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Effect of different sources of phosphate on the fodder productivity, phosphate budgeting and economics of Lucerne (*Medicago sativa*) cultivation in hot arid ecosystem of Rajasthan

K. C. Sharma
Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner - 334006 Rajasthan, India
Present address: Indian Agricultural Research Institute, Regional Station, Old Sehore Road, Indore, 452 001 (MP), India
Corresponding author email: kc_64sharma@yahoo.com
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Abstract
Field experiment was conducted during *rabi* season of 2006-07 and 2007-08 at Bikaner to find out the effect of integrated use of phosphate through inorganic, organic and biofertilizer sources on the fodder productivity, phosphate balance and economics of lucerne (*Medicago sativa* L) cultivation. Results indicated that phosphate application through inorganic source significantly increased the growth attributes and fodder yields upto the level of 26.4 kg P/ha and recorded green fodder 51.8 t/ha and dry matter 11.44 t/ha. Thereafter, improvements were not significant. Maximum crude protein yield of 2.18 t/ha was observed at highest dose of P (39.6 kg/ha). However, it was statistically at par with 26.4 kg P/ha. Highest value of net returns (Rs. 45940/ha) and B: C ratio (2.45) was observed with 26.4 kg P/ha. Agronomic phosphate use efficiency (APUE) and Physiological phosphate use efficiency (PPUE) decreased with each increase in P levels up to 39.6 kg P/ha. Seed inoculation with *Pseudomonas striata* and application of sheep manure @ 10 t/ha registered significantly higher fodder yield and yield attributes as well as economic benefits. However, APUE by Phosphate solubilizing bacteria (PSB) and APUE and PPUE by sheep manure were decreased as compared to their respective control. P application at higher dose of 39.6 kg/ha and sheep manure application resulted positive P balance, while P applications at 26.4 and 39.6 kg/ha, PSB inoculation and sheep manure application registered higher values of net change in available P content of soil as residual soil fertility. The results show that 26.4 kg P/ha alongwith PSB inoculation and sheep manure application @ 10 t/ha were useful for getting higher and quality fodder yield of lucerne along with improved soil fertility.

Key words: Alfalfa, Economics, Fodder, Lucerne, Phosphate, Phosphate solubilizing bacteria, *Pseudomonas striata*, Sheep manure, Soil fertility

Abbreviations: APUE- Agronomic phosphate use efficiency, **CP-** Crude protein, **IGNP-** Indira Gandhi Nahar Project, **P-** Phosphate, **PPUE-** Physiological phosphate use efficiency, **PSB** – Phosphate solubilizing bacteria.

Introduction

Lucerne (*Medicago sativa* L.) is an important fodder crop of winter season and grown almost in every state of India. Farmers of hot arid zone holding lands under IGNP command area or having irrigation facilities through tubewells have started cultivation of Lucerne as green fodder for livestock. The productivity of Lucerne in this region is very low due to multiple factors and imbalanced plant nutrition is one of the important reasons. Moreover, the soils of arid zone are categorized as low in available nutrients. Being a leguminous crop, Lucerne puts heavy demand of phosphate on soil. Phosphate application solely through chemical fertilizers is not only costly but also most of the time in short supply particularly at the time of sowing. It is also a fact that allocation of chemical fertilizers for fodder crops is very low. Therefore, there is utmost need to seek alternate sources of phosphate application in Lucerne. Phosphorus solubilizing bacteria (PSB) are important micro-organisms to change unavailable form of applied as well as native phosphate into available form (Tilak and Singh, 1994). As organic source, sheep manure is rich in phosphate as compared to other farm yard manures and abundantly available in the region. Integrated use of chemical fertilizer, biofertilizer and organic manure improves the soil physico-chemical and biological properties leading to improvement in crop yield. Since information on integrated use of organic, inorganic and biofertilizers for Lucerne in hot arid zone is lacking, present investigation was undertaken.

