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Efficiency of Acidulated Low Grade Udaipur Rock Phosphate with Sulphuric Acid and Phosphoric Acid

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Abstract: The present investigation was conducted for evaluating partially acidulated low grade Udaipur rock phosphate with 10, 20, 30 and 40%, sulphuric acid, phosphoric acid and their mixture in equal proportions. In incubation studies, superphosphate, untreated rock phosphate and different types of partially acidulated rock phosphate @ 200 mg kg^{-1} of soils were added and incubated for 15, 30, 45 and 60 days. Total phosphorus content in partially acidulated rock phosphate decreased successively with increasing levels of sulphuric acid. However, a reverse trend was recorded on acidulation with phosphoric acid. Water-soluble phosphorus, citrate soluble phosphorus and available phosphorus increased with the increasing levels of the acids namely H_2SO_4, H_3PO_4 and their mixture in equal proportions. However, citrate-insoluble phosphorus fraction decreased with increasing levels of all the acidulents. Available phosphorus (Olsen's P) in incubated soils and relative efficiency of partially acidulated rock phosphate (PARP) increased significantly, with the maximum value under 40% in partially acidulated with phosphoric acid treatment. The relationships between different P constituents of partially acidulated rock phosphate with available (Olsen's) phosphorus (except citrate-insoluble) in the soils at different periods of incubation showed positive significant correlation.

Key words: Partially acidulated rock phosphate, relative efficiency, sulphuric acid, phosphoric acid.

A fraction of the indigenous reserves of the rock phosphate meets the specification of the fertilizer industry, because of their low P content (low grade) and low reactivity (Narayanasamy and Biswas, 1998). Partial acidulation is one of the methods used to increase P availability of non-reactive phosphate rocks, especially for use in neutral to slightly alkaline soils. In the partial acidulation, phosphate rocks are treated only with a portion of acid i.e., actually required for complete conversion of phosphate into superphosphate or triple superphosphate. The present investigation was conducted for evaluation of partially acidulated low-grade Udaipur rock phosphate with sulphuric acid, phosphoric acid and their mixture by determining available (Olsen's) phosphorus in the soil with different time intervals. The relative efficiency (RE) of different treatments was investigated. Changes in different types of P constituents in different types of partially acidulated rock phosphates were also studied.

Materials and Methods

A low grade Udaipur rock phosphate from RSMML, Udaipur, was used in the study. The chemical composition of the material was as follows: total phosphorus:

18.6%, water-soluble phosphorus: traces, citrate soluble phosphorus: 8.75% (per cent total P_2O_5), citrate-insoluble phosphorus: 9.75%, available phosphorus: 8.85% (per cent total P_2O_5), calcium oxide (CaO): 46.50%, magnesium oxide (MgO): 4.2%, zinc (Zn): 125 ppm, copper (Cu): 110 ppm, silica oxide (SiO_2): 7.49%, fluoride- 2.00%, size: 100 mesh. Bulk soil samples (0-15 cm) were collected from Jung Ki Badi (University Farm), Udaipur, having 48.10% sand, 24.75% silt, 26.85% clay, pH 7.91, EC 0.32 dS m^{-1}, organic carbon 8.5 g kg^{-1}, available nitrogen 275 kg ha^{-1}, available P_2O_5 9.50 kg ha^{-1} and available K_2O 235 kg ha^{-1}

Finely ground (100 mesh), Udaipur rock phosphate was partially acidulated with 10.2, 20.4, 30.6 and 40.8 mL of 98% H_2SO_4 in each portion of 100 g rock phosphate to obtain 10, 20, 30 and 40% acidulation, respectively. The concentrated acid was diluted to approximately 150 mL by adding distilled water to mix the entire rock phosphate to a consistency of paste, and diluted acid was added rapidly with constant stirring to ensure contact with the entire material (Ashby *et al.*, 1966). The ingredients were mixed thoroughly for 10 minutes. The acidulated products were cured for 1 day. After curing, the products were dried in an oven at 70°C and pulverized in a porcelain mortar to pass through 100-mesh sieve. The rock phosphate was also acidulated with H_3PO_4 and their mixture in equal proportion in the similar way. Different forms of phosphorus in PARP were extracted out according to AOAC (1995).

