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Herbage production and soil fertility changes in different pastures as influenced by fertilization under semi-arid conditions

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ABSTRACT

A field study was conducted between 2001 and 2004 on six different pasture systems [natural pasture, buffel grass (*Cenchrus ciliaris* L.), stylo (*Stylosanthes hamata* L.), buffel + stylo + shrub (*Leucaena leucocephala* L.), buffel + stylo + shrub + tree (*Albizia lebbeck* L.]. The performance under fertilized and unfertilized situations in relation to amount of rainfall received was analysed over the years. A total of 19 species were encountered in natural pasture which included 6 grasses, 5 legumes and 8 forbs. Significantly the highest pasture production (9.90 t/ha) was recorded in buffel + stylo + shrub-based mixed pasture. Over all, there was about 21.8% increase in yield due to fertilizer application. The fodder shrub *Leucaena* contributed about 16% to the total biomass. The physico-chemical properties of soil improved under different pastures after 4 years in increasing water-holding capacity, pore space, and decreasing bulk density particularly under fertilized situation. The build up of organic carbon content was higher under sole *Stylosanthes*. The soil dehydrogenase and phosphatase enzymatic activity were enhanced in both fertilized and unfertilized pastures. Dehydrogenase activity was the highest in fertilized pure legume. Supplementation of legume and top feeds viz,. *Leucaena* and *Albizia* in *Cenchrus ciliaris* based fodder improved the quality in crude protein, ether extract, calcium and phosphorus contents with reduction in neutral detergent fibre and acid detergent fibre contents.

Key words : Chemical composition, Fertility, Herbage Crops, Dehydrogenase

Livestock forms an integral part of livelihood of small and marginal farmers. Inadequate availability of quality feed is a major factor of low livestock productivity in arid and semi-arid conditions. Feed scarcity during drought years is a common feature of these regions and ensuring continuous supply of forage for the animals throughout the year is an important strategy to mitigate the impact of drought. For semi-arid rainfed areas of Bundelkhand region, Buffel grass (*Cenchrus ciliaris* L.) was found to be the ideal species. Besides, it also sequesters organic carbon in the soil, which is very important function of the grass in resources sustainability and productivity. Introduction of legumes in native/cultivated pastures was found to improve the forage quality and sustenance of soil productivity (Pahwa, 1998). Introduction of shrubs and trees in grazing land containing grass-legume mixture ensures round the year availability of quality forage to the livestock. Nitrogen is one of the major nutrients/limiting factors in production of pasture from tropical soils. Response of forage mixtures to application of N was estimated in earlier studies (Tripathi and Garg, 2003) and was found to vary with climatic situation and the species composition of admixtures. The present situation warrants making a serious thinking on maintaining the productivity and enhancing quality of forage production for longer duration in an year even during the periods of drought. The present study was therefore planned to study the impact of grass-legume-woody perennial combinations on forage productivity with related soil fertility changes and soil enzymatic activity in relation to fertilization in semi-arid conditions.