Materials and Methods

A field experiment was conducted during *rabi* seasons of 2006-07 and 2007-08 at Research Farm, Central Sheep and Wool Research Institute, Arid Region Campus Bikaner. The soil was sandy (sand 86.2%, silt 6.6% and clay 7.2%) with a pH value of 8.43, low in organic carbon (0.23%), available nitrogen (141.2 kg/ha), phosphate (8.23 kg P/ha) and medium in available potassium (141.8 kg K/ha). Treatments consisted of four levels of phosphate *viz.,* 0, 13.2, 26.4 and 39.6 kg P/ha, two levels of biofertilizers *viz.,* uninoculated (control) and seed inoculation with *Pseudomonas striata* culture and two levels of sheep manure *viz*., 0 and 10 t/ha. The experiment was laid out in randomized block design with 3 replications. Lucerne variety 'T-9' was sown at 25 cm row spacing using 15 kg seed/ha. The experiment was continued for 2 years in the same field and during *kharif* season field was fallow in both the years. The crop was sown on 5th and 2nd November in first and second years, respectively. A basal dose of nitrogen (20 kg/ha) through urea and potash (40 kg K_2O/ha) through muriate of potash was applied to each plot at the time of sowing. Sheep manure (containing 0.89, 0.34 and 0.94% of NPK) and phosphate through single super phosphate were applied as per treatment. *Pseudomonas striata* culture obtained from IARI, New Delhi was used to treat seed with standard procedure. The crop was raised under irrigated condition and recommended agro-techniques were followed. Irrigation was applied at 15-20 days interval as per need of the crop. The first cut was taken after 60 days of sowing and subsequent cuts at the interval of 30-35 days. Total 5 cuts were taken each year. Soil samples were drawn 0-30 cm depth from each plot in beginning and at termination of the experiment and analysed for pH, EC, organic carbon N, P and K as per standard procedures. Shoot height of 5 plants and shoot number per running meter from three lines from each plot were recorded at all 5 cut stages. Green fodder yield were recorded at harvest and plant samples were collected from each plot for dry matter and determination of N, P and K contents. Nutrient uptake was estimated by multiplying the dry matter yield and content of nutrient in Lucerne fodder.

The agronomic phosphate use efficiency was calculated by using following expression-

$$APUE = \frac{Y_t - Y_c}{P_a}$$

Where, APUE is the agronomic phosphate use efficiency in kg dm/kg P applied, Y_t is the dry matter yield (t/ha) in P applied plot, Y_c is the dry matter yield in control plot and $_{Pa}$ is the P applied in kg/ha.

Whereas, the physiological phosphate use efficiency was calculated by using following expression-

$$PPUE = \frac{Y_t - Y_c}{P_{ut} - P_{uc}}$$

Where, PPUE is the physiological phosphate use efficiency in kg dm/kg P applied, Y_t is the dry matter yield (t/ha) in P applied plot, Y_c is the dry matter yield in control plot and P_{ut} is the P uptake (kg/ha) in treated plot and P_{uc} is the P uptake (kg/ha) in control plot.

Economics was calculated on the basis of prevailing market prices of different inputs and output.

Results and Discussion

Growth attributes and fodder yield: Pooled analysis of two years data on growth parameters *viz.,* shoot height and number of shoot per meter running row of Lucerne at different cuts showed that all the experimental variables brought about marked improvement in growth attributes (Table 1) except PSB inoculation, where improvements in growth attributes were non significant. Among treatment variables, phosphate application @ 26.4 and 36.9 kg P/ha being at par maintained significantly higher shoot height and numbers than lower level of phosphate *viz*., 13.2 kg P/ha and control, except at fifth cut stage, where differences were non-significant for both the parameters. Increased growth attributes due to phosphate application might be due to better root development, improved energy translocation and metabolic process by which translocation of photosynthate towards plant development might have occurred. Patel and Rajagopal (2003) have also reported increased growth parameters of berseem upto the level of 39.6 kg P/ha. Application of sheep manure recorded significantly greater shoot height and number than control at all 5 cut stages. It might be due to increased supply of major and micronutrients and increase in the activities of heterotrophic bacteria and fungi in soil which in-turn increased the activity of enzymes responsible for conversion of unavailable form of nutrients to available form leading to higher nutrient uptake and improvement in crop growth attributes.

