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Identification of a superior dual purpose maize hybrid among widely grown hybrids in South Asia and value addition to its stover through feed supplementation and feed processing

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ABSTRACT

Six maize hybrids (HPQM-1, HY-TEC 5101, Pinnacle, 30V 92, 900 M Gold and NK 6240) commonly grown in South Asia were analyzed for grain yields, stover yields and stover fodder quality traits by a range of agronomic, morphological, laboratory and animal experimental trials. Significant differences were found among the six hybrids in grain and stover yield and stover N, NDF, ADF, ADL, IVOMD and ME content and, when fed to sheep, significant differences were observed for stover intakes and nitrogen retentions. Laboratory traits related to stover structural carbohydrates such as NDF and ADF were highly negatively related with digestible organic matter intake (DOMI) accounting for 90% of the variation therein, while IVOMD and ME were positively associated with DOMI accounting for 90 and 94% of the variation therein, respectively. Stover from two hybrids (NK 6240, 30V 92) with the highest and second highest grain yield but with the laboratory and in vivo stover fodder quality traits falling into the statistically highest and lowest category were further investigated for animal responses through supplementation and feed processing. From these two stovers, complete diet in the form of feed block and mash were designed consisting of 60% stover. Stover-based complete diets in the form of feed mash were superior to diets offered as feed blocks. In the feed mash form, animals fed the superior stover-based diet had more than 30% greater average daily gain than those fed the lower quality stover-based feed mash diet. Stover from the popular maize hybrids were found to differ significantly with regard to the stover quality attributes-feed intake, digestibility and animal performance suggesting the possibility of exploiting these attributes by the maize breeders for developing promising dual purpose maize varieties.

1. Introduction

In India maize is now the third most important crop after rice and wheat (Directorate of Maize Research, 2011) with much of the increase in hectares planted having taken place in non-traditional maize areas (Joshi et al., 2005). In these areas maize is largely replacing sorghum, an important dual-purpose crop, the stover of which is highly valued by livestock keepers and fodder traders as feed resource of commercial value (Kelley and Rao, 1996; Blümmel and Rao, 2006). Given the prevalent fodder shortage in India, maize stover will need to substitute for the loss in sorghum stover (Erenstein et al., 2011). Nutritionally significant variations exists in stover quantity and quality of commonly grown sorghum and pearl millet hybrids and open pollinated varieties (OPV's), however, often with no or limited awareness of these variations, particularly in newer cultivars (Blümmel et al., 2010; Sharma et al., 2010).

Detecting and exploiting variations in stover fodder traits in existing and commonly grown crop cultivars is logistically undemanding since, compared with crop breeding programs, relatively few cultivars need to be investigated and phenotyped for stover traits (Sharma et al., 2010). Another advantage is that delivery pathways for information about those traits and preferential promotion of the cultivar are short. Since the cultivar is already known, seed usually exist and the seed industry increasingly looks at stover as a potentially remunerative value added trait (Syngenta, India, personal communication). Cultivars that have superior grain and stover traits can increase overall farm productivity particularly in "mixed crop livestock systems" through direct use as livestock fodder and/or through selling of stover to fodder trading and feed processing businesses (Erenstein et al., 2011; Sharma et al., 2010).

Abbreviations: ADF, acid detergent fiber; ANOVA, analysis of variance; AOAC, association of official analytical chemists; DOMI, digestible organic matter intake; CSISA, Cereal System Initiative for South Asia; GLA, green leaf area; ICRISAT, International Crops Research Institute for the Semi Arid Tropics; ILRI, International Livestock Research Institute; LSD, least significant difference; ME, metabolizable energy; N, nitrogen; NDF, neutral detergent fiber; OMD, organic matter digestibility; OMI, organic matter intake; OPV's, open pollinated varieties; SAS, statistical analysis systems.

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2. Materials and methods

2.1. Maize hybrids investigated and grain and stover yield measurements

Six popular maize hybrids (HPQM-1, HY-TEC 5101, Pinnacle, 30V 92, 900 M Gold and NK 6240) were selected based on their grain and biomass yields from previous two season small plot experiments and planted in large field plots at ICRISAT campus in Patancheru in the rainy season of 2008 on black soil (Vertisol) in two replications. About 0.1 ha were allocated to each hybrid and replication. Fertilizer application was 100 kg of Di ammmonium phosphate (DAP)/ha and a topdressing 100 kg of urea per ha. At full grain maturity after grain harvest the stovers were harvested by hand, chopped with a mechanical chopper (Hardcase Engineering), artificially dried in diesel-heated drying bins to a residual moisture content of <10%, placed into gunny bags and barn-stored until feeding trials. Stover from the two field replications were kept separately. For each hybrid and replication, two subplots of 3 m^2 were randomly selected, harvested for grain and stover yield calculations.

2.2. Stover morphology and laboratory fodder quality analysis

Fifteen plants were collected from each of the subplots and fractionated into leaf blade, leaf sheath and stem. Stem diameter (SD) was taken with a caliper near the ground and residual green leaf area was measured using a leaf area meter and plant height was measured with a tape. Additionally 15 plants were collected for whole plant analysis. Stovers were analyzed by a combination of Near Infrared Spectroscopy (see Prasad et al., submitted for publication) and conventional laboratory analysis.

