**Range Mgmt. & Agroforestry 34 (1) : 112-118, 2013**
**ISSN 0971-2070**

# Estimates of wheat straw availability and variation in straw quality

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Received: 30th July, 2012 Accepted: 22nd June, 2013

**Abstract**
A study was conducted to determine the straw grain ratios (S/G ratio) and straw quality of wheat cultivars to develop wheat straw availability estimates at national and state levels. The sampling locations were the farmer's field spread over 8 major wheat producing Indian states *viz.,* Bihar, Haryana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand and West Bengal. These states together contribute more than 85 percent of total wheat production in India. A significant variation (P<0.001) in straw to grain ratios was observed among wheat cultivars grown in different states. Variability (P<0.001) within the cultivar was also observed when it was grown under different agro climatic regions and agronomical practices. At present (year 2010-11) 112 million tonnes of wheat straw is expected to be available in the country and in next 10 years (year 2020) this quantity will increase up to 120 million tonnes, registering a growth of 6 percent. As per the projections, the share of UP in total wheat straw pool will be the highest (33 %), followed by Punjab (19%), Haryana (15%), Rajasthan (11%), MP (10%) and Bihar (6%). The straw availability from other wheat producing states is expected to be 6 percent. Similarly significant variations (P<0.01) in all the quality attributes were observed among the wheat cultivars. Among the various chemical constituents, the CP content varied greatly (50.1%) followed by the lignin (42.96%), hemi cellulose (37.12%), ADF (30.39%), cellulose (28.37%) and NDF (21.2%). The dry matter digestibility of straw from different wheat cultivars ranged from 35.0 to 52.3 percent. It was concluded that straw grain ratios are variable and therefore the projection based on area specific ratios will be more realistic for assessing the straw availability in the country. Chemical composition and digestibility of straw varied among the wheat cultivars. Results suggested that the variability in nutritional parameters among varieties need to be exploited by plant breeders, particularly in areas where straw is an important component of ruminant feed.

**Key words:** ADF, Animal nutrition, Forage availability, NDF, Lignin, Nutritive value, Straw grain ratio, Straw quality, Wheat straw availability, Wheat varieties

**Abbreviations: ADF:** Acid detergent fibre, **BW**: Body weight, **CP**: Crude protein, **DM**: Dry matter, **NBDMD**: Nylon bag dry matter digestibility, **S/G**: Straw to grain ratio, **WS**: Wheat straw

## Introduction

In India, wheat is grown primarily under rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in the plains. The share of wheat in total food grain production in India is around 35.5 percent and share in area is about 21.8 percent of the total area under food grains (Anonymous, 2009). Straw production estimates for wheat are important because wheat straw (WS) constitutes the major component of feed for ruminants in almost all small scale crop livestock systems prevailing throughout Asia. Straw production levels for wheat are estimated frequently based on measurements of grain production and the assumption of a strong relationship between grain and straw. Often this relationship is assumed to be direct or linear. One problem with this approach for estimating straw yield is that straw/grain ratios (S/G ratio) in wheat are not constant as is evident in relationships presented by Triplett and Mannering, (1978). Environmental factors, such as water and N fertility, have been identified as greatly impacting wheat straw/grain ratios (Campbell *et al*., 1977). Straw/grain ratios in wheat are also affected by genotype characteristics, in particular plant height. Wheat genotypes characterized by taller canopies are frequently observed to produce more straw per unit of grain than shorter selections, resulting in lower harvest index (grain weight/grain + straw weight) values (Donald and Hamblin, 1976; Donaldson *et al*., 2001; Sharma *et al*., 1987). In last few decades, many dwarf wheat

varieties were released to increase the grain production which has replaced the taller varieties and this would have altered the straw availability. Besides the straw/grain ratios, a wide variability in straw quality has also been observed in wheat cultivars. The International Feed Resources Group in Scotland tested up to 100 varieties of grain from wheat, barley and oats. The quality of barley and wheat in particular showed wide variations. In fact the variability was such that groups of cattle grew 300 g/d more from consuming one variety of straw than another (Orskov, 1995).