Table 1. Shoot height and number of shoots per running meter rows as influenced by treatment variables (pooled data of 2 years)

Treatment	Shoot height (cm.)					Number of shoots per running meter				
	Ist cut	IInd cut	IIIrd cut	IVth cut	Vth cut	Ist cut	IInd cut	IIIrd cut	IVth cut	Vth cut
(A) Phosphate levels (kg/ha)										
0	37.3	48.6	45.0	52.3	33.0	99.2	119.1	123.6	112.4	82.8
13.2	40.5	54.3	54.2	54.7	34.3	109.2	124.1	134.1	123.1	86.3
26.4	45.7	58.4	57.5	55.9	35.1	112.6	128.3	138.7	127.8	86.4
39.6	47.7	58.7	57.1	56.6	35.4	114.5	129.0	140.1	127.4	86.2
SEm±	1.12	1.34	1.05	0.98	1.30	2.64	2.77	2.92	2.09	2.17
CD (P = 0.05)	3.23	3.87	3.03	2.84	NS	7.64	7.99	8.44	6.04	NS
(B) Biofertilizer inoculation										
B_0	42.1	53.7	53.1	54.8	34.2	107.7	124.4	133.8	122.4	85.4
B_1	43.5	56.3	53.8	54.9	34.7	110.0	125.8	134.4	122.9	85.5
SEm±	0.79	0.95	0.74	0.69	0.92	1.87	1.96	2.06	1.48	1.53
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
(C) Sheep manure (t/ha)										
0	39.8	49.0	48.9	52.0	30.8	101.8	114.5	127.0	116.9	81.5
10	45.8	61.0	58.0	57.7	38.1	115.9	135.8	141.3	128.5	89.4
SEm±	0.79	0.95	0.74	0.69	0.92	1.87	1.96	2.06	1.48	1.53
CD (P = 0.05)	2.28	2.74	2.14	2.01	2.66	5.40	5.65	5.96	4.27	4.43

B_0 – Uninoculated and B_1- Inoculated with *PSB*

P application significantly increased the green fodder and dry matter yield upto the level of 26.4 kg/ha over lower level *viz.,* 13.2 kg/ha and control (Table 2); and thereafter increase in fodder yield was not significant. Highest green fodder and dry matter yield recorded at 39.6 kg P/ha were higher by 42.2 (15.5 t/ha) and 50.0 (3.86 t/ha) per cent, 14.5 (6.4 t/ha) and 16.8 (1.67 t/ha) per cent, and 0.77 (0.40 t/ha) and 1.22 (0.14 t/ha) per cent respectively, over 0, 13.2 and 26.4 kg P/ha. Increase in shoot height and number due to phosphate application led to a significant increase in green fodder and dry matter yields. Malik *et al*. (2004); Patel and Kotecha (2006) also reported significantly higher green fodder yields of lucerne due to phosphate application upto 35.2 and 33.0 kg P/ha, respectively. Seed inoculation with *Pseudomonas striata* (PSB) also recorded significantly higher green fodder and dry matter yields to the tune of 4.6 and 5.15 per cent, respectively over control. Increase in biomass yield due to PSB inoculation may be attributed to increases in the P availability and improved growth attributes which led to higher crop yield. Detroja *et al.* (1997b) also reported that *P. striata* did not bring out significant improvement in plant growth attributes of groundnut but pod and haulms yields were significantly influenced. Sheep manure application significantly increased the green fodder and dry matter yields over no sheep manure (control). The magnitude of increase in green fodder and dry matter yields was to the tune of 20.6 and 22.6 per cent, respectively over control. The reason for variation in fodder yields might be due to beneficial effect of sheep manure on growth attributes by creation of better soil environment and release of plant nutrients to the crop. Reddy *et al*. (2006) also reported higher fodder yield of lucerne with FYM application upto the level of 20 t FYM/ha.

