



Research article

***Boerhavia diffusa* (punarnava): A non-conventional feed resource for Indian goats in semi-arid ravines of Uttar Pradesh, India**

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Abstract

Goat augments small and marginal farmer's income by providing livelihood support to landless and economically weaker section of the society. An experiment was conducted to evaluate the suitability of *B. diffusa* L. as green fodder for goats under ravenous soil condition. Twelve male Barbari goats were randomly divided into two groups. In one group, *B. diffusa* was offered alone as green fodder and in second group, *B. diffusa* along with 200g chickpea straw was offered for a period of 21 days. The dry matter content in fresh *B. diffusa* biomass was only 10.07 percent. A metabolism trial was conducted using metabolic cages. Significant ($P<0.001$) difference was observed between two treatment groups in DMI, live body weight and CPI. However, DCP%, CP, NDF, EE digestibility were statistically similar between both the groups. TDN % was 49.61 with sole feeding of *B. diffusa* ($P<0.05$). Mineral balances for Ca, K and N were recorded higher ($P<0.001$) with chickpea straw + *B. diffusa* fed group. Rumen fermentation and haematological parameters remain unchanged for both the groups. Study indicates that *B. diffusa* can be used as non-conventional feed resource with adequate supplementation of chickpea straw.

Keywords: *Boerhavia diffusa*, Chickpea, Feed, Feed resource, Goats, Ravines

Introduction

Goats have potential to transform the economic condition of the resource poor farmers. During summer and post monsoon season, there is shortage of green fodder and goat mainly depends on dry crop residues or low-grade dry roughages at grazing sites. This available biomass for grazing is insufficient in quantity as well as poor in quality to fulfil even the maintenance requirements of the goat. The shortage of cultivated green forage and a decline in free rangeland resources decreased the availability of essential nutrients to the animals in India (Singh *et al.*, 2022) and it has been identified as main constraint in achieving desired level of livestock productivity (Meena *et al.*, 2018). Keeping these things in focus, there is need of today to find out the new non-conventional green feed resources that can fulfil the requirement or augment the availability of green fodder for goats specially during scarcity period. Therefore, an

experiment was carried out to find out the suitability of *Boerhavia diffusa* commonly known as 'Punarnava' as green feed resource for goats. *B. diffusa* has a pantropical distribution and perhaps native to the tropics of the old world (Mahesh *et al.*, 2012).

Boerhavia diffusa L. is a summer and rainy season plant and it grows on waste land and cultivated lands. It belongs to family Nyctaginaceae. It thrives well on wide range of soils with very fast-growing habit and it covers whole field in a very short period of time. In cultivated fields, it competes with crop plants for space, water in addition to soil nutrients and it act as a noxious weed. It is also known for its medicinal value as it has diuretic and laxative effect and used in kidney related problems (Chopra *et al.*, 1923). However, Alade *et al.* (2010) reported use of *B. diffusa* as forage for cattle and sheep. Ujowundu *et al.* (2008) also recommended the use of *B. diffusa* leaves as cheap source of vitamin C, B₃ and B₂, as well as other

macro- and micro-nutrients, thus can be incorporated into human and animal diet to meet their recommended daily allowances. The roots of *B. diffusa* are used in popular medicinal formulations in India (Rawat and Vashistha, 2011).

During rainy season, cultivated fields or waste lands of semi-arid ravenous soil contain sizable green cover of *Boerhavia diffusa* but its biomass is not utilized as feed resource by goat keepers. Devendra and Leng (2011) stated that the locally available feed resources act as the key driving force for improving productivity of animals in developing countries like India. Therefore, an attempt has been made to explore the use of *B. diffusa* green biomass alone and in combination with chickpea straw as feed resource for goat production. India is a major producer of chickpea pulse grain (*Cicer arietinum*), contributing 70% of the world's production in 2020-21 (Department of Agriculture & farmers welfare, 2023). Despite the substantial availability of pulse crop residues (stover) in India, around 13 million tonnes remained underutilized for livestock feeding (Maurya *et al.*, 2020), therefore, chickpea straw was taken as dry matter supplement with *B. diffusa* in second group feeding.

