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Cultivar-Dependent Variation in Food-Feed-Traits in Groundnut *(Arachis hypogaea L.)*

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ABSTRACT

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A total of 860 cultivars and breeding lines of groundnut grown in the off (Rabi) season of 2001/02 post rainy season at ICRISAT centre head quarter in India were investigated for haulm fodder quality traits and relationships between haulm traits and pod yields. Haulm fodder quality traits chosen were nitrogen (N x 6.25 equals crude protein), *in vitro* digestibility and *in vitro* metabolisable energy content. The haulm fodder quality traits were analyzed by a combination of conventional laboratory techniques and Near Infrared Reflectance Spectroscopy (NIRS). Significant ($P<0.0001$) and livestock nutritionally important cultivars differences were found for all three traits. Thus haulm nitrogen content ranged from 1.2 to 2.3%, *in vitro* digestibility ranged from 51.7 to 61.1%, and *in vitro* metabolisable energy content ranged from 6.9 to 8.8 MJ/kg. No inverse relationships were observed between any of the haulm fodder quality traits and pod and haulm yields. Haulm fodder quality analysis was repeated for 12 check cultivars in 2002 and over the two years broad sense heritabilities (h^2) for nitrogen, *in vitro* digestibility and *in vitro* metabolisable energy content were 0.72., 0.72 and 0.67, respectively. The findings of the present study suggest that pod yield, haulm yield and haulm fodder quality traits can be simultaneously improved to develop better dual purpose groundnut varieties.

Key words: Groundnut, Food-Feed-Traits, Haulm fodder, Pod yield.

INTRODUCTION

Groundnut is an important crop in mixed crop-livestock systems of the Semi-Arid Tropics (SAT). It is cultivated as a food-feed crop, where the pods provide food for humans and the haulms fodder for the livestock (Larbi *et al.*, 1999; Omokanye *et al.*, 2001). In these mixed crop-livestock systems, fodder shortage is commonly a serious constraint to higher benefit from livestock (Rangnekar, 2006). Farmers in these mixed crop-livestock systems are often resource poor with regards to land and water, which severely limits their options for mitigating feed scarcity. Fodder is provided mainly via crop production in the form of crop residues. In India, for example, crop residues

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provide for about (44%) of the country's fodder resources (NIANP, 2003). The most important leguminous crop residues are groundnut haulms, which contribute more than 30% to the fodder from leguminous residues (NIANP, 2003). It was this important dual-purpose usage of groundnut that prompted groundnut breeders and livestock nutritionists to collaboratively explore the feasibility of genetic enhancement of not only pod traits but also haulm yield and haulm quality. For this work to succeed two conditions need to be met. First, significant genotypic variations in haulm quantity and quality exist. Second, substantial trade-off relations between primary traits, notably pod yield, and haulms quantity and/or quality are absent. The work reported here investigated these two conditions in a wide range of groundnut breeding lines and cultivars.

MATERIALS AND METHODS

Experimental layout and groundnut cultivars used

The present study included 860 groundnut genotypes evaluated in different replicated trials at ICRISAT Center, Patancheru, Andhra Pradesh, India. Genotypes (breeding lines and cultivars) were from medium-duration, confectionery, rust and late leaf spot resistance and aflatoxin resistance trials. Trials were planted on 24 November 2001 in an Alfisols field in appropriate experimental designs (lattice or randomized block designs) with two replications on 150 cm raised broad beds. The plot size was 4-m long, 4 rows, 30 cm apart. The seed to seed distance within a row was either 10 cm (Spanish types) or 15 cm (Virginia types). The trials received 60 kg P_2O_5 ha^{-1} (375 kg of single super phosphate) at the time of field preparation and 400 kg ha^{-1} gypsum at the time of peak flowering. The field was sprayed with Alachlor and Paraquat (4 L each in 650 L of water ha^{-1}) soon after planting but before crop emergence to control weeds. Subsequently, three inter-cultivation operations followed by two hand weddings at 45 days after sowing (DAS) and 75 DAS were carried out. Plant protection against diseases and insect pests was need-based. During the season, only thrips damage was noticed which was controlled by spraying Nuvacron (1.0 L in 325 L water ha^{-1}) at 32 and 44 DAS, Rogor (1.0 L in 325 L water ha^{-1}) at 52 DAS, Imidocloprid (0.15 L in 325 L water ha^{-1}) at 58 DAS and Nuvacron (1.0 L in 325 L water ha^{-1}) at 68 DAS. The trials received about 12-13 irrigations (about 50 mm water each time) at 10-12 days interval during the growing season. The trials were harvested at maturity starting from 131 DAS to 144 DAS. Analyses of 12 cultivars that served as check in the 2001 trials were repeated in 2002 grown under the same conditions as in 2001 to get some initial estimates of heritability of food-feed traits.