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MATERIALS AND METHODS

The field experiment was conducted for consecutive 4 years (2001-2004) at Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (25^0 27' N latitude, 78^0 37' E longitude; 275 m above mean sea level). The 12 treatments formed by combination of 6 pasture systems viz., natural pasture - T_1, sown pasture of sole grass of *Cenchrus ciliaris* 'IGFRI 3108'-T_2, sown pasture of sole legume *Stylosanthes hamata* 'Verano'- T_3, sown pasture of grass + legume $-T_4$, sown pasture of grass + legume + shrub *Leucaena leucocephala* 'K-8'- T_5, sown pasture of grass + legume + shrub + tree *Albizia lebbeck* 'Local' $-T_6$ and 2 fertilizer treatments *(i)* application of the recommended dose of fertilizer – F_+ and *(ii)* no fertilizer application- F_0. The experiment was conducted in factorial RBD with a plot size of 40 m × 45 m in 4 replications. These treatment combinations were laid out in an area of 5 ha. The grasses were established at 1 m distance (row-to-row) and 50 cm from plant to plant in sole grass treatment. In sole legume pasture, the seed of *Stylosanthes* was broadcast sown. In grass + legume treatment, *Stylosanthes* was introduced between 2 rows of *Cenchrus ciliaris*. In treatment T_5, *Leucaena leucocephala* seedlings were planted in pits at a spacing of 6 m × 8 m; similarly in treatment T_6 both shrub and tree (*Albizia lebbeck*) component were introduced. The grasses were cut twice, legume was cut once at harvest, and shrub (from second year onwards) and tree (during last year only) were lopped once at harvest. The cut-wise yield data of grass was taken and the yield of all cuts was pooled to workout total biomass yield. The experimental soil was clay loam in texture having pH, EC (dS/m), organic carbon (%), water-holding capacity (%), porosity (%) and bulk density (g /cm^3) of 7.1, 0.43, 0.49, 19.0, 33.8 and 1.65 respectively. The soil has an available N, P and K of 160, 9.8 and 188 kg/ha respectively. Fertilizer was applied @ 40 - 8.3 - 33.3 kg N-P-K/ha to grass and 20 -17.5 - 33.3 kg N-P-K/ha to legume respectively. The source of N, P and K was urea, single superphosphate and muriate of potash, respectively. Soil samples collected at initial and after 4 years were analysed for physico-chemical parameters. The soil samples were collected at 60 DAS synchronizing with maximum enzymatic activity for estimation of dehydrogenase (Castida *et al.*, 1964) and phosphatase activities (Eivazi and Tabatabai, 1977). Chemical composition of pasture was analyzed following standard methods.

The study area has a dry tropical climate with mean annual precipitation of 900 mm, of which 70% is received during the south-west monsoon that gets initiated during June and July. In 2001, adequate amount of rainfall desirable for grass, legume, shrub and tree establishment was received during June. A total of 1,175 mm was received in about 51 rainy days during the year. On contrary, the onset of monsoon was delayed during 2002. A meagre rainfall of 21.6 mm and 41.6 mm was received during June and July respectively. However, a fairly better rainfall of (316 mm) was received in 14 rainy days during August, which helped sustaining the pasture production after the initial set back. In contrast, excess rainfall (1,194 mm) than normal was received during 2003. The 2004, witnessed lowest rainfall (484 mm) in 31 rainy days, which was 46% less than the normal rainfall. The mean maximum air temperature ranged between 22.3 and 40.7 °C and the minimum temperature ranged between 5.4 and 26.8 °C over the years during study period.

RESULTS AND DISCUSSION

Natural grassland

A total of 19 species were encountered in natural pasture which included 6 grasses viz., *Heteropogon contortus* (L.) P.Beauv., *Dichanthium annulatum* (Forsk.) Stapf, *Setaria glauca* (L.) Beauv., *Eremopogon foveolatus* (Del.) Stapf, *Aristida purpurea* Nutt., and *Digitaria adscendens* (Kunth.) Henrara: 5 legumes viz., *Tephrosia villosa* (L.) Pers., *Tephrosia tenuis* Wall, *Heylandia latebrosa* auct., *Crotalaria juncea* (L.), and *Rhynchosia minima* (L.) DC, and 8 forbs viz., *Borreria stricta* (L.f.) K. Schum, *Borreria hispida* (L.) Schum, *Trichodesma amplexicaule* Roth., *Celosia argentea* (L.), *Cyperus triceps* Endl., *Cyperus rotundus* (L.), *Convolvulus arvensis* (L.) and *Evolvulus alsinoides* (L.). The partitioning of biomass distribution (Fig 1) revealed 65% biomass contributed by *Heteropogon contortus* followed by forbs (17%), legumes (12%) and *Dichanthium annulatum* (10%).

