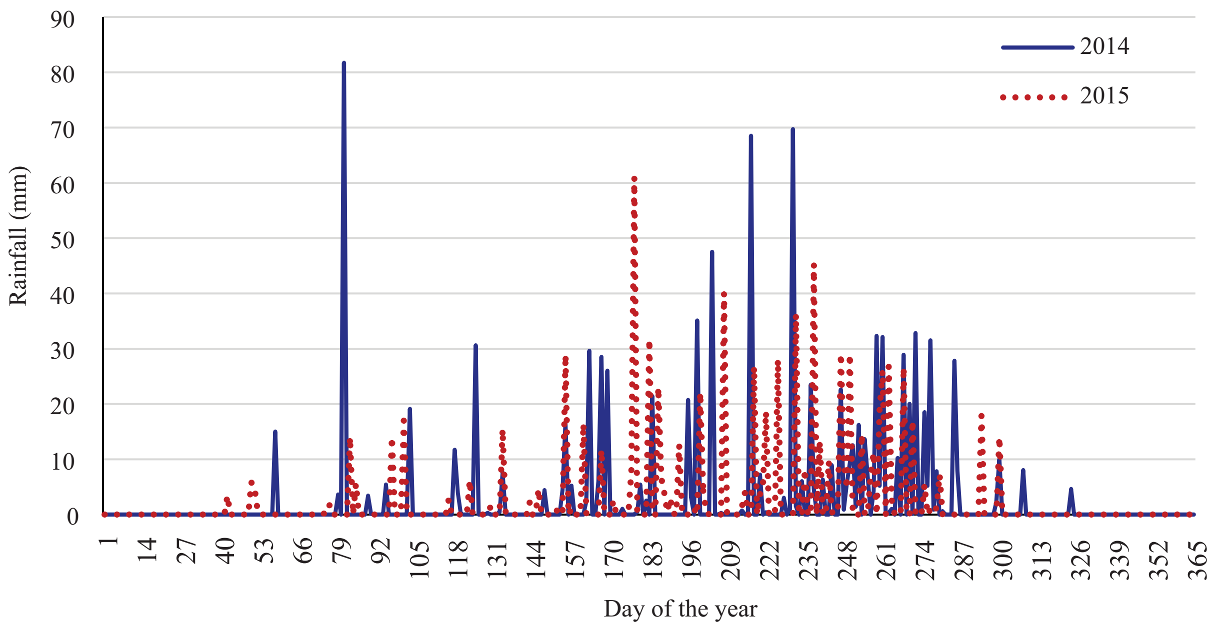

Fig. 1 Daily rainfall distribution of study area during 2014 and 2015 (Ghana Meteorological Agency, 2015).

Experimental design and procedure

Agronomic trial

A 2 yr field experiment (2014 and 2015 growing seasons) was conducted to assess the effect of four improved groundnut varieties on groundnut yield in a randomized complete block design with four replications. The groundnuts were planted in the first week of June for the 2014 cropping season and in the second week of June for the 2015 cropping season. The varieties used were early-maturing type Yenyawoso (ICGX SM 87057), late-maturing types Azivivi (RMP 12), Obolo (ICGV 97049) and Mani pinta. The early-maturing type had a 90 d growth period while the late-maturing type had 110 to 120 d. A plot size of 40 m × 25 m was used to ensure sufficient fodder yields were generated for the livestock feeding trial.

The land was ploughed and harrowed to obtain a fine tilth for planting in both years. The groundnuts were planted at one seed/hill at a spacing of 60 cm × 20 cm. A pre-emergence herbicide glyphosate (Zoomer; 3 L/ha) and post emergence herbicide pendimethalin (Stomp; 3 L/ha) were sprayed immediately after planting in the morning. Hand weeding was done once with a hoe at 5 wk after planting.

Livestock feeding trial

The groundnuts were harvested at full pod maturity and then separated into pods and fodder. The groundnut fodders were shade-dried and chopped into an average length of 3.5 cm. Sixteen Djallonké rams were obtained from the Council for Scientific and Industrial Research-Animal Research Institute at Nyankpala. The average initial live weight (± SD) of the rams was 15.0 ± 3.0 kg and they were randomly assigned to the four groundnut varieties and haulm fodder meal as a sole diet in a completely randomized design with four replicates. The rams were housed in individual wooden cages with concrete floors and fed with the dry groundnut fodder ad libitum daily for 8 wk (56 d).