Groundnut haulm fodder quality analysis

Groundnut was harvested from two 1 m^2 areas laid over the two middle rows of each plot. The biomass was air-dried in the field, after which the pods were removed and weighed. After recording their weights haulms were ground to pass through a 1 mm particle mesh. All groundnut haulm samples were scanned for stover *in vitro* digestibility and metabolisable energy content by Near Infrared Spectroscopy (NIRS), which was calibrated for this experiment against conventional nitrogen analyses. Nitrogen was determined by auto-analyzer method and *in vitro* digestibility and metabolisable energy content were estimated based on sample incubation in rumen microbial inoculum using the *in vitro* gas production technique and the associated equations described by Menke and Steingass (1988).

The NIRS instrument used was a FOSS Forage Analyzer 5000 with software package WinISI II. A total of 180 haulm samples were selected for calibration – validation procedures using WinISI II samples selection program with a Global H value of 1. Ninety samples each were randomly allocated to the calibration and the validation set. Validations were based on blind-predictions, in other words the predicted samples were not part of the set from which the NIRS equations were developed. Relationships between blind-predicted and measured variables were described by R^2 and standard error of prediction (SEP). There was good agreement between conventionally analyzed and NIRS predicted values (Table 1).

Table 1. Comparisons of NIRS blind-predicted nitrogen, *in vitro* organic matter digestibility (OMD) and metabolisable energy (ME) content with analyzed values in haulms of 90 groundnut genotypes, and goodness-of-fit of NIRS equation used for predicting the whole set of cultivars

Haulm Trait	Validation Statistics	Calibration Statistics[1]
Haulm nitrogen	R^2 = 0.94; SEP[1] = 0.06	R^2 = 0.99; SEC = 0.01
Haulm *in vitro* OMD	R^2 = 0.92; SEP = 0.88	R^2 = 0.99; SEC = 0.08
Haulm *in vitro* ME	R^2 = 0.93; SEP = 0.13	R^2 = 0.97; SEC = 0.08

[1] For assessments of SEP see also means and ranges in Table 2.

RESULTS

Cultivar dependent variation in haulm fodder quality traits

Nitrogen content, *in vitro* digestibility and metabolisable energy content differed significantly ($P<0.0001$) among cultivars and the ranges observed in all three traits were substantial (Table 2). Nitrogen content in haulms ranged by almost twofold from (1.2 to 2.3%) with a mean of 1.7%. Haulm *in vitro* digestibilities ranged from (51.7 to 61.1%) with a mean digestibility of 56.3%. Metabolisable energy (ME) contents ranged from 6.9 to 8.8 mega joule (MJ) per kg of haulm with a mean value of 7.9 MJ ME/kg.