A laboratory incubation study was carried out with 200 g air-dried soil taken in 500 g capacity polyethylene bags (10 x 15 cm) and kept in upright position. The treatments included [T_1:- soil (control), T_2: soil + 200 mg P as SSP kg^{-1} soil, T_3: soil + 200 mg P kg^{-1} soil through unacidulated rock phosphate, T_4: soil + 200 mg P kg^{-1} soil through PARP with 10% H_2SO_4, T_5: soil + 200 mg P kg^{-1} soil through PARP with 20% H_2SO_4, T_6: soil + 200 mg P kg^{-1} soil through PARP with 30% H_2SO_4, T_7- soil + 200 mg P kg^{-1} soil through PARP with 40% H_2SO_4, T_8: soil + 200 mg P kg^{-1} soil through PARP with 10% H_3PO_4, T_9: soil + 200 mg P kg^{-1} soil through PARP with 20% H_3PO_4, T_{10}: soil + 200 mg P kg^{-1} soil through PARP with 30% H_3PO_4, T_{11}: soil + 200 mg P kg^{-1} soil through PARP with 40% H_3PO_4, T_{12}: soil + 200 mg P kg^{-1} soil through PARP with 10% H_2SO_4 and H_3PO_4 in equal proportion, T_{13}: soil + 200 mg P kg^{-1} soil through PARP with 20% H_2SO_4 and H_3PO_4 in equal proportion, T_{14}: soil + 200 mg P kg^{-1} soil through PARP with 30% H_2SO_4 and H_3PO_4 in equal proportion, and T_{15}: soil + 200 mg P kg^{-1} soil through PARP with 40% H_2SO_4 and H_3PO_4 in equal proportion. In each treatment P was calculated on the basis of total phosphate, allocated randomly with three replications. Moisture in the bags was maintained at field capacity and incubated at room temperature for 15, 30, 45 and 60 days. Soil samples were scooped out of each treatment in duplicate at 15 day interval and analyzed for available P (Olsen *et al.*, 1954), and relative efficiency of PARP was calculated as given below (Basak and De, 1997):

$$RE = \frac{\text{Treatment P} - \text{Control P}}{\text{Super phosphate P} - \text{Control P}} \times 100$$

A separate pot experiment with wheat crop (cv. Lok 1) was conducted with all the treatments (in triplicate) and relative efficiency of rock phosphate was calculated at crop harvest.

Results and Discussion

Total phosphorus (TP)

Total phosphorus content in PARP decreased successively with increasing levels of sulphuric acid as compared with raw rock phosphate (Table 1). The possibility of occurrence of several reactions exists and it is also known that a large number of them lead to production of several gasses, which normally escape from the matrix, thereby causing a reduction in mass through the treatment of RP with H_2SO_4, as reported by Biswas and Narayanasamy (1995). Partial acidulation with phosphoric acid alone and mixture of sulphuric and phosphoric acids increases the total amount of P (19.98 to 24.36%) compared to raw rock phosphate (18.60%) due to the addition of P through the H_3PO_4. The results of the present investigation are in line with the findings of Marwaha *et al.* (1983), Biswas and Narayanasamy (1995) and Basak and De (1996).

Water-soluble phosphorus (WSP)

Water-soluble fraction increased successively with increasing degree of acidulation. The H_3PO_4-acidulated rock phosphate showed significantly higher

Table 1. Effect of partial acidulation on different forms of phosphorus (%)

Treatment	Total phosphorus (TP)	Water-soluble phosphorus (WSP)	Citrate-soluble phosphorus (CSP)	Citrate-insoluble phosphorus (CISP)	Available phosphorus (AP)
Unacidulated rock phosphate	18.60	0.10	8.74	9.75	8.84
10% partially acidulated with H_2SO_4	18.32	0.21	9.10	8.75	9.38
20% partially acidulated with H_2SO_4	18.12	0.30	9.70	7.88	10.00
30% partially acidulated with H_2SO_4	17.93	0.40	10.14	7.30	10.54
40% partially acidulated with H_2SO_4	17.84	0.52	10.40	6.81	10.92
10% partially acidulated with H_3PO_4	21.20	2.26	10.05	8.86	12.32
20% partially acidulated with H_3PO_4	22.68	2.27	12.24	8.18	14.49
30% partially acidulated with H_3PO_4	23.80	2.97	13.12	7.69	16.07
40% partially acidulated with H_3PO_4	24.36	3.61	13.72	7.01	17.34
10% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	19.98	1.41	9.80	8.76	11.21
20% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	20.91	2.50	10.31	8.08	12.82
30% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	21.34	3.07	10.75	7.50	13.83
40% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	21.54	3.60	11.01	6.91	14.62
SEm±	0.51	0.04	0.23	0.17	0.25
CD ($P = 0.05$)	1.501	0.130	0.688	0.522	0.729