Data collection

Agronomic trial

An area of 9 m^2 in the middle of each plot was marked for data collection on the number of pods/plant, pod size, dry pod weight, seed/pod, seed yield and fodder yield. Pod and seed yields were measured after oven-drying pods at 65ºC to a moisture content of 12% and the fodder yield was determined after oven-drying samples at 65ºC to a constant weight. Ten plants were randomly sampled from the harvest area from each plot for measuring the pod length and pod width using Vernier calipers. The pod size was then calculated based on the pod length and pod width.

Livestock feeding trial

The dried groundnut fodder of each variety was sampled and analyzed for dry matter (DM), nitrogen using the Kjeldahl method and crude protein (CP), calculated by multiplying the nitrogen by 6.25 (Association of Official Analytical Chemists, 2000). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined exclusive of residual ash following the method of Van Soest et al. (1991) using an Ankom200 fiber analyzer (ANKOM Technology, O'Neil Road, Macedon, USA).

Daily dry matter feed intake was measured as the difference between the initial weight of feed given to animals and the weight of left-over feed after feeding on each day. The live weight gain of each ram was determined as the difference between the final weight of the ram at the end of the experiment (56 d) and the initial weight of the ram. The feed conversion efficiency (FCE) was estimated as the ratio of the live weight gain and feed intake.

Statistical analysis

The general linear model of the Statistical Analysis System for Windows software package (SAS Institute Inc., 2011) was used to analyze all measured data. The year was considered as a random variable in the statistical analysis with the objective of identifying a groundnut variety whose average effect over the 2 yr of the experiment would be stable and high (Gomez and Gomez, 1984). The agronomic traits and fodder quality data were analyzed using Equation 1:

$$Y_{ij} = \mu + B_i + V_j + e_{ij} \quad (1)$$

where Y_{ij} is an observation, μ is the experimental mean, B_i is the block effect, V_j is the variety effect and e_{ij} is the residual.

The live weight grain of rams was analyzed using the initial weight of the rams as a co-variate as shown in Equation 2:

$$Y_{ij} = \mu + V_i + B(x_{ij} - \pi_i) + e_{ij} \quad (2)$$

where Y_{ij} is an observation, μ is the experimental mean, V_i is the variety effect, B is the slope, x_{ij} is the observation of the covariate under the i^{th} group, π_i is the i^{th} group mean and e_{ij} is the residual.

Orthogonal contrast was used to separate treatment means at $p \leq 0.05$. Univariate correlation and regression analysis were performed to establish a relationship and the predictive equation for seed yield from the agronomic data and live weight gain from the livestock feeding data. Variables with a correlation co-efficient of 60% and above were used in the regression equation.

Results and Discussion

Agronomic trial

Yield

The pod and seed yields varied among the groundnut varieties (Table 1). Generally, the early-maturing groundnut variety (Yensyawoso) had lower ($p < 0.01$) pod and seed yields than the late-maturing varieties (Table 1). The pod and seed yields were not significantly different among the late-maturing groundnut varieties (Table 1). Seed yield was positively correlated with pod yield ($r = 0.97$, $p < 0.0001$) and pods/plant ($r = 0.68$, $p < 0.0001$) and could be expressed using Equation 3 :

$$Y_{Seed\ yield} = -7.33 - 1.22_{Pod/plant} + 0.72_{Pod\ yield},\ r^2 = 0.94 \quad (3)$$

Table 1 Effect of groundnut variety on pod, seed and fodder yields during 2014 and 2015 cropping seasons.

Variety	Pod yield (kg/ha)	Seed yield (kg/ha)	Fodder yield (kg/ha)
Yenyawoso (Early)	725.0	510.0	3746.9
Azivivi (Late)	1311.3	851.3	6562.5
Obolo (Late)	1373.8	1008.8	2768.8
Mani pinta (Late)	1152.5	771.3	5457.5
SE	161.88	118.56	497.62
p-value	*	*	**
Contrast probability of *p*-value			
Early versus Late	**	**	*
Azivivi versus (Obolo + Mani pinta)	ns	ns	**
Obolo versus Mani pinta	ns	ns	**

** = $p < 0.01$; * = $p < 0.05$; ns = $p > 0.05$.

Table 2 Effect of groundnut variety on pods/plant, pod size and seeds/pod during 2014 and 2015 cropping season.

