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Utilization of harvested rainwater for ensuring green-fodder availability in arid Rajasthan

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ABSTRACT

The efficient use and management of natural resources are important factors for success in agricultural farming. An experiment was conducted on round the year fodder production at ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan during 2017–18 to 2019–20 by harvesting rainwater from the rooftop of buildings and irrigating crops using a solar operated water pump though drips and micro-sprinklers for efficient use of harvested water. In the 3 m inter-row spaces of bajra napier hybrid (BNH) variety CO 4, three legumes *Vigna unguiculata* (cowpea), *Clitoria ternatea* (butterfly pea) and *Lablab purpureus* (*sem*) received 40 and 60 kg P/ha, grown as intercrops during the rainy (*kharif*) season and lucerne in succession on residual P during winter (*rabi)* season. Among three *kharif* legumes, significantly higher green (11.19 t/ha) and dry (1.60 t/ha) fodder yields were recorded with cowpea that received 60 kg P/ha. An average 243.97 t/ha green and 37.55 t/ha dry fodder yields was recorded from the system in which share of BNH in green and dry fodder yield was 67.57 and 61.81% respectively. BNH gave 164.85 and 23.21 t/ha green and dry fodder from six cuts, *kharif* legumes contributed 7.43 t/ha in the green fodder and 1.12 t/ha in dry fodder from a single cut and lucerne produced 71.53 t/ha green and 10.32 t/ha dry fodder from the seven cuts in a year. This system has the capacity to meet out the green fodder requirement of 4–5 adult cattle unit (ACU) round the year from the land unit of 0.1 ha.

Keywords: Bajra napier hybrid, Cowpea, Fodder yield, Lucerne, Water productivity

Livestock rearing is the mainstay of the farming in arid western Rajasthan and animal husbandry sector contributed more than 50% in the total economy of the arid districts and about 8% in the state GDP (Anonymous 2016). Mitigating scarcity of dry fodder and managing availability of green fodder round the year is a serious challenge for the livestock policy planners, as majority of the farmers are resource poor and unable to produce and store livestock feed and forages. The total annual availability of feed and fodder for livestock in arid Rajasthan worked out to be 38.46 million tonnes against the requirement of 58.39 million tonnes (Kumawat and Misra 2020) and there is deficit supply of 40.47% for green fodder and 74.34% for concentrate. The area under cultivated fodder is less than 2% of the reported area in the region (Kumawat and Misra 2020). Thus, the huge livestock population is suffered from deficit supply of green fodder which is reflected in reduced milk production and poor health of the livestock. The two natural resources solar radiation (plenty) and rainfall (scarce) of arid regions would be worthy if harvested judicially. Though the rainfall is less than 450 mm annually in the arid parts of the state, harvesting of rainwater into suitable structures and judicious use of the harvested water through pressurized irrigation for cultivation of fodder crops may solve the problem of green fodder. Napier hybrid grass has potential to produce 200 t/ha green fodder in a year and is perennial in nature (Wangchuk *et al.* 2015). The wider spacing of the grass may have permitted to grow it under drip system. To supply fodder round the year there is need to evolve a cropping system that could supply quality fodder to the livestock in all the seasons with minimum requirement of water. Therefore present study was undertaken to test different cropping systems for optimal and sustainable fodder availability and input use efficiency in rainfed ecology.

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MATERIALS AND METHODS

Field experiment: The field experiment was conducted at ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan during 2017–20. The aridity of the atmosphere typically characterizes the region's climate. The long term average annual rainfall and potential evapotranspiration were 379 mm and 2002 mm. The soil of the experimental field was sandy in texture and shallow in depth (50 cm) having 0.28% organic carbon, 116.64 kg/