Table 2. Means and ranges of nitrogen content, *in vitro* organic matter digestibility (OMD) and metabolisable energy (ME) content and their least significant difference (LSD) and probability values (*P*) for haulms of 860 groundnut genotypes

Haulm trait	Mean	Range	LSD	P
Nitrogen (%)	1.7	1.2 to 2.3	0.16	< 0.0001
In vitro OMD (%)	56.3	51.7 to 61.1	1.9	< 0.0001
In vitro ME (MJ/kg)	7.9	6.9 to 8.8	0.4	< 0.0001

Haulm fodder quality traits and their relation with pod and haulms yields

Relationships between haulm nitrogen contents and pod and haulm yields are presented in Figures 1a/b. Haulm nitrogen content was significant and positively ($P < 0.0001$) associated with both pod yield and haulm yield but the R^2 values for the associations were close to zero (≤ 0.08). Broad sense heritability (h^2) for haulm nitrogen content as estimated in 12 cultivars that served as checks in two consecutive growing seasons was 0.72. Relationships between haulm *in vitro* digestibility and pod and haulm yields are presented in Figures 2a/b. There was no significant relationship between haulm *in vitro* digestibility and pod yield. Haulm *in vitro* digestibility and haulm yield were positively ($P < 0.0001$) associated but the R^2 value for the association was again very low (0.04). The h^2 for haulm *in vitro* digestibility in the 12 check cultivars was 0.72.

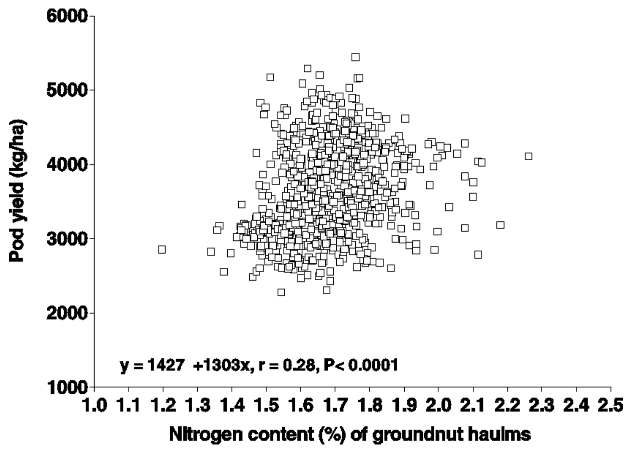

Fig. 1a. Relationship between haulm nitrogen content and pod yield in 860 cultivars of groundnut

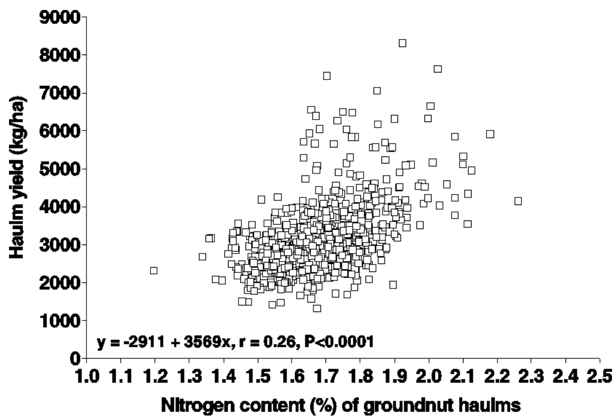

Fig. 1b. Relationship between haulm nitrogen content and haulm yield in 839 cultivars of groundnut

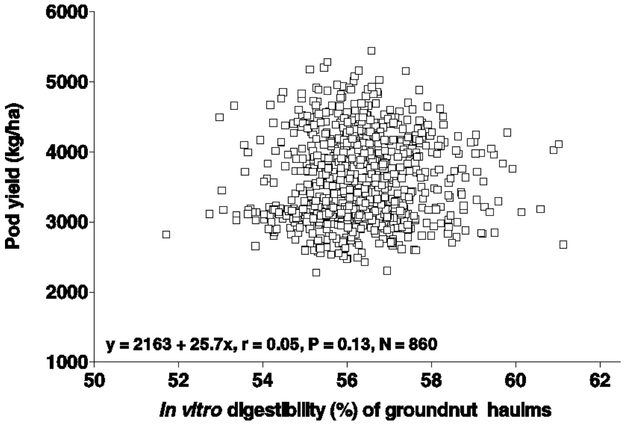

Fig. 2a. Relationship between pod yield and *in vitro* digestibility of haulms in 860 cultivars of groundnut