Variety	Pods/plant (number)	Pod size (cm^2)	Seeds/pod (number)
Yenyawoso (Early)	16.0	34.7	2.1
Azivivi (Late)	30.7	37.2	2.1
Obolo (Late)	19.7	50.3	2.1
Mani pinta (Late)	21.0	36.3	2.0
SE	2.32	1.02	0.03
p-value	**	**	ns
Contrast probability of *p*-value			
Early versus Late	**	**	*
Azivivi versus (Obolo + Mani pinta)	**	**	ns
Obolo versus Mani pinta	ns	**	ns

** = $p < 0.01$; * = $p < 0.05$; ns = $p > 0.05$.

Fodder yield showed a significant response to groundnut varieties (Table 1). The fodder yield for the late-maturing varieties was higher ($p < 0.01$) than that of the early-maturing variety (Table 1). Azivivi variety had a higher ($p < 0.01$) fodder yield among the late-maturing varieties.

The variation in pod, seed and fodder yields observed among groundnut varieties was in consonance with earlier findings (Larbi et al., 1999; Caliskan et al., 2008; Naab et al., 2009; Kombiok et al., 2013; Tarawali and Quee, 2014). This difference could be attributed to genetic traits, influenced by the environment or a combination of both. The seed yield differences among the varieties were partly due to the variation in pod yield and number of pods/plant. The Azivivi variety produced substantial pod, seed and fodder yields which makes it more suitable for smallholder crop-livestock system in the savanna agro-ecological zone where livestock fodder demand is on the rise, especially in the dry season (Njie and Reed, 1995; Akapali et al., 2018). The significant increase in pod, seed and fodder yields of the late-maturing varieties could possibly have been due to more growth days for the accumulation and partitioning of dry matter into yield.

Yield component

The number of pods/plant and pod size were significant among the groundnut varieties, but the number of seeds/pod was not affected by the groundnut variety (Table 2). The late-maturing groundnut varieties had higher ($p < 0.01$) pods/plant and pod size than the early-maturing variety (Table 2). The Azivivi variety had a higher ($p < 0.01$) number of pods/plant than the other late-maturing varieties. However, Obolo variety had a bigger pod size ($p < 0.01$) among the later maturing varieties (Table 2).

The difference observed among the groundnut varieties regarding the number of pods/plant could largely be attributed to the genetic traits of the varieties. This result confirmed earlier reports on the effect of groundnut varieties on the number of pods/plant (Virk et al., 2005; Ahmad et al., 2007; Caliskan et al., 2008; Ekeleme et al., 2011). The increase in pod size among groundnut varieties agreed with earlier reports on the effect of groundnut variety on pod size (Anderson et al., 1993). The variation in pod size may have been due to genetic and environmental effects.

Livestock feeding trial

Fodder quality

The groundnut variety showed a significant effect on the dry matter, crude protein, neutral and acid detergent fiber contents (Table 3). The dry matter and crude protein of the early-maturing variety were higher ($p < 0.01$) than those of the late-maturing varieties (Table 3). The Azivivi variety had a higher ($p < 0.01$) crude protein content among the late-maturing varieties (Table 3). In contrast with the dry matter and crude protein contents, the late-maturing variety had higher ($p < 0.01$) neutral and acid detergent fiber contents than the early-maturing variety (Table 3). The neutral and acid detergent fiber contents of the fodder from the Obolo variety was higher ($p < 0.001$) than for the other later-maturing varieties (Table 3).

Table 3 Effect of groundnut variety on fodder quality 2014 and 2015 cropping season.