Therefore, the present study was taken-up with different wheat cultivars and with different agro climatic regions of the country to find out straw/grain ratios for developing projections on future availability of wheat straw as animal feed resource along with the determination of variability in straw quality attributes.

## Materials and Methods

***Study area and sampling*:** The sampling locations were the farmer's field spread over 8 major wheat producing states (Bihar, Haryana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand and West Bengal) as more than 85 percent of wheat produced in India comes from these regions. Multistage random sampling procedure was adopted for sampling and representative plant samples were collected following the standard procedure (Snedecor and Cochran, 1967). Hand sickles were used to harvest the aboveground plant biomass. All hand-clip samples collected from 10 different locations of the field were placed in a paper sack and dried in oven at 50°C and then threshed to determine grain yield, straw yield, and straw/grain ratios. After determination of straw yield, the plant samples of 10 different locations of each field were pooled together for chemical analysis.

***Model formulation for straw yield projections*:** Models were formulated on the basis of growth trends, observed in last 20 years data records (1950-51 to 2001-02) available with Directorate of Economics and Statistics, DAC, Ministry of Agriculture, Government of India, with the assumption that the current trends of acreage as well production would have a strong association with the previous year data of both production and farm produce prices of commodities as the current status is very much dependent on the previous year status. The following models were formulated for calculation:

***Acreage function***

$Ln(At) = a + b\ Ln(PP \text{ at } t\text{-}1) + c\ Ln,(A\ t\text{-}1)$

where At = area under production at time $t^{th}$ year, A(t-1)= area under production at $(t\text{-}1)^{th}$ year, and PPt-1= Farm produce price of concerned crop at time $(t-1)^{th}$ year. (Ln stands for $Log_e$)

***Production function***

$Ln(Yt) = a + b\ Ln(PP_{t-1}) + c\ Ln,(\text{Urea price}_{t-1}) + d\ Ln(Y_{t-1})$

where Yt = yield at time $t^{th}$ year $Y_{(t-1)}$ = production at $(t\text{-}1)^{th}$ year, Urea price $_{t-1}$ = Price of urea in previous year, $PP_{t-1}$ is the farm produce price of the crop in the previous year.

***Chemical analysis:*** The plant samples were dried at 60 to 70°C and ground to pass a 1-mm sieve and were used for chemical analysis. The OM was determined by ashing at 550°C for 4 h and nitrogen was determined by Kjeldahl technique (AOAC, 2000). Neutral detergent fibre (NDF) and acid-detergent fibre (ADF) were determined by a procedure of Van Soest *et al.,* (1991). Acid-detergent lignin (ADL) was determined according to the method described by Robertson and Van Soest (1981).

***In Sacco degradability:*** Two buffalo calves (335$\pm$12.5 kg BW and 36-40 months old) fitted with rumen cannulae were used for *in sacco* degradability trial. Calves were maintained on wheat straw-based diet (roughage to concentrate ratio, 65:35). The WS samples were ground through 1 mm sieves before *in sacco* rumen incubation. Triplicate samples 2.5g DM of each test straw were weighed in to separate nylon bags. Nylon bags were suspended in the rumen as per the method described by Mehrez and Ørskov, (1977) for 48 h. After incubation, the bags with residues were taken out from rumen, dipped immediately into cold water to stop the microbial activity and then rinsed with cold water to remove the particles from outside the bags. The bags were washed in a washing machine 15 minutes, dried at 45°C till the constant weights.

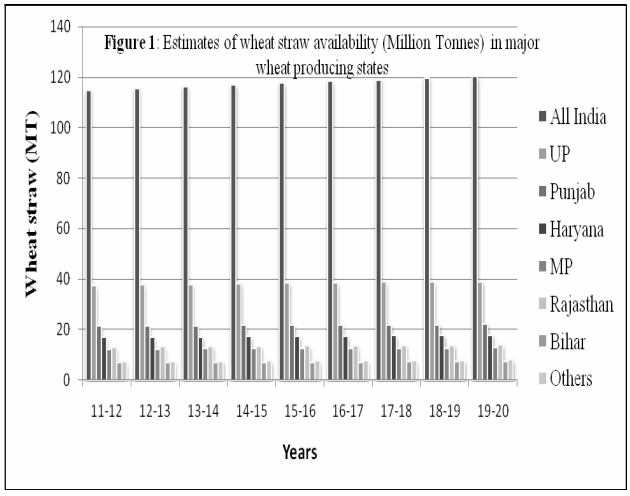
***Statistical analysis:*** Statistical analyses, including ANOVA and Pearson correlation analysis were performed with SPSS13.0 (SPSS software products, USA).