Interaction effect of phosphate and sheep manure on green and dry fodder yields was found significant (Table 3). Increase in P level significantly increased the green fodder and dry matter yields at same levels with or without sheep manure only upto 26.4 kg P/ha. Green fodder and dry matter yields recorded at 26.4 or 39.6 kg P/ha alongwith sheep manure were almost similar but significantly higher over all the other interactions. 26.4 kg P/ha alongwith sheep manure gave 12.0 and 12.9 per cent higher green fodder and dry matter yields, respectively over 39.6 kg P/ha alone. It was also noted that green fodder and dry matter yields obtained with 13.2 kg P/ha alongwith sheep manure were significantly greater than 0 to 39.6 kg P/ha application without sheep manure.

Crude protein yield: Crude protein (CP) yield was significantly influenced by all the experimental variables (Table 2). Among treatments, phosphate application @ 39.6 kg P/ha recorded maximum CP yields (2.18 t/ha) and it showed statistical parity with 26.4 kg P/ha but

significantly higher over lower level *viz*., 13.2 kg P/ha and control. The magnitude of increase at highest dose of P was to the tune of 56.8, 19.1 and 1.39 per cent over 0, 13.2 and 26.4 kg P/ha, respectively. The increase in CP yield was mainly because of variation in dry matter yield and slight improvement in N content of fodder due to P application. Seed inoculation with PSB significantly increased the CP yield to the extent of 4.89% over un-inoculated (control). Sharma and Agrawal (2003) also reported higher CP yield due to *P. striata* inoculation in *Egyptian clover*. Application of sheep manure gave significantly higher CP yields to the tune of 25.7 per cent over control. Reddy *et al*. (2006) also reported significant increase in CP content of Lucerne due to FYM application. The interaction effect of P levels and sheep manure on CP yield was also found significant and CP yields recorded at 26.4 or 39.6 kg P/ha along with sheep manure were statistically at par but significantly greater than all other interactions.

Nutrient uptake: Although any of the treatment variables did not bring out significant change in N, P and K contents of fodder but uptakes were significantly influenced by different treatments (Table 2). Application of phosphate significantly increased the N, P and K uptakes upto the level of 26.4 kg P/ha. The increase in nutrients uptakes at highest dose of phosphorus *viz*., 39.6 kg/ha were 57.1, 18.9, 1.42 per cent in N, 64.4, 23.4 and 1.68 per cent in P and 56.6, 17.9 and 1.75 per cent in K respectively, over 0, 13.2 and 26.4 kg P/ha. Seed inoculation with PSB also significantly increased the N, P and K uptakes to the extent of 4.95, 8.33 and 5.23 per cent, respectively over control. Mehta *et al.* (1995) and Detroja *et al.* (1997a) have also reported significant increase in P uptake in groundnut due to *P. striata* inoculation. Differences in N, P and K uptakes due to sheep manure application were significant as compared to no sheep manure (control). Improvement in nutrients uptake due to sheep manure application @ 10 t/ha was to the tune of 25.8% in N, 26.6% in P and 26.1% in K over control. This improvement was the function of higher dry matter yields and nutrients content in fodder. Interaction effect of phosphate and sheep manure for nutrients N, P and K uptakes was significant and results were similar to the fodder yields.

Phosphate use efficiency: Computation of APUE and PPUE showed that all the treatment variables decreased the values of above as compared to their respective control, except the PPUE value of PSB inoculation, where increased value was noted (Table 4). The decrease in APUE values was mainly because the increase in dry matter yields of lucerne due to application of phosphate at increased levels, PSB inoculation and sheep manure application was not in same proportion of P applied. But its contrary, the reason for lower value of PPUE with increase in phosphate level and sheep manure application was mainly because of comparatively higher differences in P uptake than that of increase in dry matter yields. Whereas, PSB inoculation increased the value of PPUE (215.3 kg dm/kg P uptake) as compared to control, which shows better P use efficiency where each kg of P uptake recorded higher dry matter yields.