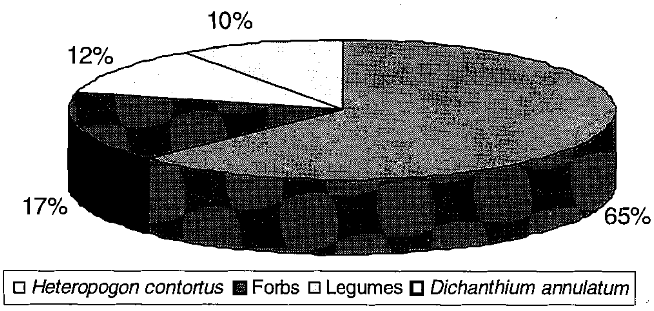

Fig. 1. Species composition of native pastures in semi-arid condition at Jhansi

Performance of shrub and tree

There was significant increase in the growth of shrub (*L. leucocephala*) and tree (*A. lebbeck*) over the years. The shrub attained faster growth when compared with tree. The mean of 4 years growth of shrub and tree indicated faster growth of *Leucaena* than *A. lebbek*. The mean shrub height (3.25 m), collar diameter (2.86 cm), and secondary branches (19.14) were significantly higher compared to corresponding values of tree (2.56 m, 2.33 cm and 13.49) respectively (Fig 2).

Pasture production

The perusal of data (Table 1) on dry pasture yield indicated a significant improvement in established pasture

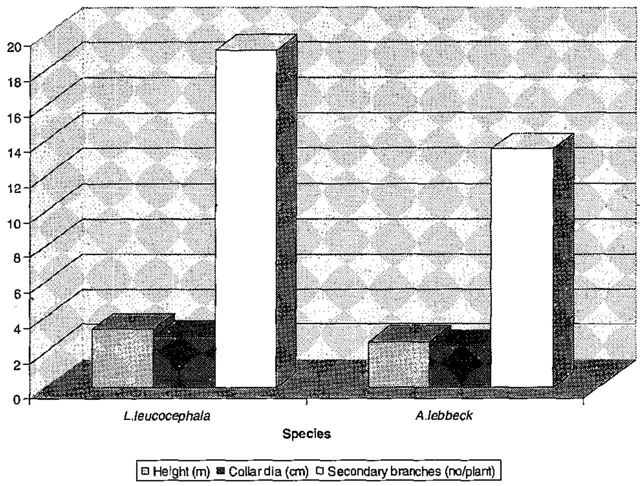

Fig. 2. Performance of introduced shrub and tree in mixed pastures at Jhansi (Mean of four years)

when compared with natural pasture. The productivity of different pastures varied in relation to amount of rainfall received and climatic condition. During the first year, significantly the highest pasture yield was recorded in sown pasture of *C. ciliaris* both under fertilized (6.83 t/ha) and unfertilized (5.87 t/ha) conditions. This was closely followed by *C. ciliaris* + *Stylosanthes* (5.96 t/ha) and *C. ciliaris* + *Stylosanthes* + *Leucaena* + *A. lebbeck* (5.95 t/ha). The lowest pasture yield was recorded in natural pasture (3.30 t/ha). Over all there was about 23% increase in dry forage yield due to fertilizer application. The forage yield recorded in T_4, T_5 and T_6 were statistically at par in fertilized plots. The interaction effect between different type of pastures and fertilization was not significant. During 2002, significant differences were observed in each of the treatments. The interaction effect between different kind of pastures and fertilization was also found significant. The dry pasture production was influenced initially due to aberrant weather and delayed onset of monsoon. However, the growth picked up with good amount of rainfall received during August. Among the treatments receiving fertilizer, there was significant increase in pasture yield (7.09 t/ha) in grass +legume + shrub followed by sole grass and grass +legume + shrub + tree registering 6.70 and 6.31 t/ha respectively. The fodder shrubs contributed 1.29 and 1.31 t dry matter/ha (leaves + tender stems) in T_5 and T_6 respectively. On an average, there was about 18% increase in yield due to fertilizer application. The higher yields in these treatments could be attributed to significantly higher plant vigour of grass, legume and shrub components over other treatments. The year 2003 was favourable in total rainfall received. Significant differences were observed in each of the treatments. The interaction effect between different types of pastures and fertilization was also found to be significant. There was a

Table 1. Dry pasture production (t/ha) as influenced by different pasture combinations and fertilization