## Results and Discussion

**Straw/Grain ratios:** Straw/grain (S/G) ratios varied greatly ($P<0.01$) among collections form the states and also within the states covered for sampling (Table 1). S/G ratios ranged from 0.80 to 2.28. Varietal variations ($P<0.01$) in S/G ratios were also evident in the samples collected

from different locations (Table 2). The highest S/G ratios were observed for the variety UP262 (X=2.62) and the lowest for VL736 (X=0.72). These ratios were affected by the cultivar selection, environmental factors, such as water and N fertility, (Campbell *et al.,* 1977) and as a result the same cultivar grown under different agro climatic regions and agronomical practices yielded different S/G ratios (Table 3). Straw/grain ratios were generally increased by available soil N levels (Engel *et al.,* 2003).

***Straw yield projections:*** On the basis of S/G ratios discussed above, the projection model for straw availability was developed and projections for all India availability of wheat straw are presented in Figure 1. At present 113 million tonnes of wheat straw is expected to be available in the country and in next 10 years (up to year 2019-20) this quantity will increase up to 120 million tonnes, registering a growth of 6 percent annually. The area under wheat cultivation is not expected to be altered significantly; however, the increase in the yield potential of the cultivars will contribute in the grain as well as straw pool. As per the projections, the share of UP in total wheat straw pool will be the highest (33 %), followed by Punjab (19%), Haryana (15%), Rajasthan (11%), MP (10%) and Bihar (6%). The straw availability from other wheat producing states is expected to be 6 percent.




***Straw quality variability:*** Straw quality parameters of different wheat cultivars are presented in tables 4 and 5. Significant variations (P<0.01) in all the quality attributes *viz*., CP, NDF, ADF, hemicellulose, cellulose and lignin was observed among the wheat cultivars. Among the various chemical constituents, the CP content varied greatly (50.1%) followed by the lignin (42.96%), hemi cellulose (37.12%), ADF (30.39%), cellulose (28.37%) and NDF (21.2%). These large variations among quality attributes of some wheat cultivars have already been reported (Rajesh, 1998; Chaudhry, 2000; Haddad and Hussein, 2001) and could be due to genetic inheritance of different cultivars, change in agronomic practices and the climate. The composition of cell walls of wheat straw is variable and Winugroho (1981) found that the ranges in NDF composition in stem internodes, leaf sheaths and leaf blades were usually narrower than in samples of whole straws. Thus, much of the variation observed may also be due to differences in the proportions of plant morphological fractions, rather than differences in cell wall composition *per se*. It has been observed that application of nitrogen fertilizer improves nitrogen content (Moreira, 1989; Daniel, 1990) and tropical plants are more lignified as compared to temperate climate. A significant (P<0.01) variability (35.0 to 54.71 percent) in *in sacco* straw DM disappearance was also observed. Lower lignin content in wheat straw varieties might have resulted in higher *in sacco* DM disappearance. Lignin content of forage is negatively associated with digestibility (Tripathi *et al*., 1996) and the findings of present investigation (Table 6) also substantiate these reports. Lignin forms the complex with plant carbohydrate which remains un- dissociated under anaerobic environment of rumen (Hammel *et al*., 1985) as lignin degrading enzyme system does not exist in anaerobic environment. A negative relationship of CP content of wheat straw with its cell wall content (NDF, ADF and lignin) was observed (Table 6). The increased CP content of wheat straw linearly improves dry matter digestibility (Leng, 1990) and there is interaction between CP content and fiber utilization in forage based diets. It was also noticed that some of the wheat straw samples which were harvested little early by the farmers showed higher CP content than the samples of normal or delayed harvesting. However, due to limited data on such samples a relationship could not be established. It indicates that besides other parameters, the management of harvesting time may also play an important role in conserving the straw quality. The rapid deterioration in the straw quality may be attributed to the increasing proportion of lignin in comparison to the cellulose, in later phase of growth *i.e*., plant maturity (Pearce *et al*., 1979).