ha available N, 25.13 kg/ha available P_2O_5, 481.81 kg/ha available K_2O, with *p*H 7.9. Concretions of $CaCO_3$ at an average depth of 50 cm below soil surface are common characteristics of the study region. The experiment was laid out in Randomized Block Design with three replications. The base crop bajra napier hybrid (BNH) was planted at 3 m row spacing and 1 m spacing within the row during rainy (*kharif*) season 2016. Three legumes *Vigna unguiculata* (cowpea), *Clitoria ternatea* (butterfly pea) and *Lablab purpureus* (sem) were grown as intercrops during *kharif* and lucerne during winter (*rabi*) season while in sole BNH plot, no fodder legumes were grown during both the season. The three *kharif* legumes were given 40 and 60 kg P/ha through DAP as per the treatments just before sowing and *rabi* lucerne was grown on the residual P of *kharif* legumes. *Kharif* legumes were sown in July with the onset of monsoon while succeeding *rabi* lucerne was grown in the last week of October. The BNH was irrigated through drip while lucerne through micro-sprinklers. BNH was not irrigated from July–April except control in which irrigation was given through drip on the same day while lucerne was irrigated by micro-sprinklers every week. The Napier hybrid was cut six times from August–June for growth attributes and fodder yield. Similarly *kharif* legumes were harvested in the month of September for fodder yield. The *rabi* lucerne was cut seven times from December–April.

Plant sampling of BNH was taken by cutting two plants from each replication (6 m^2 area) treatment wise. Total number of tillers counted and tallest tiller in each plant was used to measure height, tiller circumference, leaves per tiller and nodes per tiller. Dry weights of plant parts were obtained after drying at 70°C for 72 h, to determine stem dry matter and its distributions. The dry fodder yield was calculated by multiplying the dry matter content of each sample. The sampling from a m^2 quadrat was used for computation of fresh and dry fodder yields from fodder legumes. To test the significance of variation due to treatments, experimental data obtained for various treatment effects were analyzed using SAS software. The data were analyzed separately for three years, i.e. 2017–18, 2018–19 and 2019–20 and individual year's data were subjected for pool analysis to obtain a trend among results over the years.

Proximate analysis and feeding trial: The oven dried fodder samples from each treatment were ground to pass through 1 mm screen and analysed for crude protein (CP), ash content and minerals as per the methods of AOAC (1995). The cell wall constituents were estimated by the methods of Goering and Van Soest (1991). For assessing the effect of green fodder during lean period on small ruminants, a feeding trial was conducted from February–July on growing kids of goat and sheep. The experimental test crop BNH was used for feeding growing kids as green fodder. In the trial 16 kids (male and female) of age group 3–4 months were divided into two equal groups of 8 each forming control (C) and treatment (T). The control group was provided *ad libitum* lentil straw only in addition to suckling, whereas treatment group was provided additional 7 kg fresh chopped BNH (85% OM and 13.34% CP) daily from February to mid-July. The change in body weight was recorded periodically from both the groups.

RESULTS AND DISCUSSION

Growth characteristics of BNH: The effect of legumes introduction on basal tiller circumference, tiller height, tiller number, leaf number per tiller and nodes per tiller were recorded for assessing the effect of intercrops on BNH. The circumference of tiller was recorded non-significant for the individual years but in pooled mean it was recorded significantly higher with sole napier hybrid over intercrop of napier + *Clitoria* or sem grown with 40 kg P/ha. However, these two treatments recorded significantly higher tiller height over control during 2017–18, 2019–20 and in pooled mean. The significant height of tillers with intercrop treatments is attributed to better ambient humid conditions as compared to sole napier hybrid where dry air flows freely in the inter-row spaces. The number of tillers per plant, leaf number and nodes per tiller did not vary significantly with the introduction of *kharif* legumes among all the treatments. The number of tillers per plant were 54.6–62.6, leaves per tiller 12.3–14.8 and nodes per tiller 8.3–9.3 among the treatment on the basis of pooled mean. The non-significant response of *kharif* legume intercropping on plant growth attributes of napier hybrid revealed that these legume plants had neither supplemented nor detrimental effects on the napier hybrid.