Materials and Methods

Animals and feeding: Twelve male adult Barbari goats with average body weight of 38.19 ± 1.56 were divided in two groups with six goats in each group. Green biomass of *Boerhavia diffusa* was collected on daily basis through cut and carry method from waste and arable lands of Yamuna ravines of the institute farm area during the post monsoon season and it was offered fresh as green fodder to adult male Barbari goats of both the groups. One group of animals was offered with sole green biomass of *B. diffusa*. However, second group was offered *B. diffusa* in combination with 200 g. chickpea (*Cicer arietinum*) straw to each animal. Animals of both the groups were penned in well-ventilated individual enclosures, and were fed *ad lib* *B. diffusa* and drinking water for 21 days and after 21 days' preliminary feeding, a metabolism trial of 10 days was conducted.

Metabolism study: A metabolism trial of 10 days (3 days' adaptation in metabolism crates followed by 7 days of sample collection) duration was carried out on 22nd day of feeding on all animals. Daily intake of fodder was recorded, and output of faeces and urine of 24 hours were collected. Samples of feed, orts, faeces and urine were collected every morning. The air DM of fodders, faeces and orts was determined by drying to a constant weight in a forced air oven at 70°C. Urine DM was not determined. Dried samples for each day of the 7 days collection were pooled, ground to pass a 1 mm screen and preserved for chemical analysis. For Nitrogen estimation, samples of faeces (1/1000) and urine (1/100)

from individual animals were collected every morning in a 500 ml flask containing 25 ml of concentrated sulphuric acid.

Rumen fermentation parameters: Samples of rumen fluid (50 mL) were withdrawn from all intact animals at 4 hours post-feeding using a stomach tube at the end of experiment. Each sample was placed in a 100 mL glass jar and the pH was determined using a portable pH meter within 4 to 5 minutes of sampling. Thereafter, rumen fluid was strained with four layers of muslin cloth. A few drops of saturated mercuric chloride were added to arrest microbial activity and stored at -20°C for further analysis. The N was determined using Kjeldahl technique (AOAC, 1990), total volatile fatty acids (TVFA) as per Barnett and Reid (1957) procedure, ammonia nitrogen by Conway (1962) method, while TCA-N was determined by following the procedure of Tagari *et al.*, (1964).

Haematology study: Blood samples were collected once at the end of the feeding experiment. Samples were drawn by puncture of jugular vein in EDTA impregnated tubes for haematology study. Haematological observations namely haemoglobin (Hb), haematocrit, red blood cells, white blood cells, lymphocytes and mean corpuscular haemoglobin concentration were determined in whole blood immediately after blood collection using automated blood analyzer (Nihon Kohden, Japan) dedicated for goat haematology.

Chemical analysis: Feed, refusals and faeces samples were analysed for DM by drying at 70°C until constant weight. Organic matter was determined by ashing at 550°C for 4 h (AOAC, 1990) and crude protein was estimated by Kjeldahl technique ($N \times 6.25$; AOAC, 1990). Procedure of Van Soest *et al.* (1991) was used for neutral detergent fibre (NDF) determination without sodium sulphite or α -amylase, whereas acid detergent fibre (ADF) and lignin were determined according to the method of Robertson and Van Soest (1981). The estimates of NDF and ADF were presented with residual ash. Sequential procedure was followed for the estimation of NDF, ADF, hemicellulose, cellulose, and lignin on the same sample. Total crude fat was estimated by solvent extraction procedure (AOAC, 1990) with ethyl ether by a Soxhlet's apparatus.

Statistical analysis: Data on intake, nutrient digestibility, rumen fermentation and haematological parameters were analysed by independent 't' test as described by Snedecor and Cochran (1994).