Table 2. Available phosphorus (Olsen's P) content of soils in incubation studies (P_2O_5 kg ha^{-1})

Treatments		Period of incubation (days)			
		15	30	45	60
T_1	Absolute control	9.90	12.34	13.80	14.97
T_2	Single superphosphate	14.99	18.74	23.50	24.00
T_3	Unacidulated rock phosphate	10.60	13.52	14.29	16.44
T_4	10% partially acidulated with H_2SO_4	11.65	15.62	17.49	18.29
T_5	20% partially acidulated with H_2SO_4	13.78	20.36	19.24	20.69
T_6	30% partially acidulated with H_2SO_4	15.38	24.20	23.44	25.15
T_7	40% partially acidulated with H_2SO_4	16.97	30.64	31.49	32.14
T_8	10% partially acidulated with H_3PO_4	12.73	20.95	21.22	22.50
T_9	20% partially acidulated with H_3PO_4	15.90	27.60	28.90	31.75
T_{10}	30% partially acidulated with H_3PO_4	17.99	32.79	33.44	35.00
T_{11}	40% partially acidulated with H_3PO_4	20.15	39.34	41.49	45.49
T_{12}	10% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	11.99	19.95	20.99	22.50
T_{13}	20% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	14.86	26.18	28.24	30.12
T_{14}	30% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	15.90	28.71	30.32	32.62
T_{15}	40% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	18.00	33.51	34.95	35.65
	SEm±	0.32	0.54	0.55	0.68
	CD (P = 0.05)	0.941	1.561	1.608	1.972

amount of water-soluble P than H_2SO_4. Partial acidulation with H_2SO_4 may lead to irreversible agglomeration of the fertilizer granule by the cementing action of the calcium sulphate formed and thereby reducing the water-soluble P (Table 1).

Citrate-soluble phosphorus (CSP)

All the acidulents increased the citrate-soluble P content of the PARP (Table 1). In partially acidulated RP with H_3PO_4, CSP fraction increased significantly over H_2SO_4-treated RP because a significant portion of P in the PARP was derived from H_3PO_4 itself.

Citrate-insoluble phosphorus (CISP)

Citrate-insoluble P fraction in the acidulated PR decreased with the increasing levels of all acidulents. The partial acidulation with sulphuric acid/phosphoric acid converts part of the insoluble phosphate (tricalcium phosphate) into soluble phosphates (monocalcium and dicalcium phosphates) resulting in a fall of this fraction.

Available phosphorus (AP)

The water-soluble phosphorus (WSP) and citrate-soluble phosphorus (CSP) represents the available phosphorus content of PARP. The available phosphorus content

Table 3. Relative efficiency of partially acidulated rock phosphate (%)