Year	Pasture system												
	Natural pasture (T_1)		Sole grass (T_2)		Sole legume (T_3)		Grass + legume (T_4)		Grass + legume + shrub (T_5)		Grass + legume + shrub + tree (T_6)		Mean
	F0	F+	F0	F+	F0	F+	F0	F+	F0	F+	F0	F+	
2001	3.20	3.40	5.87	6.83	3.36	5.50	5.29 (3.7 + 1.59)	6.64 (4.7 + 1.94)	4.18 (2.9 + 1.3)	6.30 (4.5+1.8)	5.43 (3.93+1.5)	6.47 (4.8+1.7)	5.21
2002	2.92	3.20	6.10	6.70	3.52	5.88	4.40 (3.3 + 1.1)	5.90 (4.2 + 1.7)	5.01 (2.92 + 0.8 + 1.3)	7.09 (4.3+ 1.5+ 1.29)	5.11 (3.1+0.7+1.31)	6.31 (3.8+1.2+1.31)	5.18
2003	3.16	3.39	7.49	8.50	6.63	7.48	7.60 (6.2 + 1.4)	8.70 (7.0 + 1.6)	8.63 (6.1 + 1.1 + 1.37)	9.90 (7.1+1.4+ 1.37)	8.38 (6.0+1.13+ 1.27)	9.74 (7.0+1.5+1.27)	7.47
2004	2.62	3.24	6.16	7.12	4.93	5.87	6.34 (5.4 + 0.9)	7.43 (6.2 + 1.2)	6.80 (5.2 + 0.8 + 0.76)	8.34 (6.0+1.6+ 0.76)	6.67 (5.0+0.7+0.3+0.62)	8.29 (6.1+1.2+0.3+0.62)	6.15
Mean	2.98	3.31	6.41	7.29	4.61	6.18	5.91	7.17	6.16	7.91	6.40	7.7	

	Pasture		Fertilizer		Interaction	
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
2001	0.280	0.550	0.150	0.320	0.260	NS
2002	0.180	0.351	0.253	0.496	0.252	0.759
2003	0.109	0.213	0.063	0.123	0.154	0.464
2004	0.138	0.413	0.078	0.239	0.198	0.597

F0: Without fertilizer, F+: - with fertilizer yield increase of 26 to 31% among different treatment combinations when compared with previous year due to higher amount of rainfall received during the year. The highest pasture yield (9.90 t/ha) was recorded in grass +legume + shrub (T_5) followed by grass + legume + shrub + tree (T_6) and grass + legume (T_4) registering 9.74 and 8.70 t/ha respectively. The fodder shrub contributed 1.37 and 1.27 t dry matter/ha (leaves +tender stems) in T_5 and T_6 respectively. Introduction of shrubs and trees in grazing land containing grass-legume mixture ensure round the year availability of quality forage to the livestock especially the role of top feeds during low rainfall years was found to be noteworthy. In general, the dry pasture production recorded was more with treatments receiving fertilizer over no fertilizer treatments. There was 14% increase in yield due to fertilizer application over all treatments compared to no fertilizer application.

The pasture production in 2004 followed a similar trend as obtained in 2003. Mixed pasture involving shrubs contributed the highest pasture yield (8.34 t/ha). However, the pasture yield was reduced to the extent of 22% over mean pasture yield owing to less amount of rainfall received during 2004. Based on mean data of 4 years, the dry forage yield was 21.8% higher under fertilized condition over no fertilizer. The herbage productivity in mixed pastures of *C. ciliaris* + *Stylosanthes* + *Leucaena* was maximum under fertilized condition and 2 to 2.65 times more when compared with natural pasture under fertilized condition (2.98 t/ha). Tripathi and Garg (2003) observed response of fertilizer application in both sole as well as intercrops. Tripathi *et al.* (2002) reported increase in biomass yield with the introduction of legume intercrop in rainfed pasture grasses under arid environment. The productivity improvement of mixed pastures in the presence of legumes may be because of nitrogen-fixation by legume as the grasses are usually N-deficient.