Results and Discussion

Chemical composition:

B. diffusa has notably high-water content, with only 10.07% dry matter (Table 1), but low dry matter content

also reported by Musa (2003). The crude protein content of *B. diffusa* was 13.58%, which was 1.74 times higher ($P < 0.05$) than that of chickpea straw on a dry matter basis. This level of crude protein was sufficient to meet the protein requirements of goats, as outlined by Kears (1982) and exceeds the critical minimum of 8% crude protein typically required for ruminants. Chopra *et al.* (1923) also reported that *B. diffusa* rich in proteins and fat. In terms of mineral content, *B. diffusa* was particularly rich, with an ash content of 22.35%, which is 2.35 times greater than that found in chickpea straw ($P < 0.001$). This elevated ash content is indicative of a high mineral profile (Beegum *et al.*, 2014). There were significant amounts of sodium (4.12%), potassium (2.34%) and calcium (0.85%) recorded (Table 1). These minerals play vital roles in electrolyte balance, bone health and overall metabolic functions in ruminants. Puranik *et al.* (2012) also reported that the leaves of *B. diffusa* contained significant quantity of vitamin C, phosphorus, sodium, calcium, and magnesium.

In *B. diffusa*, the contents of fat, acid detergent fiber, cellulose, lignin and hemicellulose were found similar ($P > 0.05$) with chickpea straw (Table 1). These values for NDF, ADF and cellulose fall very close to the range as reported by Bilatu *et al.* (2012) and Singh *et al.* (2018) for cowpea fodder. The high organic matter content (77.63%) and total carbohydrate content (62.39%) suggest that *B. diffusa* provides a considerable source of fiber and energy for ruminants, although the relatively high fiber content (NDF and ADF) may affect its digestibility. Awouhouedji *et al.* (2013^a) also observed rich energy in *B. diffusa*. The

chemical composition of chickpea straw was within the range as reported by Singh *et al.* (2020).

Intake, digestibility and mineral balance: Mean DMI of 0.91 and 1.58 % of the live body weight of goats and DM intake (g DM/kg. $w^{0.75}$) under both the groups was much lower than the requirement for maintenance indicated that the dry matter intake was inadequate in quantity to meet the nutrients requirement. The dry matter requirement (g DM/kg. $w^{0.75}$) for Barbari goats were 76 to 94 and 102.63 to 110.66 suggested by Singh and Sengar (1970) and Rajpoot *et al.* (1981), respectively. Low dry matter intake under both the groups could be due to very high water content and low dry matter content in green biomass of *B. diffusa*. Therefore, inclusion of chickpea straw @200 g/animal in diet enhanced dry matter content in animal's diet which led to increase in DMI (g/animal/day) by 1.88 times over sole *B. diffusa* fed animals (Table 2). This difference is significant ($P < 0.001$). In the same pattern, DMI/ $w^{0.75}$ and % live body weight also had a significant ($P < 0.001$) increase over sole feeding of *B. diffusa*, however, DMI intake was much lower than the voluntary intake of dry matter as reported by Tripathi *et al.* (2007); Dutta *et al.* (2010) in natural pasture. The poor intake of dry matter was responsible for low nutrient intake led reduction in animal's body weight was observed in *B. diffusa* fed animals as well as in combined diet also but average body weight between both the groups was observed with non-significant variation. Awouhouedji *et al.* (2013^b) also suggested that most commonly available feed resources in the tropics are unbalanced and they require proper supplementation to feed the animals.

Crude protein intake (g/animal/day) was 1.81 times higher ($P < 0.001$) with combined diet of chickpea straw + *B. diffusa* than sole *B. diffusa* fed animals. It might be due to high moisture content in green biomass of *B. diffusa* restricted total CP intake. However, DCP% remain with no variation ($P < 0.05$) between the groups. The values observed in this study, particularly the 2.72 g/kg $w^{0.75}$ for the mixed diet, would be beneficial for growing or lactating goats, as it exceeded the recommended intake for maintenance but may still require further supplementation for higher production stages. However, DCP intake g/kg $w^{0.75}$ in both the groups fall within range of requirement, Sengar (1980) and Rajpoot *et al.* (1981) recommended 1.42 and 3.05 g DCP/kg $w^{0.75}$ as the minimum and maximum requirements for maintenance. In contrast, the percentage of total digestible nutrients (TDN) was significantly lower ($P < 0.05$) in the combined diet of chickpea straw and *B. diffusa*. This reduction in TDN content can be attributed to the relatively high fiber content of chickpea straw, which may decrease the overall digestibility of the mixed diet. Despite the decrease in TDN, the combined feeding of chickpea straw and *B. diffusa* significantly ($P < 0.001$) improved dry matter intake (DMI), crude