Treatments		Period of incubation (days)				At harvest of crop
		15	30	45	60	
T_1	Single superphosphate	100.00	100.00	100.00	100.00	100.00
T_2	Unacidulated rock phosphate	13.31	12.32	6.47	15.83	14.29
T_3	10% partially acidulated with H_2SO_4	33.81	35.02	37.99	36.76	35.20
T_4	20% partially acidulated with H_2SO_4	76.05	85.53	56.24	64.03	78.17
T_5	30% partially acidulated with H_2SO_4	108.15	126.53	99.97	113.95	110.38
T_6	40% partially acidulated with H_2SO_4	141.54	194.48	184.32	191.01	142.37
T_7	10% partially acidulated with H_3PO_4	55.33	91.57	77.13	83.29	57.18
T_8	20% partially acidulated with H_3PO_4	118.66	162.63	158.07	186.13	121.14
T_9	30% partially acidulated with H_3PO_4	161.50	217.46	205.90	223.43	163.04
T_{10}	40% partially acidulated with H_3PO_4	203.51	287.16	289.29	334.62	206.90
T_{11}	10% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	40.44	80.87	73.72	84.30	39.91
T_{12}	20% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	98.79	147.44	149.64	168.62	97.27
T_{13}	30% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	120.84	174.02	172.85	196.08	121.21
T_{14}	40% partially acidulated with H_2SO_4 and H_3PO_4 in equal proportion	162.14	225.00	220.66	229.59	163.38
	SEm±	10.17	5.00	10.62	11.63	5.59
	CD (p = 0.05)	29.462	14.492	30.769	33.704	16.217

was increased with partial acidulation of RP because of the conversion of tricalcium phosphate (TCP) into dicalcium phosphate (DCP) and monocalcium phosphate (MCP) through acidulation (Table 1). Similar results were also reported by Biswas and Narayanasamy (1995) and Basak and De (1996).

Available phosphorus in the soils

Throughout the period of incubation (up to 60 days), phosphate-treated soil samples maintained a high level of P status over control as well as unacidulated rock phosphate (Table 2). Each degree of partially acidulated rock phosphate significantly increased the available (Olsen's) P status of soils over control as well as unacidulated rock phosphate at all incubation periods. PARP with H_2SO_4 at the level of 10% (T_4) and 20% (T_5) did not increase the available P status of soils to any significant level as compared to SSP (T_2) throughout the periods of incubation, but 20% PARP with H_2SO_4 (T_5) exhibited its superiority at 30 days of incubation. Except these treatments, all the treatments significantly increased P status of soils throughout the incubation periods except T_3 and T_2 at 15 and 45 days of incubation. Results of the present investigation are in agreement with the findings of Biswas and Narayanasamy (1995), Rajkhowa and Baroova (1996) and Prakash *et al.* (1997).

prostrate annual herbs like *Indigofera*

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to a different feeding system or on account of varieties of pasture species in different locations. A particular breed of sheep thrives best in the locality in which it has been reared. The species suitable for one breed, therefore, may not be suitable for others (Lander, 1949).

Preference ranking of various pasture species reported from India is mostly based on *ad lib* stall feeding and it shows a spectrum of relative palatability, which varies as per plant and animal species (Dabadghao and Marwaha, 1962; Chakravarty *et al*., 1970; Rai, 1990; Rai *et al*., 1980; Rai and Patil, 1983). The need, therefore, was felt to gather information on grazing preferences of animals during *in situ* grazing of a vegetation mix and also *inter alia* to interpolate this information for grazing tolerance ranking and designing of a suitable pasture for single or mix herd. In a series of experiments, cattle grazing preference was first reported by Singh and Shankar (1994). This paper reports findings on sheep grazing preferences for pasture species under *in situ* grazing condition of a protein bank cafeteria comprising 18 grasses and 18 legumes grown in 45x10 m alternate strips.