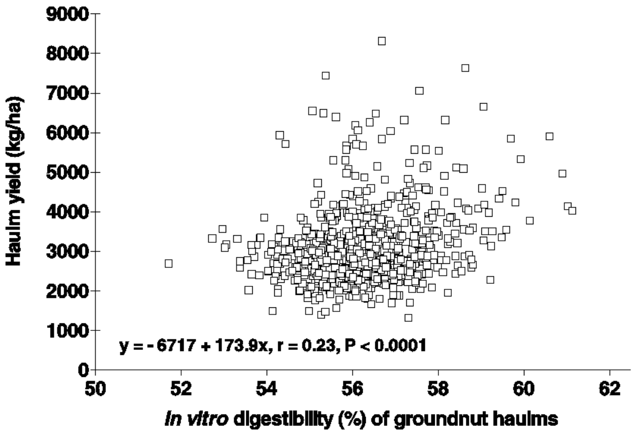

Fig. 2b. Relationship between haulm yield and *in vitro* digestibility of haulms in 839 cultivars of groundnut

Relationships between ME content of haulms and pod and haulm yields are presented in Figures 3a/b. They were significant and positive but the R^2 value was low. The h^2 for haulm ME content as estimated in 12 cultivars was 0.67.

Haulm yield was significantly positively associated with pod yield but the R^2 value for the relationship was only about 0.2, reflecting considerable variation in harvest index among cultivars (0.34–0.69). Mean haulm yield was 3071 kg/ha ranging from 1322 to 8313 kg/ha ($P<0.0001$, LSD=823). The h^2 for haulm yield and digestible haulm yield in the 12 check cultivars were 0.90 and 0.91, respectively. Similarly, yield of haulm metabolisable energy (mean 24 224 MJ/ha; range 10 634 – 66 724 MJ/ha) and pod yield were significantly positively associated, however, the R^2 value for the relationship was only about 0.2

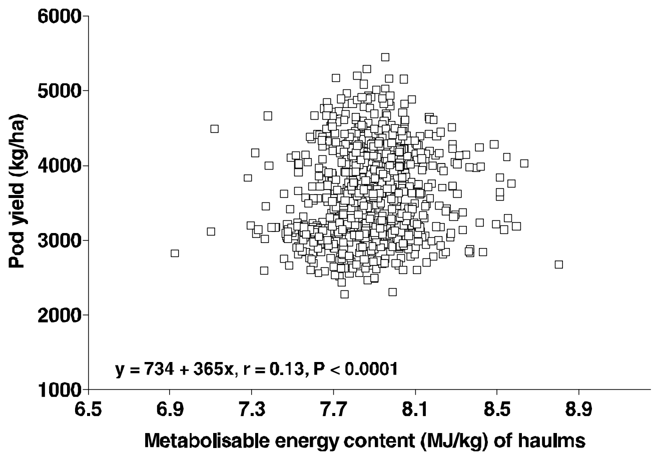

Fig. 3a. Relationship between metabolisable energy content of haulms and pod yields in 860 cultivars of groundnut

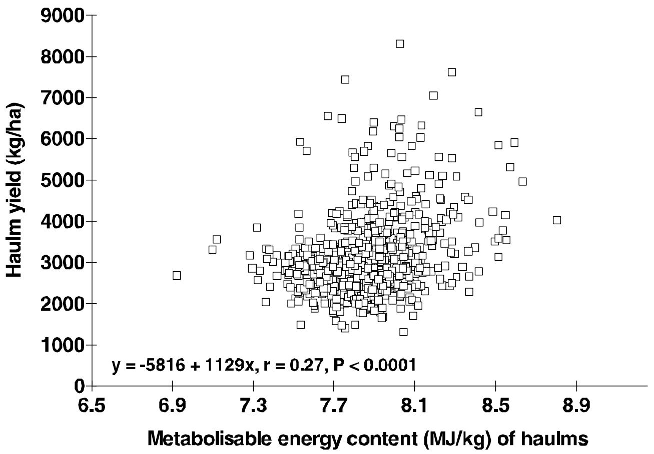

Fig. 3b. Relationship between metabolisable energy content of haulms and haulm yield in 839 cultivars of groundnut