Table 1. Chemical composition (% on dry matter basis) of *Boerhavia diffusa* and chickpea straw

Parameters	<i>B. diffusa</i>	Chickpea straw	P value
Dry matter content	10.07 ± 0.01	95.00 ± 0.03	<0.001
Crude protein	13.58 ± 0.36	7.80 ± 0.02	0.001
Ether extract (fat)	1.63 ± 0.09	1.47 ± 0.07	0.297
NDF	50.87 ± 0.69	55.41 ± 1.62	0.034
ADF	36.12 ± 1.20	39.72 ± 2.76	0.220
Cellulose	24.16 ± 2.03	27.70 ± 1.40	0.321
Lignin	8.89 ± 0.65	8.82 ± 0.33	0.933
Hemicellulose	14.74 ± 1.11	15.69 ± 1.13	0.412
Ash	22.35 ± 0.037	9.52 ± 0.005	<0.001
Organic matter	77.63 ± 0.037	90.47 ± 0.005	<0.001
Total carbohydrate	62.39 ± 0.46	81.20 ± 0.075	<0.001
Na content (%)	4.12 ± 0.52	0.23 ± 0.02	<0.001
K content (%)	2.34 ± 0.28	1.42 ± 0.005	0.081
Ca content (%)	0.85 ± 0.035	0.88 ± 0.04	0.684

NDF: Neutral detergent fibre; ADF: Acid detergent fibre

Table 2. Intake, digestibility and mineral balance in experimental animals during metabolic trial

Parameters	B. diffusa as sole feed	B. diffusa + chickpea straw	P value
Initial body weight (kg)	37.15 ± 1.99	39.22 ± 1.24	0.187
Final body weight (kg)	35.99 ± 1.24	39.0 ± 0.85	0.185
Metabolic body weight (W ^{0.75})	14.67 ± 0.63	15.60 ± 0.25	0.178
Dry matter intake (g/animal/day)	328.45 ± 19.55	617.18 ± 37.24	0.00
DMI (per 100 kg. live body weight)	0.913 ± 0.019	1.58 ± 0.10	0.00
DMI/W ^{0.75}	22.33 ± 0.53	39.63 ± 2.52	0.00
CPI (g/animal/day)	42.60 ± 2.58	77.50 ± 4.93	0.00
CPI (per 100 Kg. live body weight)	118.48 ± 2.58	199.34 ± 13.69	0.003
CPI (g/ W ^{0.75})	2.89 ± 0.069	4.97 ± 0.33	0.00
DCP%	7.73 ± 0.14	7.03 ± 0.27	0.055
DCPI (g/animal/day)	25.41 ± 1.58	43.29 ± 2.85	<0.001
DCPI/ (per 100kg Live body weight)	70.56 ± 1.23	111.08 ± 7.18	<0.001
DCPI/ ((g / kg w ^{0.75})	1.72 ± 0.04	2.72 ± 0.17	<0.001
TDN %	49.61 ± 1.44	45.12 ± 1.04	0.026
TDNI (g/animal/day)	170.35 ± 12.72	279.98 ± 22.50	0.001
TDNI/(per100kg Live body weight)	478.24 ± 37.15	721.35 ± 62.67	0.00
TDNI (g) / W ^{0.75})	11.66 ± 0.84	18.00 ± 1.52	0.002
Digestibility (%)			
Dry matter	58.35 ± 2.70	52.90 ± 1.17	0.053
Crude protein	60.70 ± 1.56	56.10 ± 2.30	0.103
EE	59.79 ± 3.70	63.52 ± 1.87	0.84
NDF	43.32 ± 4.00	40.55 ± 1.66	0.23
ADF	58.35 ± 2.70	36.12 ± 2.12	0.001
Cellulose	64.44 ± 1.71	55.07 ± 0.82	0.004
Hemi Cellulose	63.91 ± 2.44	52.01 ± 3.59	0.013
Organic matter	63.23 ± 2.91	53.41 ± 1.36	0.014
Total Carbohydrate	63.83 ± 3.25	53.05 ± 1.82	0.033
Mineral balance in body (g/day/animal)			
Na balance	7.20 ± 0.83	9.29 ± 1.17	0.188
Ca balance	1.82 ± 0.15	3.88 ± 0.19	0.00
K balance	1.48 ± 0.59	10.22 ± 0.59	0.00
Nitrogen balance	-2.51 ± 0.36	0.028 ± 0.002	0.00