Variety	Dry matter (%)	Crude protein (%)	NDF (%)	ADF (%)
Yenyawoso (Early)	60.8	11.4	42.7	36.6
Azivivi (Late)	49.7	11.2	42.5	39.0
Obolo (Late)	48.9	6.8	53.0	49.5
Manipinta (Late)	57.2	10.3	44.9	36.7
SE	2.03	0.58	1.18	1.34
p-value	**	**	**	**
Contrast probability of *p*-value				
Early versus Late	**	**	**	**
Azivivi versus (Obolo + Mani pinta)	ns	**	**	ns
Obolo versus Mani pinta	*	**	**	**

NDF = neutral detergent fibre; ADF = acid detergent fibre

** = $p < 0.01$, * = $p < 0.05$ and ns = $p > 0.05$.

The fodder quality varied among the groundnut varieties possibly due to the differences in growth duration of the groundnut varieties. The crude protein and neutral detergent fiber contents of the groundnut varieties reported in this study were in a similar range to that reported by Larbi et al. (1999). The crude protein content in all the groundnut varieties except the Obolo variety were within the minimum crude protein requirement for the maintenance of small ruminants (National

Research Council, 2007). This shows the potential of these groundnut varieties for use as sole diet for feeding small ruminants or as supplemental diet when small ruminants are fed with low protein, cereal crop residues especially during dry seasons.

Livestock growth

The feed conversion efficiency for dry matter and crude protein of the Djallonké sheep increased with the different groundnut varieties (Table 4). Feeding the early-maturing variety fodder to Djallonké sheep resulted in a significantly higher feed conversion efficiency for the dry matter and crude protein than for the late-maturing varieties (Table 4). Thus, Djallonké sheep used less dry matter and crude protein in the early-maturing variety to produce more live weight gain than the late-maturing varieties. The differences in the efficiency of both dry matter and crude protein utilization among the groundnut varieties could have been due to variations in the growth period which might have affected the leaf-to-stem ratio and the accumulation of the ADF content of plants. This was in line with the report of Wilson and Kennedy (1996) who found a lower leaf-to-stem ratio and a higher ADF with increasing maturity days of plants. A higher ADF content has been found to limit voluntary feed intake and digestibility (Riaz et al., 2014) and this could have also accounted for the low efficiency in dry matter utilization. The authors in a meta-analysis of the effect of dietary nutrient constituents on the voluntary feed intake and digestibility also found that CP positively influenced intake and digestibility, and this confirmed the relatively higher protein use efficiency recorded in the early-maturing plants.

Table 4 Effect of groundnut variety on feed conversion efficiency (FCE) of fodder during 2014 and 2015 cropping season.

Variety	Dry matter FCE (%)	Protein FCE (%)
Yenyawoso (Early)	15.47	1.74
Azivivi (Late)	164.67	18.81
Obolo (Late)	63.45	4.76
Mani pinta (Late)	23.60	2.43
SE	18.84	2.26
p-value	**	**
Contrast probability of *p*-value		
Early versus Late	**	**
Azivivi versus (Obolo + Mani pinta)	ns	ns
Obolo versus Mani pinta	ns	ns

** = $p < 0.01$, * = $p < 0.05$ and ns = $p > 0.05$.

The live weight gain of the Djallonké sheep increased among the improved groundnut varieties (Fig. 2). The live weight gain of the Djallonké sheep fed with the early-maturing variety was higher ($p < 0.01$) than for the late-maturing varieties. Similarly, the live weight gain of Djallonké sheep fed with the Mani pinta variety was also higher ($p < 0.01$) than those fed the other late-maturing variety. Live weight gain was positively correlated with dry matter content (r = 0.62; $p < 0.01$), and CP content (r = 0.64; $p < 0.01$) but negatively correlated with FCE for dry matter (r = -0.71; $p < 0.01$). Live weight gain of Djallonké rams fed with these varieties could be predicted using Equation 4:

$$Y_{\text{Live weight gain}} = 0.75 + 0.03_{\text{Dry matter}} - 0.05_{\text{FCE dry matter}} + 0.32_{\text{FCE crude protein}},\ r^2 = 0.71 \qquad (4)$$