DISCUSSION

Cultivar variation in haulm fodder quality traits

Low nitrogen content is widely considered the most limiting factor in utilization of crop residues for livestock feeding. This constraint is more pronounced in cereal than in leguminous crop residues (Sundstol and Owens, 1984). Rumen microbes require a minimum of 1 to 1.2% (equivalent to 6.25-7.5% crude protein) in the fodder to effectively degrade it (Van Soest, 1994). Nitrogen contents below this threshold result in low

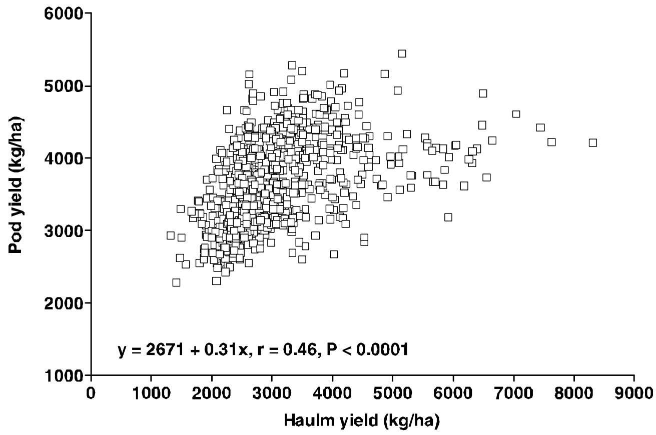

Fig. 4a. Relationship between haulm yield and pod yield in 839 cultivars of groundnut

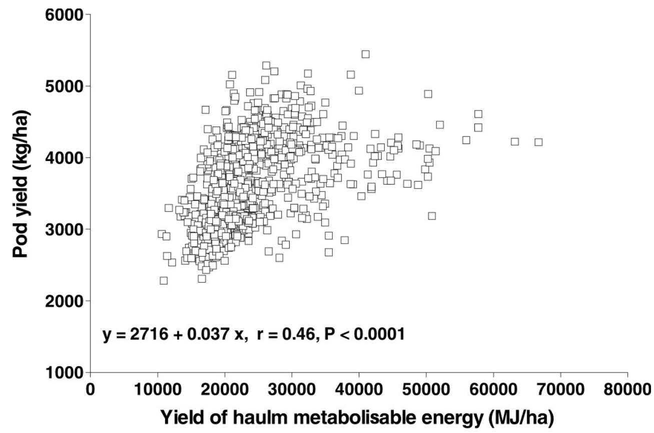

Fig. 4b. Relationship between yield of metabolisable energy in haulms and pod yield in 839 cultivars of groundnut.

voluntary feed intakes and consequently in low livestock productivity (Van Soest, 1994). Nitrogen content in haulms among the groundnut genotypes studied varied by about 100 percent (Table 2), ranging from 1.2 to 2.3% (7.5 to 14.4% crude protein content) with a mean value of 1.7%. Thus, even haulms from cultivars relatively low in nitrogen will supply minimum microbial nitrogen requirement resulting in good levels of intake and therefore livestock productivity. In fact, Vellaikumar *et al.* (2009)-investigated haulms from 10 popular groundnut cultivars with male growing sheep and observed average daily voluntary feed intake of more than 4% of the live weight of the sheep. Such intake levels are very high and rarely observed in non lactating animals on any kind of feed and/or fodder (Forbes *et al.* 1986). Thus, groundnut haulms provide indeed excellent fodder since high voluntary feed intake is one of the most important criteria for quality crop residues.