Chemical composition of pasture

Pure *Stylosanthes* was found to contain higher crude protein, ether extract, calcium and phosphorus and lower neutral detergent fibre, acid detergent fibre when compared with other pasture based diets (Table 2). The quality of *C. ciliaris* in its chemical composition was superior to natural pasture. Supplementation of legume and top feeds viz., *Leucaena* and *Albizia* in *C. ciliaris* based fodder improved the crude protein, ether extract, calcium and phosphorus contents with reduction in neutral detergent fibre and acid detergent fibre contents. Pailan *et al.* (2002) reported that incorporation of different levels of legumes like *S. hamata* or shrubs and tree leaves in *C. ciliaris* based diets improved the nutrient content of diets and their utilization in sheep.

Soil fertility changes

As compared to initial fertility and soil physical characteristics of the soil (Table 3), the soil under different pastures after 4 years improved in increasing water holding capacity, pore space, and decreasing bulk density particularly under fertilized condition. However, such improvement was highest under pure legume pasture of *Stylosanthes*. Organic carbon content was influenced by different pasture systems over the years. All the sown pastures showed higher organic carbon (OC) build up than the natural pasture. The build up of OC content was higher under pure *Stylosanthes* and grass +legume + shrub + tree treatment in general and under fertilization in particular. Mean data of 4 years indicated organic carbon, available N, P and K increased by 19.3, 15.6, 53.3 and 36.5% respectively due to fertilizer application over no fertilizer in sole pasture of *Stylosanthes*. The increase in water-holding capacity, pore space, organic carbon, available N, P and S was improved to the extent of 5.2-34.7, 11.9-24.8, 10.2-35.7, 9.6-34.6, 4-88.7 and 8-14.5%, re-

Table 2. Chemical composition of different pasture based diets (% DM basis)

Attributes	Natural pasture	Pure grass	Pure legume	Grass (G) + legume (L)	G + L + shrub (S)	G + L + S+ tree
Organic matter	95.1 ± 1.60	95.6 ± 1.70	96.0 ± 1.80	95.8 ± 2.70	95.9 ± 2.00	95.8 ± 2.70
Crude protein	3.66 ± 1.40	7.31 ± 0.05	18.9 ± 1.20	12.4 ± 0.65	15.5 ± 0.71	15.2 ± 0.85
NDF	71.7 ± 1.10	71.0 ± 1.40	67.4 ± 0.45	69.6 ± 0.90	68.6 ± 0.55	65.6 ± 1.15
ADF	50.1 ± 1.70	46.8 ± 0.15	40.3 ± 2.90	45.7 ± 0.75	42.2 ± 2.10	43.2 ± 1.35
Crude fibre	38.7 ± 1.30	35.3 ± 0.50	28.1 ± 1.90	32.9 ± 0.40	29.5 ± 1.50	30.0 ± 0.75
Ether extract	2.10 ± 0.32	2.03 ± 0.26	2.40 ± 0.22	2.25 ± 0.15	2.38 ± 0.05	2.32 ± 0.17
NFE	50.6 ± 1.35	50.9 ± 0.65	46.5 ± 3.20	48.4 ± 1.50	48.6 ± 2.80	42.3 ± 1.70
Calcium	0.58 ± 0.02	0.60 ± 0.01	1.58 ± 0.02	1.10 ± 0.04	1.02 ± 0.01	1.16 ± 0.02
Phosphorus	0.10 ± 0.02	0.10 ± 0.02	0.28 ± 0.01	0.18 ± 0.01	0.21 ± 0.01	0.19 ± 0.005

NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre; NFE: Nitrogen Free Extract

Table 3. Soil fertility changes after 4 years of cropping and fertilization under various pastures