Materials and Methods

The grass-legume cafeteria was established in 1991 at the Central Research Farm of IGFRI, Jhansi, with 45 x 10 m alternate stands of 18 perennial grasses and 18 herbaceous/shrubby legumes. The grasses were: *Bothriochloa intermedia* (R. Br.) A. camus, *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf., *B. decumbens* Stapf., *Cenchrus ciliaris* L., *C. setigerus* Vahl, *Cenchrus* Hybrid (*C. ciliaris* x *C. setigerus*), *Chloris gayana* Kunth. ex Stapf., *Chrysopogon fulvus* (Spr.) Chiov., *Cynodon dactylon* (L.) Pers. (2 Bermuda grass strains), *Dichanthium annulatum* (Forssk.) Stapf., *Heteropogon contortus* (L.) P. Beauv., *Panicum antidotale* Retz., *P. maximum* Jacq., *Pennisetum pedicellatum* Trin (perennial), *P. polystachyon* (L.) Schult., *Pennisetum* Trispecific Hybrid [(*Pennisetum americanum* x *P. purpureum*) x *P. squamulatum*] and *Setaria sphacelata* (Schumach.) Stapf., and the legumes: *Arachis glabrata* Benth., *A. hagenbeckii* O. Kuntze., *Atylosia scarabaeoides* (L.) Benth., *Cajanus cajan* (L.) Millsp., (perennial), *Clitoria ternatea* L., *Desmanthus virgatus* (L.) Willd., *Indigofera suffruticosa* Mill., *Lablab purpureus* (L.) Sweet (cv. JLP-3, JLP-4), *Macrotyloma uniflorum* (Lamk.) Verdc., *Macroptilium atropurpureum* (DC.) Urb., *M. lathyroides* (L.) Urb., *Mimosa invisa* Mart., *Rhynchosia minima* (L.) DC; *Stylosanthes guianensis* (Aubl.) Sw., *S. hamata* (L.) Taub., *S. scabra* Vog., along with a stand of *Leucaena leucocephala* (Lamk.) de Wit with understorey of the Caribbean stylo (*S. hamata*). A 45 x 10 m strip of a medicinal plant having forage value, i.e., *Boerhavia diffusa* L., was also included in the cafeteria.

A total of 12 sheep of Muzaffarnagri breed were grazed @ 1.5 ACU ha^{-1} from August 1993 to February 1994. The sheep were allowed to move about freely for 8 h to graze/browse any of the species.

Results

Time spent

The total grazing time spent was minimum in the monsoon (Fig. 1). Later on, with diminishing forage availability, the time spent for grazing gradually increased. During monsoon and post-

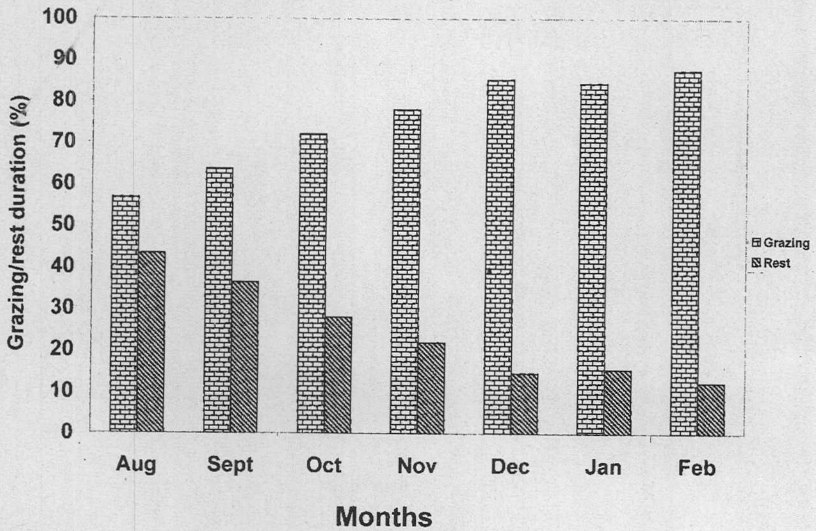

Fig. 1. Sheep grazing/rest duration.

monsoon period sheep spent more time grazing legume. Consumption of grasses increased in late winter (December - January) and in spring (February). About 15% of the grazing time across seasons was devoted to grazing of annual weeds (Fig. 2).

Forage choice

Monsoon: At the start of grazing, sheep devoted 22.9% of the total grazing time to the Carribean stylo *(S. hamata*), followed by *S. scabra* > *R. minima* > *M. atropurpureum* (Table 1). Other legumes like *Macrotyloma uniflorum, Arachis glabrata, A. hagenbeckii, Mimosa invisa, Atylosia scarabaeoides* were either grazed little or disliked. Among the grasses *Cynodon dactylon* (Bermuda-1) showed highest preference with 7.11% of total grazing time. Grasses like *C. dactylon*-Bermuda-2, *Heteropogon contortus* and *Pennisetum pedicellatum* were also eaten. Fourteen grasses were less preferred. *Brachiaria brizantha, Panicum antidotale* and *Pennisetum* Trispecific Hybrid were the least consumed grasses. The annual weeds preferred by sheep were: *Celosia argentea, Digera muricata, Ipomoea pestigridis* and *Tridax procumbens*. The perennial climber *Rivea hypocrateriformis* was liked by sheep. Annual grasses viz., *Eragrostis* spp., *Setaria glauca, Sporobolus diander* that came up in the pigeonpea stand were also preferred.