In the present study, across genotypes *in vitro* haulm digestibility ranged from 51.7 to 61.1% (Table 1) that is a range of almost 10% units. Similarly, the ME content in the haulms ranged from 6.9 to 8.8 MJ/kg (Table 1). Estimates of feed metabolisable energy (ME) content take account of feed energy lost in faeces, urine and methane and ME can by application of an efficiency factor *k* be converted into feed net energy that can be retained by the animal as meat or converted into milk (McDonald *et al.*, 1988). The efficiency factor *k* is dependent on the concentration of ME in the feed. The higher the ME concentration, the higher is *k,* that means proportionally more of the feed ME is retained as net energy (McDonald *et al.*, 1988). The ME content in the haulms ranged from 6.9 to 8.8 MJ/kg (Table 1), which would provide 3.8 (k = 0.55) and 5.2 (k = 0.59) MJ net energy for milk production (calculated based on the equations of McDonald *et al.*, 1988). One liter of milk contains approximately (depending on fat content) 3.5 MJ of net energy and 1 kg of lower (6.9 MJ) and high (8.8 MJ) quality groundnut haulms would provide the energy for 1.1 and 1.5 liter of milk, respectively. Expanding these calculations assuming a dairy cattle of 400 kg live weight, including energy requirements for the maintenance of the cattle and a daily intake of 4% of the live weight (i.e. in this case 16 kg), haulm of lower quality (6.9 MJ/kg and 110.4 MJ ME intake / day) would provide energy for about 9 liter of milk daily, while haulm of high quality (8.8 MJ/kg and 140.8 MJ ME intake / day) would provide energy for about 16 liter of milk daily (calculated based on the equations of McDonald *et al.,* 1988). These calculations are simplified since, for example, mineral, vitamin and protein needs are not considered but they do exemplify the possible variations in livestock productivity as a result of cultivar dependent differences in groundnut haulm quality.

Haulm fodder quality traits and pod and haulm yields

Above calculations show the potential of groundnut genotypes with high haulm quality for livestock productivity. For the Deccan plateau of India, Rama Devi *et al.* (2000) concluded that pods/grain and fodder from the residues in groundnut and sorghum cropping systems contributed almost equally to livelihoods in the mixed crop-livestock systems. A recent survey (Times of India, 16-11-2006) of groundnut farmers in rainfed India indicated that haulms are essential to the overall economics of the crop. Still, the primary target trait in groundnut improvement is the pod, and inclusion of haulm quality traits in selection must not occur at the expense of pod yield. In the present study, we did not find any inverse association between either pod yield and haulm quality or haulm quality and haulm yield (see Figures 1 to 4). These findings suggest that groundnut cultivars are already available that have high pod yield, high haulm yield and quality. Groundnut is commonly cultivated as a food-feed crop that provides food for human consumption and haulms for livestock feeding, and superior dual-purpose cultivars are in high demand. Despite this demand, many conventional groundnut improvement programs continue to focus exclusively on the pod, ignoring even haulm yield (Nigam, personal communication).

As is evident from Figure 3a, pod yield and haulm yield are only moderately associated, and a considerable degree of independency exists between the two traits. For example, at high pod yields of more than 4 t/ha, haulms yield in India could easily vary three and even fourfold. As a first step, the inclusion of haulm yield into breeding and selection schemes and finally, into new cultivar-release decisions seem, therefore, highly commendable. Similarly, cultivar-dependent variation in haulm quality traits was substantial (see Figures 1 to 3) and groundnut improvement should seek ways in providing this information along with pod and haulms yield data. However, the logistical investment here will be higher than in the case of haulms yield observation since haulms need to be ground and subjected to NIRS analysis. Plant breeding generates high numbers of plant entries from small plots rendering conventional laboratory feed and fodder analysis and animal experimentation unsuitable for employment in multidimensional crop improvement. The findings presented in Table 1 show that NIRS technology is a highly appropriate screening tool for crop residue research where many samples require quick and affordable analysis for fodder quality traits.

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