Treatment		pH	EC (dS/m)	OC (%)	WHC (%)	Pore space (%)	BD (Mg/m³)	Available nutrients (kg/ha)			
								N	P	K	S
Natural pasture	F0	7.0	0.45	0.51	19.7	35.0	1.61	151	8.5	156	8.0
	F+	6.9	0.50	0.54	20.0	37.4	1.58	176	10.2	172	9.5
Grass (G)	F0	7.0	0.50	0.54	20.2	38.0	1.55	183	10.2	121	7.8
	F+	7.0	0.54	0.57	22.6	39.5	1.50	216	13.5	156	9.2
Legume (L)	F0	7.2	0.53	0.57	21.0	39.0	1.50	201	12.2	143	7.0
	F+	7.3	0.60	0.66	25.2	42.2	1.42	217	18.5	168	8.6
Grass + legume	F0	6.9	0.50	0.54	20.8	39.5	1.52	191	10.3	148	7.3
	F+	7.2	0.56	0.57	24.5	40.6	1.47	202	17.7	159	8.9
G + L + Shrub	F0	6.8	0.49	0.55	20.5	39.2	1.52	192	11.0	145	7.6
	F+	7.0	0.56	0.59	23.2	41.0	1.48	209	17.0	157	9.0
G + L +	F0	6.8	0.48	0.56	20.8	39.7	1.53	196	11.9	154	7.5
shrub + tree	F+	7.1	0.57	0.63	23.6	41.5	1.47	212	16.8	168	9.0
Initial (2000-01)		7.1	0.43	0.49	19.0	33.8	1.65	160	9.8	188	8.3
SEm±		0.05	0.01	0.01	0.57	0.64	0.02	4.5	0.96	4.9	0.24
CD(P=0.05)		NS	0.03	0.03	1.11	1.25	0.03	9.7	1.88	9.7	0.47

F0 – Without fertilizer , F+ – With fertilizer

spectively. The decrease in bulk density was to the tune of 4 to 14% under fertilized pastures over initial level of soil fertility. The unfertilized natural pasture depleted more available N and P. Similarly, there was a drastic reduction in available K (36 to 38%) under no fertilized condition where maximum reduction in K was found in soil under legume pasture. This might be due to continuous removal of nutrients by the plants in absence of fertilizer. The available S content was also lowered in unfertilized pastures by 4 to 16% from the initial (8.3 kg/ha S) and the highest was found in legume pasture followed by grass + legume pasture. The grass + legume + shrub pasture and grass + legume + shrub + tree pasture was more or less similar in available S both under fertilized and non-fertilized situations. Thomas *et al.* (1996) reported that the N-fixation by forage legumes plays significant role in determining the N status of the grass + legume based pasture systems. This may be the reason for enhanced nitrogen status of the soil under these systems. The soil pH after experimentation did not vary significantly from the initial (pH 7.1). The soluble salts (EC) increased under different sown pastures and the highest was recorded in pure *Stylosanthes* with fertilizer application.

Soil enzyme activity

Dehydrogenase, a measure of microbial activity in the soil, was enhanced in the rhizospheric and bulk soil due to introduction of *C. ciliaris* and *Stylosanthes*. The microbial activities were lowest with the natural pasture. Dehydrogenase activity was the highest in fertilized pure legume (5.21 p kat) closely followed by *C. ciliaris* + *Stylosanthes* mixture (4.64 p kat). Similarly, the phosphatase activity under both acid and alkali condition was higher in all the sown pastures when compared with natural pasture both under fertilized and unfertilized conditions. The activity was the highest in fertilized stylo pasture followed by *C. ciliaris* + *Stylosanthes* + *Leucaena*+ *Albizia* based mixed pasture (Fig 3). As soil enzymes are mainly microbial in origin, the differences between pastures may be due to the pattern of root exudation which influences different groups of micro-organisms and causes temporal diversity. Higher enzymatic activity in the legume may be due to increase in below-ground inputs of C and N under legumes which often increase microbial populations, their activity and subsequent enzyme synthesis. Significant effect of grass-legume intercropping on soil characteristics and pasture productivity may be due to lower C: N ratio in their crop residue (Rao *et al.*, 1995).