The live weight gain of the Djallonké rams was in a similar range to the live weight gain of 'Yankassa' rams fed with groundnut fodder (Ajeigbe et al., 2011). The differences in the live weight gain of rams fed with different groundnut varieties was possibly due to the variation in the fodder quality of the groundnut varieties and the FCE for the dry matter and crude protein of the fodder. The 155% increase in live weight gain recorded for the early-maturing groundnut variety (Yenyawoso) compared to the late-maturing varieties might also be attributed to the short growth period which affects the accumulation of the acid and neutral detergent fiber contents of plants. The short growing period may have also limited the extent of stem elongation in favor of greater leaf production. Stems normally have a high concentration of non-photosynthetic tissues such as sclerenchyma, xylem fibers and xylem vessels which limit digestion due to the presence of some recalcitrant fiber (Wilson and Kennedy, 1996). The live weight gain of rams fed with the Yenyawoso and Mani pinta varieties showed the potential of these two varieties to be used as the sole diet for fattening rams under the conditions of this study or as a supplementary diet. This result agreed with earlier reports on the use of groundnut fodder to enhance the growth performance of sheep (Abdou et al., 2011; Ajeigbe et al., 2011).

The agronomic study showed that the late-maturing varieties significantly increased the pod, seed and fodder yields and the number of pods/plant and pod size more than for the early-maturing variety (Yenyewoso). Obolo had a higher pod size whilst Azivivi had a higher fodder yield and number of pods/plant among the late-maturing varieties. The seed yield was positively correlated with pod yield and pods/plant. The fodder quality analysis showed that Yenyewoso had higher dry matter and crude protein contents than the other varieties. In contrast, the late-maturing variety had higher acid and neutral detergent fiber contents than Yenyewoso. The live weight gain of the Djallonké sheep fed with Yenyewoso was significantly higher than for those fed with the other varieties. Live weight gain was positively correlated with dry matter content FCE for the dry matter and crude protein contents. Small-scale groundnut farmers interested in both seed and livestock growth could use Mani pinta; those interested in only seed yield could use Obolo; and those interested in quality fodder for fattening small ruminants could use Yenyawoso. The results indicated that seed and fodder yields, fodder quality and the growth performance of livestock increased significantly with groundnut varieties. Therefore, groundnut breeding programs could consider fodder quality in addition to seed and fodder yield in the selection criteria to develop varieties that fit well into crop-livestock farming systems.

Conflict of Interest

The authors declare that there are no conflicts of interest.

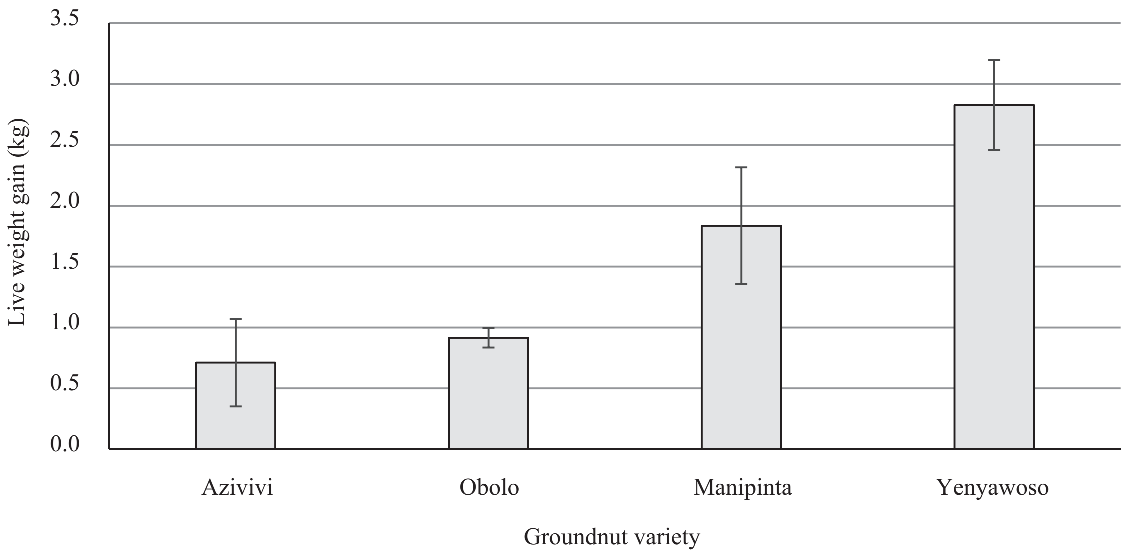

Fig. 2 Effect of groundnut variety on Djallonké sheep live weight gain; error bars indicate ± SD.

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