Fodder yield and leaf to stem ratio (LSR): The data for green and dry fodder yield are presented in Table 1 and Table 2. Green and dry fodder yields from napier hybrid was not affected significantly in all the six harvestings with intercropping of legumes in both the seasons. The highest green (49.99 t/ha) and dry (7.06 t/ha) fodder yields were recorded from the 1st cut taken in the month of August and decreased gradually up to 3rd cut taken in November. These yields started increasing for the 4th and 5th cuts taken in March and May. The 6th cut that was taken in June recorded almost equal green and dry fodder yields as was recorded in March harvesting, but recorded 65 and 54% higher green and dry fodder yields over 3rd cutting. This showed that this crop can be a good source of green fodder to the livestock in peak summer when green fodder availability is in acute shortage in arid parts of the country. The *kharif* sown legumes recorded on an average 7.43 and 1.12 t/ha green and dry fodder yields from a single harvesting in September. Among three *kharif* legumes, significantly higher green (11.19 t/ha) and dry (1.60 t/ha) fodder yields were recorded with cowpea that received 60 kg P/ha over rest of the legumes and P levels. This is attributed to better compatibility of intercropped cowpea with C_4 tall cereals because of lesser competition for soil moisture (Prasanthi 2012) and better use of cowpea in intercropping through its extensive root system compared to *Clitoria* and *Lablab*. The preceding *kharif* legumes and residual P did not affect the green and dry fodder yields of *rabi* lucerne significantly at all the seven harvestings. The green and dry fodder yields

Table 1 Green fodder yield (t/ha) under napier hybrid based fodder production system (average of three years)

Treatment	Napier							*Kharif* legumes	*Rabi* lucerne								Total green fodder
	1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	Total		1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	7th cut	Total	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Sole Napier	48.93	20.07	12.86	25.46	39.42	25.72	163.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	163.89
Napier + Cowpea 40 kg P/ha-lucerne	50.62	16.78	14.07	25.05	41.34	27.67	166.30	9.39	9.28	11.62	12.81	12.37	10.31	8.72	6.56	71.69	247.38
Napier + *Clitoria* 40 kg P/ha-lucerne	51.41	16.01	12.50	25.95	43.05	27.49	167.24	3.71	8.86	11.00	13.21	12.34	9.84	8.78	6.44	70.47	241.43
Napier + *Lablab* 40 kg P/ha-lucerne	48.60	16.21	13.65	25.27	40.46	24.78	160.71	7.80	9.40	11.20	13.08	12.17	10.53	8.59	6.57	71.53	240.05
Napier + Cowpea 60 kg P/ha-lucerne	50.15	16.75	12.98	27.52	41.68	26.46	166.72	11.19	9.82	11.74	12.78	12.52	10.45	8.80	6.63	72.72	250.63
Napier + *Clitoria* 60 kg P/ha-lucerne	49.36	16.93	14.76	25.37	40.78	25.13	163.95	5.61	10.02	11.65	12.58	12.06	9.99	8.63	6.64	71.56	241.12
Napier + *Lablab* 60 kg P/ha-lucerne	50.86	15.97	13.63	25.79	41.58	25.99	165.15	6.87	9.46	11.22	12.89	12.01	10.17	8.77	6.70	71.21	243.23
Average	49.99	16.96	13.49	25.77	41.19	26.18	164.85	7.43	9.47	11.41	12.89	12.25	10.22	8.72	6.59	71.53	243.97
SEm±	2.16	0.97	0.91	1.22	2.85	1.17	3.56	0.37	0.31	0.43	0.47	0.38	0.35	0.32	0.32	0.92	3.59
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	1.07	NS	NS	NS	NS	NS	NS	NS	NS	10.29

Table 2 Dry fodder yield (t/ha) under napier hybrid based fodder production system (average of three years)