**Implication**

Accurate estimates of wheat straw availability in different parts of the country are important. Traditionally, straw production has been estimated by multiplying grain yield with a constant factor (generally 1:1) of straw to grain ratio. However, there exists variability in straw grain ratios that occurs with plant genotype type and agronomic

practice as evidenced in present investigation. Results from this study demonstrate that application of prediction model based on region specific straw grain ratio would provide considerably better and precise estimates of straw yield. Increasing sampling area would further improve the efficacy of prediction model. A growth of 6 percent in wheat straw availability is expected to occur in next decade.

Chemical composition and digestibility of straw varies among wheat varieties. This variability presumably could be exploited to improve the nutritional value of the straw of future varieties. The straw crude protein and lignin contents are directly related with DM digestion. Therefore, plant breeder must consider these two components while designing the wheat breeding programs.

**Table 1:** Straw to grain ratios (kg straw per kg grain) in wheat cultivars grown in different parts of India

| States | Average S/G ratio | Range | SEM |
|---|---|---|---|
| Bihar (31) | 1.30 | 1.10-2.28 | 0.04 |
| Haryana (30) | 1.61 | 1.17-2.23 | 0.05 |
| Madhya Pradesh (10) | 1.59 | 1.20-2.19 | 0.08 |
| Uttrakhand (11) | 1.51 | 0.73-2.06 | 0.11 |
| Uttar Pradesh (38) | 1.36 | 1.01-1.97 | 0.04 |
| Rajasthan (22) | 1.39 | 0.80-1.94 | 0.06 |
| Punjab (27) | 1.23 | 0.92-1.81 | 0.04 |
| West Bengal (11) | 1.49 | 1.28-1.71 | 0.04 |
| *P* and SEM Between States | 0.001** | - | - |

Figures in parenthesis indicates the number of sampling locations;
*P*= Statistical significance; **= P<0.01; SEM= Standard error of means

**Table 2**: Varietal variations in straw to grain ratios (kg straw per kg grain) in wheat cultivars

| Wheat cultivars[1] | Mean | Range | Wheat cultivars[1] | Mean | Range |
|---|---|---|---|---|---|
| PBW343 | 1.24 | 1.13-2.23 | VL804 | 1.79 | 1.31-2.06 |
| PBW226 | 1.18 | 1.17-1.19 | VL802 | 1.54 | 1.49-1.54 |
| Lok 1 | 1.61 | 1.07-2.19 | VL738 | 1.40 | 1.30-1.47 |
| Local | 1.83 | 1.76-1.89 | VL736 | 0.73 | 0.71-0.75 |
| 17DBW | 1.05 | 1.05-1.05 | VL616 | 1.47 | 1.31-1.63 |
| K68 | 1.41 | 1.40-1.42 | UP262 | 1.56 | 1.20-2.28 |
| PBW443 | 1.39 | 1.24-1.58 | RR21 | 1.15 | 1.11-1.18 |
| HW2045 | 1.12 | 1.12-1.12 | PBW344 | 1.01 | 0-98-1.04 |
| HUW234 | 1.66 | 1.35-1.97 | Raj4079 | 1.11 | 0.95-1.27 |
| HD2733 | 1.17 | 1.01-1.30 | Raj3765 | 1.65 | 1.34-1.94 |
| HD2687 | 1.48 | 1.16-1.81 | Raj3077 | 1.30 | 1.05-1.53 |
| HD2428 | 1.18 | 1.17-1.19 | Raj1551 | 1.49 | 1.31-1.67 |
| HD1767 | 1.12 | 1.11-1.13 | PDW291 | 1.37 | 1.14-1.57 |
| HD1761 | 1.44 | 1.36-1.54 | PBW711 | 1.40 | 1.35-1.45 |
| DWR28 | 1.39 | 1.39-1.39 | PBW550 | 1.02 | 0.95-1.08 |
| A73 | 0.93 | 0.92-0.94 | PBW502 | 1.19 | 1.16-2.16 |
| RD2618 | 1.66 | 1.58-1.74 | WH542 | 1.14 | 1.08-1.21 |
| WH147 | 1.24 | 1.01-1.75 | Sonalika | 1.45 | 1.28-1.57 |
| *P* | ** | SEM | 0.21 | | |