DMI: Dry matter Intake; W^{0.75}: Metabolic body weight; CPI: Crude protein intake; DCP: Digestible crude protein; DCPI: Digestible crude protein intake; TDN: Total digestible nutrients; TDNI: Total digestible nutrients intake

protein intake (CPI), and total digestible nutrients intake (TDNI), both in terms of grams per day per animal, percentage of live body weight and per kgW^{0.75} (Table 2). Thus, supplementing *B. diffusa* with chickpea straw enhanced overall feed intake and nutritional intake. For adult goats, the NRC (2007) recommended a minimum TDN level of 55-60% for maintenance and higher levels for productive animals (e.g., lactating or growing goats).

The TDN values observed in both diet groups (49.61% and 45.12%) fall below the recommended minimum level for maintenance. This suggests that *B. diffusa* based diets may support basic maintenance needs, but, are likely insufficient to meet the higher energy demands associated with growth, lactation, or other productive functions. To meet the energy requirements of goats, these diets would benefit from the inclusion of more

Table 3. Rumen and haematological parameters as influenced by *B. diffusa* based diets

Parameters	<i>B. diffusa</i> as sole feed	<i>B. diffusa</i> + chickpea straw	P value
Rumen parameters			
pH	6.39 ± 0.07	6.34 ± 0.06	0.73
NH ₃ -N (mg/dL)	22.4 ± 1.61	21.94 ± 1.63	0.84
TCA-N (mg/dL)	12.13 ± 1.12	11.71 ± 1.24	0.81
TVFA (mmol/dL)	11.70 ± 0.66	11.11 ± 0.54	0.50
Total-N (mg/dL)	50.86 ± 2.52	50.80 ± 2.55	0.98
NPN (mg/dL)	38.73 ± 1.83	38.80 ± 2.55	0.984
Haematological parameters			
Haemoglobin (g/dL)	7.43 ± 0.81	6.68 ± 0.33	0.387
Haematocrit (g/dL)	22.68 ± 2.92	21.11 ± 1.4	0.601
RBC (x 10 ⁶ /μL)	15.42 ± 2.43	12.90 ± 0.62	0.304
WBC (x 10 ³ /μL)	20.50 ± 2.32	16.92 ± 1.51	0.212
MCH (pg)	7.15 ± 0.88	5.18 ± 0.10	0.077
MCHC (g/dL)	33.36 ± 1.35	31.65 ± 0.21	0.203
LY%	67.56 ± 0.59	49.81 ± 7.74	0.99
GR%	51.95 ± 10.97	43.38 ± 6.36	0.498

TVFA: Total volatile fatty acids; NPN: Non precipitable nitrogen; EE: Ether extract; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; RBC: Red blood corpuscles; WBC: White blood corpuscles; MCH: Mean corpuscular haemoglobin; MCHC: Mean corpuscular haemoglobin concentration; LY: Lymphocytes; GR: Granulocytes; pg: Picogram; g/dL: Gram per decilitre; μL: Micro litre

energy-dense feedstuffs. The NRC (2007) recommended a TDN intake of around 10-12 g/kg W^{0.75} for maintenance in adult goats. The observed TDN intake/kg W^{0.75} values (11.66 for sole *B. diffusa* and 18.00 g/kg for the mixed diet) indicated that the diets could potentially meet the energy needs of maintenance goats but would need to be supplemented further for higher production levels such as lactation or growth in high-performance goats.