Treatment	Napier							*Kharif* legumes	*Rabi* lucerne								Total green fodder
	1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	Total		1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	7th cut	Total	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Sole Napier	6.90	3.77	2.10	4.34	6.27	4.06	23.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.08
Napier + Cowpea 40 kg P/ha-lucerne	7.11	3.11	2.27	4.25	6.57	4.38	23.40	1.36	1.52	1.66	1.67	1.49	1.48	1.39	1.12	10.32	37.91
Napier + *Clitoria* 40 kg P/ha-lucerne	7.26	2.95	2.00	4.43	6.83	4.38	23.42	0.62	1.44	1.57	1.76	1.49	1.40	1.40	1.10	10.15	37.15
Napier + *Lablab* 40 kg P/ha-lucerne	6.89	3.00	2.28	4.30	6.42	3.90	22.56	1.18	1.53	1.60	1.73	1.48	1.52	1.37	1.12	10.35	37.03
Napier + Cowpea 60 kg P/ha-lucerne	7.02	3.10	2.09	4.69	6.60	4.19	23.35	1.60	1.59	1.68	1.68	1.52	1.50	1.40	1.13	10.50	38.39
Napier + *Clitoria* 60 kg P/ha-lucerne	7.02	3.14	2.52	4.32	6.46	3.94	23.27	0.92	1.63	1.67	1.65	1.45	1.42	1.37	1.13	10.33	37.34
Napier + *Lablab* 60 kg P/ha-lucerne	7.24	2.96	2.28	4.38	6.62	4.08	23.26	1.02	1.54	1.60	1.69	1.43	1.45	1.40	1.14	10.25	37.47
Average	7.06	3.15	2.22	4.39	6.54	4.13	23.21	1.12	1.54	1.63	1.7	1.48	1.46	1.39	1.12	10.32	37.55
SEm±	0.30	0.18	0.17	0.21	0.43	0.19	0.52	0.08	0.05	0.07	0.06	0.05	0.05	0.05	0.05	0.13	0.58
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	0.23	NS	NS	NS	NS	NS	NS	NS	NS	1.66

from lucerne increased gradually from 1st cut (December) to 3rd cut (mid-February) when average temperature remained less than 20°C. The yields from lucerne started decreasing consistently with gradual rise in temperature and reached to lowest in 7th cut taken at the end of April. An average 243.97 t/ha green and 37.55 t/ha dry fodder yields was recorded from the system in which share of napier hybrid in green and dry fodder yield was 67.57 and 61.81% respectively. Napier hybrid gave 164.85 and 23.21 t/ha green and dry fodder from six cuts, *kharif* legumes contributed 7.43 t/ha in the green fodder and 1.12 t/ha in dry fodder from a single cut and lucerne produced 71.53 t/ha green and 10.32 t/ha dry fodder from the seven cuts in a year. The findings of the study agree with the results of Alalade *et al.* (2013) in guinea grass-stylosanthes mixture and Anita *et al.* (2015) for napier hybrid-cowpea mixture.

The green and dry fodder yield of *kharif* legumes did not vary with the application of 40 and 60 kg P/ha). Similarly, the residual effect of phosphorus on green and dry yields from lucerne was found non-significant. However, among *kharif* legumes cowpea recorded 10.29 and 1.48 t/ha of green and dry fodder yield which was 121 and 92% higher than the yields recorded with *Clitoria*. The non-significant effect of P on the fodder yields may be due to higher availability of inherent soil P to the plants because of climate regulating functions such as maintenance of higher ambient humidity and hence higher soil moisture in the legumes rhizosphere due to bajra napier hybrid. Daniel and Harper (1995) reported that higher effective rainfall is associated with low calcium content and high phosphorus content of alfalfa hay compared to low effective rainfall. The leaf fraction determines the pasture quality and performance of animal is related to the amount of leaf in the diet (Tudsri *et al.* 2002). In the study proportion of leaf and LSR of napier hybrid was recorded for first two cuts only. The proportion of leaf and LSR not affected significantly with the intercrop legumes for all the years under study. The proportion of leaf increased almost two times from 1st cut (44.13%) in August to 2nd cut (77.385%) in October and LSR recorded four times increase (0.80 to 3.54%) indicating more leafiness with successive harvesting stages and hence increased palatability of fodder to animals. The lower leaf proportion and LSR during 1st cut might be due to faster growth and more height of the crop during rainy season. Halim *et al.* (2013) reported that negative relationship between height of the plants and LSR and opined that dwarfism is associated with higher number of tillers, leaf area index and percentage of leaf in napier grass.