*P*= Statistical significance; SEM= Standard error of means; **= P<0.01);
[1]Name of wheat cultivars are based on information provided by the farmers during sample collection

**Table 3:** Variations in straw to grain ratios (kg straw per kg grain) in same wheat cultivars grown in different locations

| Wheat cultivars | MP | Punjab | UP | Bihar | Haryana | WB |
|---|---|---|---|---|---|---|
| Lok-1 | 1.62 | - | 1.27 | - | - | - |
| PBW343 | - | 1.20 | 1.34 | 1.23 | 1.77 | - |
| PBW502 | - | 1.19 | - | - | 1.59 | - |
| UP262 | - | - | - | 1.56 | - | 1.66 |
| Local varieties | 1.39 | - | 1.24 | - | - | - |

**Table 4:** Variability in nutrient content (% DM basis) and dry matter digestibility (%NBDMD) of straw of different wheat cultivars grown in various regions

| Wheat cultivars | CP | NDF | ADF | HC | Cellulose | Lignin | NBDMD |
|---|---|---|---|---|---|---|---|
| 17DBW | 3.60 | 79.18 | 50.99 | 28.19 | 40.27 | 6.44 | 45.10 |
| A73 | 3.80 | 75.79 | 48.93 | 26.86 | 38.13 | 6.65 | 44.20 |
| DWR28 | 3.72 | 71.60 | 37.87 | 33.73 | 33.12 | 6.00 | 45.12 |
| HD1761 | 3.94 | 77.69 | 46.24 | 31.45 | 38.13 | 7.44 | 48.01 |
| HD1767 | 3.32 | 79.08 | 48.36 | 30.72 | 38.46 | 7.56 | 47.20 |
| HD2428 | 2.50 | 81.13 | 46.99 | 34.13 | 39.56 | 8.98 | 44.75 |
| HD2687 | 3.15 | 81.70 | 52.20 | 29.50 | 42.31 | 6.70 | 44.78 |
| HD2733 | 3.13 | 78.67 | 48.14 | 30.52 | 38.34 | 8.34 | 44.38 |
| HUW234 | 3.47 | 77.52 | 47.32 | 30.20 | 38.48 | 8.25 | 42.26 |
| HW2045 | 2.24 | 77.15 | 51.01 | 26.14 | 39.90 | 7.41 | 44.73 |
| K308 | 2.26 | 76.84 | 54.40 | 22.44 | 39.35 | 10.13 | 37.16 |
| K68 | 2.89 | 75.07 | 42.64 | 32.43 | 36.27 | 6.48 | 44.00 |
| LOCAL | 3.43 | 76.32 | 47.28 | 29.04 | 40.53 | 7.16 | 45.22 |
| LOK-1 | 3.35 | 74.60 | 48.68 | 25.93 | 37.90 | 7.14 | 46.00 |
| PBW226 | 2.79 | 74.32 | 51.86 | 22.46 | 38.33 | 10.19 | 41.81 |
| PBW343 | 3.09 | 77.49 | 48.49 | 29.00 | 38.56 | 7.59 | 44.58 |
| PBW443 | 3.51 | 77.64 | 48.58 | 29.06 | 38.14 | 8.39 | 41.49 |
| PBW502 | 2.68 | 75.54 | 50.57 | 24.97 | 39.14 | 8.15 | 40.43 |
| PBW550 | 2.90 | 81.05 | 54.40 | 26.66 | 42.90 | 6.70 | 48.13 |
| PBW711 | 2.96 | 72.78 | 49.70 | 23.08 | 37.06 | 9.52 | 40.78 |
| VL804 | 2.73 | 76.01 | 50.38 | 25.63 | 38.76 | 7.96 | 45.61 |
| RAJ1551 | 4.01 | 73.69 | 50.74 | 22.95 | 39.79 | 9.05 | 41.10 |
| RAJ3077 | 2.71 | 77.25 | 44.48 | 32.78 | 38.13 | 8.55 | 39.26 |
| RAJ3765 | 2.88 | 79.01 | 47.33 | 31.68 | 37.37 | 7.72 | 45.15 |
| RAJ4079 | 3.67 | 73.71 | 41.28 | 32.43 | 33.48 | 6.82 | 47.63 |
| RD2618 | 2.27 | 79.67 | 46.11 | 33.56 | 37.35 | 10.70 | 37.40 |
| RR21 | 3.04 | 72.51 | 48.29 | 24.22 | 37.53 | 9.07 | 44.84 |
| SONALIKA | 3.25 | 77.88 | 48.23 | 29.65 | 37.51 | 8.40 | 42.76 |
| UP262 | 3.37 | 79.25 | 47.13 | 32.11 | 37.35 | 8.24 | 46.04 |
| VL616 | 2.53 | 77.04 | 50.41 | 26.64 | 45.98 | 8.00 | 42.77 |
| VL736 | 3.60 | 64.36 | 42.28 | 22.08 | 39.38 | 8.00 | 52.30 |
| VL738 | 2.47 | 76.08 | 49.51 | 26.57 | 45.59 | 8.00 | 46.37 |
| VL802 | 2.20 | 70.38 | 48.92 | 21.46 | 46.24 | 8.00 | |
| VL804 | 3.47 | 72.52 | 49.24 | 23.27 | 44.00 | 8.00 | 44.29 |
| WH147 | 3.10 | 75.35 | 50.05 | 25.30 | 38.77 | 7.96 | 45.36 |
| WH542 | 3.30 | 79.63 | 53.43 | 26.20 | 42.28 | 6.72 | 43.50 |
| *P* | ** | ** | ** | ** | ** | ** | ** |
| *SEM* | 0.23 | 1.85 | 1.12 | 1.19 | 1.01 | 0.87 | 1.45 |