Response function: The relationship between P application and dry matter yield of lucerne at different levels of PSB inoculation and sheep manure application was found to be quadratic. On the basis of mean data of 2 years the response equations were as given below:-

$Y_{Bo} = 7241.0 + 98.7167\ x - 0.56389\ x^2$

$Y_{B1} = 8113.0 + 92.1\ x - 0.58333\ x^2$

$Y_{So} = 6203.0 + 110.267\ x - 0.6444\ x^2$

$Y_{S1} = 9161.0 + 79.7\ x - 0.49444\ x^2$

$Y_{P} = 7682.0 + 95.233\ x - 0.57222\ x^2$

Where, Y_{Bo}, Y_{B1}, Y_{So}, Y_{S1} and Y_{P} are dry matter yields of lucerne (kg/ha) at without PSB inoculation, with PSB inoculation, without sheep manure, with sheep manure @ 10 t/ha and overall phosphorus levels, respectively and x is dose of phosphorus in kg P/ha.

The maximum yield dose of P and maximum expected yields of lucerne worked out at B_0, B_1, S_o, S_1 and overall P application were 38.5, 34.7, 37.6, 35.5 and 36.6 kg P/ha; and 11.56, 11.75, 10.92, 12.37 and 11.64 t/ha , respectively.

P content: Phosphate application at lower rates *viz.,* 13.2 kg/ha and control as well as no sheep manure treatments resulted negative values of change in available P after two years. While, higher dose of P, PSB inoculation and sheep manure application showed positive balance and recorded greater values of net change in available P contents of soil. Positive balance of P may be because of lower P uptake by lucerne crop in two years than applied P through inorganic and organic (sheep manure) sources. Higher value of change in available P status of soil due to PSB inoculation may be because of its nature as renewable source of P solubilizing activities.

Table 2. Green fodder, dry matter, crude protein yields and nutrients uptake as influenced by treatment variables (Pooled data over 2 years)

Treatment	GFY (t/ha)	DMY (t/ha)	CPY (t/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
(A) Phosphate levels (kg/ha)						
0	36.7	7.72	1.39	222.1	29.5	144.3
13.2	45.6	9.91	1.83	293.4	39.3	191.6
26.4	51.8	11.44	2.15	344.0	47.7	222.1
39.6	52.2	11.58	2.18	348.9	48.5	226.0
SEm±	0.59	0.14	0.03	4.55	0.74	3.33
CD (P = 0.05)	1.66	0.39	0.08	12.88	2.10	9.43
(B) Biofertilizer inoculation						
B_0	45.5	9.91	1.84	294.6	39.6	191.0
B_1	47.6	10.42	1.93	309.2	42.9	201.0
SEm±	0.41	0.10	0.02	3.22	0.53	2.36
CD (P = 0.05)	1.17	0.28	0.06	9.11	1.49	6.67
(C) Sheep manure (t/ha)						
0	42.2	9.13	1.67	267.4	36.4	173.4
10	50.9	11.19	2.10	336.4	46.1	218.6
SEm±	0.41	0.10	0.02	3.22	0.53	2.36
CD (P = 0.05)	1.17	0.28	0.06	9.11	1.05	6.67

Table 3. Interaction effect of phosphate levels and sheep manure on green fodder, dry matter and crude protein yield, nutrients uptake and net returns

	Phosphate levels (kg/ha)			
Sheep manure (t/ha)	0	13.2	26.2	39.6
Green fodder yield (t/ha)				
0	30.0	41.2	48.4	49.2
10	43.5	50.1	55.1	55.2
SEm±	0.83			
CD (P = 0.05)	2.34			
Dry matter yield (t/ha)				
0	6.24	8.80	10.67	10.81
10	9.20	11.02	12.21	12.33
SEm±	0.19			
CD (P = 0.05)	0.55			
Crude protein yield (t/ha)				
0	1.07	1.58	1.97	2.06
10	1.70	2.08	2.34	2.28
SEm±	0.04			
CD (P = 0.05)	0.11			
N Uptake (kg./ha)				
0	172.3	257.0	318.8	321.5
10	271.9	329.8	369.2	374.7
SEm±	6.44			
CD (P = 0.05)	18.22			
P Uptake (kg./ha)				
0	22.7	34.3	43.6	45.0
10	36.4	44.5	51.8	52.0
SEm±	1.05			
CD (P = 0.05)	2.97			
K Uptake (kg./ha)				
0	113.9	167.1	203.9	208.7
10	174.9	216.0	240.3	243.2
SEm±	4.71			
CD (P = 0.05)	13.33			
Net returns (Rs./ha)				
0	18590	34492	44562	44750
10	31747	40742	47317	46560
SEm±	1294.02			
CD (P = 0.05)	3736.92			