It can be concluded that the fertilized sown pastures of improved grass, legume and shrub involving *C. ciliaris* + *S. hamata* + *L. leucocephala* was superior in herbage productivity and fertilized sown pasture of *S. hamata* was most efficient in improving soil fertility and soil enzymatic activity. Incorporation of different levels of *S. hamata, Leucaena* and *Albizia* improved the quality of pasture based diets.

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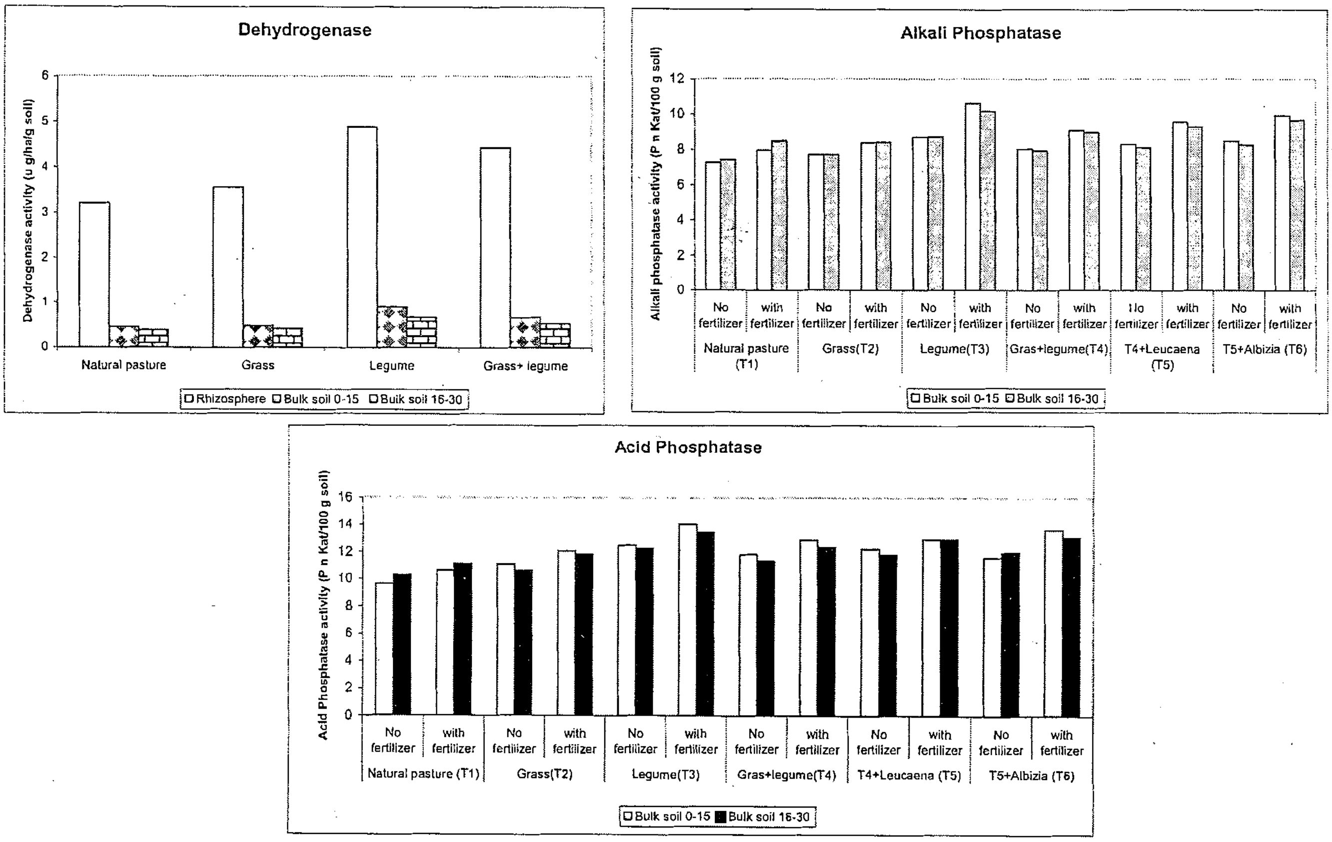

Fig. 3. Soil enzyme activity under pasture based systems at Jhansi

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