Proximate composition of fodder crops and their effect on growing kids of goat: In general, BNH grown as sole and in combinations with different legumes received varying levels of P recorded statistically at par values of crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ash, silica (Si), calcium (Ca) and phosphorus (P). Earlier research work conducted elsewhere also reported non-significant effect of legumes on the nutritional quality of cereal fodder. Further, nutritional composition of a plant species is governed by its genetic makeup and would not be affected significantly with agronomic manipulations. Amongst *kharif* sown legumes, significantly higher CP was recorded with *Clitoria* (23.13%) than cowpea (18.71%) and *Lablab* (17.32%). The ADF was recorded at par with all the three legumes. The significantly lower NDF of 62.20% was recorded with *Clitoria* than cowpea (68.23%) and *Lablab* (66.95%). Total ash content ranged from 10.90% for *Clitoria* to 16.80% for *Lablab*. Among different mineral elements Ca and P considered important from the animal nutrition point of view and significantly higher content of Ca was recorded with cowpea (2.45%) which was 30% more than the content found with *Clitoria* and *Lablab*. The content of P ranged from 0.33% for cowpea to 0.41% for *Lablab*. The proximate composition of lucerne sown in succession after three *kharif* legumes with residual P have non-significant values of CP, ADF, Si, Ca and P for the preceding crops as well as residual P in the experiment. The significant values of NDF with higher P level recorded in the study. The application of phosphorus fertilizer decreased neutral detergent fiber (NDF) content and there were no notable effects on acid detergent fiber (ADF) (Dasci *et al.* 2010). The chemical compositions and cell wall constituents of green fodders were in the range reported earlier by other workers (Datt *et al.* 2009 and Garg *et al.* 2012). There was no difference in the initial body weight (BW) among the two dietary treatment groups. However, the animals fed with the BNH diet resulted in higher final BW than the control group (Fig 1). The difference in body weight gain was more during May with treatment group and remained higher during the last two months of the study. The CP and NDF contents of napier grass in this study were similar to the values reported by Rahman *et al.* (2015). It is believed that the feeding of BNH provided better growth response due to the higher DM digestibility and CP content of Napier grass compared to control group. This premise was supported by Rahman *et al.* (2015) who also reported increased body weight with goats fed with BNH plus oil palm frond (OPF).

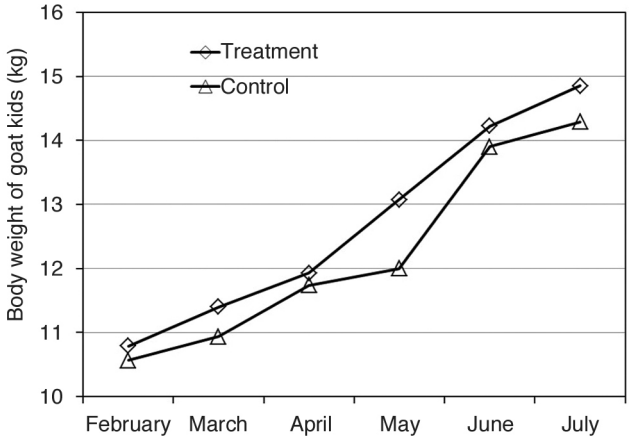

Fig 1 Feeding effect of napier hybrid on goat kids (body weight).

The genetic potential of elite arid zone livestock is not realized due to deficit supply of feed and fodder. The exploration of high biomass producing fodder crops are the need of time. Bajra napier hybrid (BNH) can be remunerative

green fodder choice for supplying green during most part of the year because of its perennial nature and high yield potential. Under the study yield of BNH not affected with the intercrop legumes grown during rainy and winter season for enriching the fodder value of this cereal fodder. Among rainfed fodder legumes, cowpea found better in terms of yield over *Clitoria* and *Lablab* and produced 11.19 t/ha green fodder. The *rabi* sown lucerne produced 71.53 t/ha green fodder. Further, green fodder yield from BNH during peak summer (June) was 65 and 54% higher than the cutting taken during November. This showed that crop is a good source of green fodder to the livestock in peak summer when green fodder availability is in acute shortage in arid parts of the country. The combination of BNH + cowpea (60 kg P/ha)-lucerne produced highest green fodder yield of 250.63 t/ha. Hence, it is recommended to follow BNH + cowpea (60 kg P/ha)-lucerne cropping system for sustaining 5 adult cattle unit from a land unit of 0.1 ha.

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