Post-monsoon: Carribean stylo continued to be the highly preferred legume as sheep devoted maximum grazing time in its stand, followed by *S. scabra, M. atropurpureum* and *R. minima*. In the later phase sheep also showed preference for *A. hagenbeckii*. Sheep showed a low preference for grasses. The grasses most liked were: *C. dactylon* - Bermuda-2, which

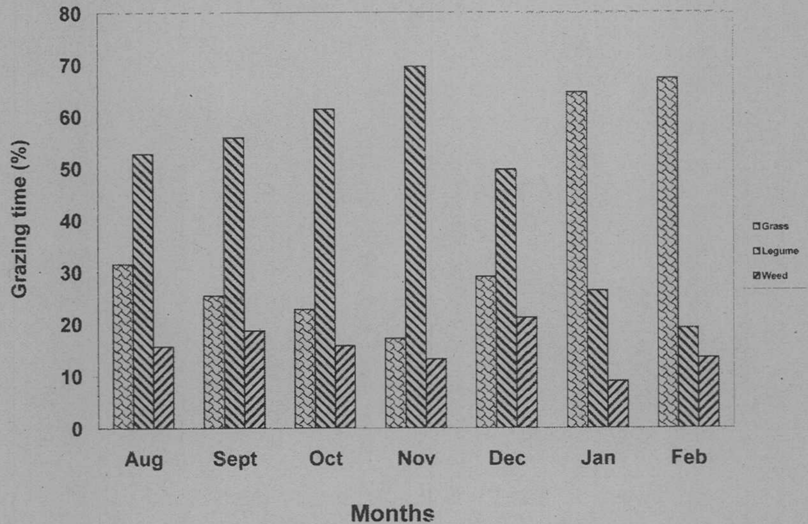

Fig. 2. Sheep grazing time allocation.

scored over Bermuda-1, although it had more biomass and leafiness. *P. pedicellatum* was next to it in preference ranking. Some grasses viz., *Chrysopogon fulvus* and *Bothriochloa intermedia* were not grazed by sheep. Among weeds, *Sida acuta, S. cordata, Ipomoea pes-tigiridis* were preferred.

Winter: Sheep devoted maximum time to legumes in early winter, but later on shifted to grasses due to diminishing biomass of legumes. *S. hamata* and *S. scabra* continued to be grazed avidly. The preference for subabul (*L. leucocephala*) and forage groundnut (*A. hagenbeckii*) ranked next to stylos with 3.7% of total grazing time devoted to each. Among grasses *C. dactylon* - Bermuda 1 and 2, *C. ciliaris, C. setigerus* and *Brachiaria decumbens*, were highly preferred. The next in order were: *Pcnicum maximum, Cenchrus* Hybrid, *P. pedicellatum* and *P. antidotale, Dichanthium annulatum, Pennisetum polystachyon*. Other grasses were least consumed. Among weeds *Waltheria indica, Sida cordata, Boreria hispida, Tephrosia purpurea, Vicoa indica*, etc., were preferred over other weeds.

Spring: Sheep devoted about 67% of the total grazing time to grasses and 18.6% time to legumes, probably due to low availability of leguminous forage. Extensively consumed legumes were: *S. hamata, S. scabra, A. hagenbeckii, L. leucocephala, M. atropurpureum, R. minima* and *Desmanthus virgatus*. The preferred grasses were: *Panicum maximum, Cenchrus* Hybrid, *Pennisetum* Trispecific Hybrid, *C. setigerus, Panicum antidotale* and *C. dactylon* cv. Bermuda-2. The other grasses, viz., *C. ciliaris, C. dactylon* cv. Bermuda 1, *Brachiaria decumbens, Bothriochloa intermedia, P. pedicellatum, Chrysopogon fulvus, Chloris gayana* and *Setaria sphacelata* were least preferred. The perennial weeds viz., *Cocculus hirsutus,*

Table 1. Per cent grazing time spent by sheep in stands of various pasture species