2.3. Stover palatability and metabolic trials with sheep

Two experiments were conducted with sheep. In the first experiment, stovers from all six hybrids were tested as providing approximately 90% of the total feed intake (a concentrate/mineral/vitamin mix supplement was given to each sheep at a flat rate of 50 g/d) in 2008/2009. In the second experiment, stover from two contrasting hybrids were collected from farmer fields in the 2011 cropping season and used as major fodder ingredients to design complete total mixed diet in the form of feed blocks and mash. The studies were carried out at the livestock experimental facilities of the International Livestock Research Institute (ILRI) hosted by the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) at Patancheru in India. In the first trial 60 growing local Deccani male sheep of about 20 kg live weight were allocated to 12 groups of 5 sheep each. The sheep were de-wormed and vaccinated against common diseases and housed in metabolic cages in a well-ventilated barn. Each of the twelve stovers (stovers from six hybrids in two field replication) was offered ad libitum to five sheep allowing for refusals of about 10–15%. Before stover feeding the sheep were offered 50 g of concentrate (grain, cotton cake and mineral–vitamin mix) from 08:30 to 09:30 h in the morning to mitigate the general low energy, protein and mineral/vitamins content of maize stover (concentrate was for all practical purposes completely consumed). The feeding period was 4 weeks with a fecal and urine collection period during the last 10 days of the trial. Feed offered and orts were analyzed for dry matter (925.40), organic matter (923.03) and nitrogen by Kjeldahl using AOAC (1990) standard procedures. Neutral detergent fiber (NDFom – without heat stable amylase but with sodium sulfite) and acid detergent fiber (ADFom) were analyzed according to Van Soest et al. (1991) and the results were reported on residual ash exclusive basis. In vitro digestibility and metabolizable energy (ME) contents were analyzed according to Menke and Steingass (1988) method.

In the second experiment, the design of a complete total mixed ration was adopted from the Indian feed block manufacturer, Miracle Fodder and Feed Pvt. Ltd. in Hyderabad who produced a commercial total mixed ration feed block based on sorghum stover (Shah, 2007; Blümmel et al., 2012). For this experiment we substituted sorghum stover with maize stover from hybrids NK 6240 and 30V 92 purchased from farmers in early 2012. From these stovers, complete diets with 60% of maize stover, 15% of pigeon pea husks, 15.5% cotton cake, 8% molasses, 0.3% urea, 1% mineral mix and 0.2% vitamin mix were designed.

The complete maize stover based diets using two cultivars were produced in two different physical forms: as feed blocks using chopped maize stover and as feed mash where maize stover was ground to a particle size of about 8 mm. Each of the four treatments (NK 6240 based feed block, NK 6240 based feed mash, 30V 92 based feed block and 30V 92 based feed mash) was allocated to 7 sheep with average starting group weight of about 15 kg. As a control, a feed block where the maize stover was replaced by a premium sorghum stover was offered to 4 sheep in the same trial and under the same conditions. All sheep were de-wormed and vaccinated against common diseases and housed in metabolic cages in a well-ventilated barn. All complete diets were fed ad libitum allowing for about 10 to 15% of refusals. Feeding period was 60 days. Feed offered and residues were analyzed as in the first experiment.

2.4. Statistical analysis

The computer program SAS Version 9.2 (2008) was used for ANOVA using SAS Proc GLM. Simple linear relationships between morphological, chemical and in vitro measurement and in vivo data were analyzed by SAS Proc Corr.

The model $Y_{ij} = \mu + t_i + e_{ij}$ was used for the analysis of the data, where Y_{ij} represents the jth observation ($j = 1, 2, \ldots, n_i$) on the ith treatment ($i = 1, 2, \ldots, k$ levels). So, μ overall mean effect, t_i represents the ith treatment effect and e_{ij} represents the random error present in the jth observation on the ith treatment. The errors e_{ij} were assumed to be normally and independently (NID) distributed, with mean zero and variance σ^2_e.

The comparison of means between treatments were carried out using Fisher's least significance difference (LSD) test at 5% level of significance

To compare the treatment effects-Physical form (mash versus block), variety (NK6240 versus 30V92) and crop (maize versus sorghum stover) orthogonal contrasts was tested using the computer program SAS Proc GLM.

3. Results

3.1. Agronomic performance of hybrids and their morphological and laboratory stover fodder quality traits

Grain yield, stover yield and stover laboratory fodder quality traits of the 6 maize hybrids fed to sheep are presented in Table 1. Significant differences among the hybrids were observed for grain and stover yield and for all stover laboratory fodder quality traits. Highest and second highest grain yields were observed in hybrids NK 6240 and 30V 92, respectively. However all stover fodder quality traits in NK 6240 were significantly superior compared to those of 30V 92 and these two stover demarcated the observed range in stover quality for most traits.

Morphological stover traits are reported in Table 2. Significant differences among the hybrids were observed for plant height, stem