*P*= Statistical significance; SEM= Standard error of means**= P<0.01

**Table 5:** Fiber, protein and dry matter (NBDMD) digestibility (% of DM) of straw of wheat cultivars collected from different locations

| Attributes | n | Mean | Minimum | Maximum | SEM | SD |
|---|---|---|---|---|---|---|
| NDF | 180 | 76.67 | 64.36 | 85.22 | 0.25 | 3.37 |
| ADF | 180 | 48.70 | 37.87 | 57.72 | 0.28 | 3.74 |
| Hemi cellulose | 180 | 27.97 | 20.54 | 36.61 | 0.30 | 3.98 |
| Cellulose | 180 | 39.10 | 32.57 | 47.98 | 0.25 | 3.35 |
| Lignin | 180 | 7.82 | 6.00 | 12.73 | 0.09 | 1.16 |
| Protein | 180 | 3.09 | 2.00 | 4.85 | 0.05 | 0.68 |
| NBDMD | 180 | 44.53 | 35.00 | 52.30 | 0.24 | 2.88 |

**Table 6**: Correlation among chemical constituents and DM digestibility of wheat straw

| Parameter | NDF | ADF | Cellulose | Lignin | CP | NBDMD |
|---|---|---|---|---|---|---|
| NDF | 1 | .37** | .30** | .20** | -.32** | .11 |
| ADF | .37** | 1 | .62** | .130 | -.31** | -.35* |
| Hemi cellulose | .49** | -.62** | -.32** | .048 | .02 | .33 |
| Cellulose | .30** | .62** | 1 | -.047 | -.23** | .15 |
| Lignin | .20** | .13 | -.04 | 1 | -.10 | -.56** |
| CP | -.32** | -.31** | -.23** | -.10 | 1 | .42** |
| NBDMD | .11 | -.35* | .15 | -.56** | .42** | 1 |

* & ** Correlation is significant at the level P<0.01 and P<0.05, respectively; n=180

**Acknowledgement**

Authors are thankful to Director, IGFRI, Jhansi for providing necessary facilities. Assistance provided in sample collection work by the State Agricultural Universities and ICAR Institutes is also thankfully acknowledged.

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