Table 4. Phosphate use efficiency net change in P content and economics as influenced by treatment variables

Treatment	Phosphate use efficiency		Net available P change in soil (kg/ha)			Economics*			
	APUE (kg dm /kg P applied)	PPUE (kg dm /kg P uptake)	Initial P content in soil	Actual P balance in soil	Change	Cost of cultivation returns (x10^3 Rs./ha)	Gross returns (x10^3 Rs./ha)	Net returns (x10^3 Rs./ha)	B:C ratio
(A) Phosphate levels (kg/ha)									
0	-	-	8.23	8.08	(-) 0.15	29.9	55.1	25.2	1.82
13.2	73.0	230.5	8.23	8.17	(-) 0.06	30.8	68.4	37.6	2.22
26.4	62.1	204.4	8.23	8.78	0.55	31.7	77.6	45.9	2.46
39.6	42.9	203.2	8.23	9.15	0.92	32.6	78.7	45.6	2.41
SEm±								0.91	0.03
CD (P = 0.05)								2.64	0.08
(B) Biofertilizer inoculation									
B_0	62.5	205.5	8.23	8.24	0.01	31.2	68.3	37.1	2.19
B_1	56.4	215.3	8.23	8.85	0.62	31.3	71.6	40.1	2.28
SEm±								0.65	0.02
CD (P = 0.05)								1.87	0.06
(C) Sheep manure (t/ha)									
0	70.1	211.7	8.23	8.01	(-) 0.22	27.7	63.3	35.6	2.28
10	48.4	206.8	8.23	9.01	0.78	34.8	76.6	41.6	2.20
SEm±								0.65	0.02
CD (P = 0.05)								1.87	0.06

*Price of Lucerne fodder Rs. 1500/tonne, Labour wages Rs. 150 per manday, Common cost of cultivation Rs. 26304.00/ha, Cost of sheep manure Rs. 610/tonne, and Cost of P per kg inclusive of application charges through sheep manure Rs. 288.8 and inorganic fertilizer Rs. 30/-.

Economics: Computation of net returns and benefit: cost (B: C) ratio showed that all the treatment variables had significant effect on both the traits (Table 4). Among P levels, application of 26.4 kg P/ha recorded maximum net returns (Rs. 45940/ha) and B: C ratio (2.46) and these values were statistically at par with that of 39.6 kg P/ha but significantly higher over other levels of phosphate. The extent of increase was to the tune of 82.5, 22.1 and 0.66 per cent in net returns and 35.2, 10.8 and 2.07% in B: C ratio over 0, 13.2 and 39.6 kg P/ha, respectively. Seed inoculation with PSB significantly increased the net returns (Rs. 40068/ha) and B: C ratio (2.28) over no inoculation to the tune of 8.50 and 4.11%, respectively. Higher net returns and B: C ratio have also been reported by Sharma and Agrawal (2003) due to increase in dose of phosphate up to 26.4 kg P/ha as well as PSB inoculation in Egyptian clover. Although application of sheep manure significantly increased the net returns Rs 41777/ha (17.4%), but B: C ratio was significantly lower than no sheep manure (control). Lower value of B: C ratio with sheep manure was mainly because of proportionately lower increase in fodder yields of lucerne than that of cost involved on sheep manure and its application. Interaction effect of phosphate and sheep manure application on net returns was significant and maximum net returns (Rs. 47317/ha) was obtained with 26.4 kg P/ha + sheep manure.

Conclusion

Overall, study indicates that for getting higher and economical fodder yield of Lucerne along with improved fodder quality and soil fertility, 26.4 kg P/ha through inorganic source along with seed inoculation with *Pseudomonas striata* (PSB) and sheep manure @ 10 t/ha can be applied in hot arid ecosystem of Rajasthan.

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