Digestibility of nutrients and mineral balance:

The addition of chickpea straw to *B. diffusa* fodder had no effect (P>0.05) on the digestibility of dry matter (DM), crude protein (CP), ether extract (EE) and neutral detergent fiber (NDF) compared to feeding *B. diffusa* alone. However, the digestibility of acid detergent fiber (ADF), cellulose, hemicellulose, organic matter, and total carbohydrates was significantly reduced (P<0.05) in combined diet fed animals (Table 2). This reduction in digestibility may be due to the higher fibre content in chickpea straw, which likely hampers the digestibility of these nutrients.

Sodium (Na), calcium (Ca) and potassium (K) were observed with positive balance under both the groups of diets. Beegum et al. (2014) and Puranik et al. (2012)

also reported rich content of macro and micro minerals in *B. diffusa*. However, Na, Ca, K and nitrogen balances in the animal body were higher in animals fed with *B. diffusa* in combination with chickpea straw. The K and nitrogen balances showed variation between the groups. The K balance in the *B. diffusa* + chickpea straw group was 6.9 times higher than in the group fed *B. diffusa* alone (Table 2). Sole feeding of *B. diffusa* resulted in a negative nitrogen balance in the animals, a finding consistent with results were reported by Tripathi and Singh (2006) when *Aerua sp.* fed to sheep. The negative nitrogen balance may be due to excess urination by the animals fed solely *B. diffusa*. Chopra et al. (1923) also noted the diuretic properties of *B. diffusa*. However, supplementing *B. diffusa* with chickpea straw improved the nitrogen balance in the animals' bodies. These mineral balances are directly linked to dry matter intake, digestibility, and the mineral content of the feed on a dry matter basis. The addition of 200 g of chickpea straw to *B. diffusa* did not affect the sodium (Na) balance compared to sole feeding of *B. diffusa*.

Rumen fermentation parameters: Rumen fermentation parameters i.e. NH₃- Nitrogen (mg/dl), TCA-N (mg/dl), TVFA (mmol/dl), Total-N (mg/dl), NPN (mg/dl) were found similar between sole *B. diffusa* fed animals and combined diet of *B. diffusa* + chickpea straw fed animals (Table 3). Rumen fluid NH₃-N and TVFA levels of the present study were within the reported range of variations for small ruminants (Tripathi et al., 2007; Chaudhary et al., 2013). The rumen NH₃-N concentration between 15 to 18 mg/dL was reported adequate for optimum rumen fermentation (Satter and Slyter, 1974). The rumen NH₃-N in the present experiment, ranging from 21.94 to 22.4 mg/dL, was greater than adequate to support better rumen fermentation and microbial growth. Addition of chickpea straw with *B. diffusa* did not change rumen fermentation pattern when compared with sole feeding of *B. diffusa*. Chaturvedi et al. (2016) also reported that *B. diffusa* did not affect rumen fermentation pattern adversely and improved propionate during fermentation process.

Haematological parameters: The values of haematological parameters such as haemoglobin (g/dL), haematocrit (g/dL), RBC (x10⁶/μL), WBC (x10³/μL), MCH (pg), MCHC (g/dL) were observed with non-significant difference between the groups. Except haemoglobin (Hb), all other haematological parameters were within the normal range in goats under all treatments. Hb concentration in all the groups was slightly lower than the reference value (8.0-12.0 g/dL) for goats (Radostits et al., 2000). However, Kaneko (1997) reported normal range of Hb from 6 to 12 g dL⁻¹. Almost similar types of haematological observations were reported earlier with green fodder in Indian goats (Durge et al., 2014; Chaudhary

et al., 2013; Sahoo and Walli, 2008). Lymphocytes (%) and Granulocytes (%) were also observed without any significant variation between the groups, however, values of all the haematological parameters had high numerals with sole feeding of *B. diffusa*.

Conclusion

B. diffusa has nutritional potential similar to green fodder, but due to high moisture in green biomass, its feeding alone as green fodder is not able to supply required dry matter for maintenance as well as production purpose in goats. Therefore, it may be used as a quality green fodder with adequate supplementation of legume straw so that dry matter requirement of the goats can be fulfilled. During this study, no adverse effect on goat's health was observed.

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