Monsoon		Post-monsoon		Winter		Spring	
Species	% Time	Species	% Time	Species	% Time	Species	% Time
Grasses	29.3	**Grasses**	20.0	**Grasses**	47.0	**Grasses**	67.1
C. dactylon-1	7.1	*C. dactylon*-2	7.7	*C. dactylon*-2	4.8	*P. maximum*	6.8
C. dactylon-2	3.9	*C. dactylon*-1	4.5	*C. dactylon*-1	4.8	*C. hybrid*	6.5
H. contortus	3.5	*P. pedicellatum*	1.4	*C. ciliaris*	4.7	P. Trihybrid	6.3
P. pedicellatum	2.3	Other grasses	6.4	C. setigerus	4.5	*C. setigerus*	6.0
Other grasses	12.5			*B. decumbens*	4.4	*P. antidotale*	5.6
				Other grasses	23.8	*C. dactylon*-2	5.0
						C. ciliaris	4.5
						Other grasses	26.4
Legumes	54.3	**Legumes**	65.0	**Legumes**	38.2	**Legumes**	18.6
S. hamata	23.0	*S. hamata*	31.5	*S. hamata*	14.4	*S. hamata*	5.8
S. scabra	9.0	*S. scabra*	10.5	*S. scabra*	6.4	*S. scabra*	5.2
R. minima	4.4	M. atropurpureum	4.2	*L. leucocephala*	3.7	*A. hagenbeckii*	2.4
M. atropurpureum	3.6	*R. minima*	3.8	*A. hagenbeckii*	3.7	Other legumes	5.2
Other legumes	14.3	Other legumes	15.0	Other legumes	10.0		
Weeds	16.4	**Weeds**	5.0	**Weeds**	14.8	**Weeds**	14.3

Sida cordata and *Tephrosia purpurea* were preferred over other weeds.

Discussion

The tendency of sheep preferring legumes over grasses was amply clear. The sheep diet, therefore, contained a greater proportion of legumes. This trend was noticed by Bedell (1968) who reported that sheep preferred clover to grass. Curll *et al.* (1985) also reported apparent selection of clover in preference to perennial rye grass over a wide range of sward clover content. The sheep is reported to prefer protein-rich diet (Shankar and Singh, 1996). The Carribean stylo (*S. hamata*) was the most preferred species, particularly during lambing. The Bikaneri sheep is also reported (Rai and Patil, 1993) to show high preference for the stylos, viz., *S. humilis*, followed by *S. hamata* in a relative acceptability trial on *Stylosanthes* species. In another study of relative palatability of pasture legumes (Rai, 1990), Mandya sheep showed high preference for *S. humilis*, followed by Caribbean stylo during monsoon.

The Bermuda and Dinanath are reported to be the most preferred grasses by cattle (Singh and Shankar, 1994). In general sheep devoted greater time to *Cenchrus setigerus* compared to *C. ciliaris* and *Cenchrus* hybrid. The birdwood grass (*C. setigerus*) is reported (Chakravarty *et al.,* 1970) to be highly preferred by sheep compared to *C. ciliaris* and *Lasiurus sindicus* in the arid zone of Rajasthan. The grass *Chrysopogon fulvus* was the least preferred. In a relative palatability trial Dabadghao and Marwaha (1962) and Debroy and Dabadghao (1969) observed that *C. fulvus* was the least preferred grass by cattle and sheep. Among the two *Brachiaria* species, *B. decumbens* was preferred compared to *B. brizantha.*

Conclusions

The sheep showed strong seasonality in their grazing preference for a particular species. By and large, the sheep showed higher preference for legumes over grasses which were eaten only when the legume biomass was exhausted. This study corroborates the fact that sheep prefer diets rich in protein and hence a great liking for legumes over grasses. All the legumes are not preferred in equal measure as sheep show maximum and minimum preferences among the legumes. For example, stylos in general show very high preference ranking compared to very low preference for other species, which they graze at a late stage when stylos are finished. Among the grasses too this tendency is reflected clearly as the sheep showed maximum preference for Bermuda grass. Findings of this study will help in finalizing the list of preferred species in each season for future grazing trials with sheep and also for selection of species for large sheep pastures.

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