OPTIMIZING PHOSPHORUS FERTILIZER RATES FOR MAXIMIZING FORAGE YIELD AND PHOSPHORUS USE EFFICIENCY IN BERSEEM (*TRIFOLIUM ALEXANDRINUM* L.) GENOTYPES

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SUMMARY

During *Rabi* season of 2022-2023 a field study was conducted to examine how varying phosphorus levels affected performance of berseem genotypes. Six genotypes (PC-114, JB-08-17, JHB-20-1, JHB-20-2, Wardan and bundel berseem-3 (BB-3)) and three phosphorus levels (60, 80 and 100 kg P_2O_5/ha) with three replications were evaluated in the split plot design. Results indicated that the genotype BB-3 produced the best green forage yield (GFY) and gave the highest net return and B:C ratio among the genotypes. Similarly, GFY, dry matter yield and crude protein yield with 100 kg P_2O_5/ha were 8.3, 20.0 and 22.6%, respectively greater than those of 60 kg P_2O_5/ha and gave the highest net return. BB-3 and JHB-20-2 among genotypes and lower dose of P (60 kg P_2O_5/ha) recorded the highest phosphorus use efficiency. The P fertilizer rate for maximum yield and economical P fertilizer rate was found to be 101 and 97 kg/ha, respectively.

Key words: Berseem, P management, Economical P fertilizer rate, production economics and phosphorus use efficiency

Berseem (*Trifolium alexandrinum* L.) is a Mediterranean-native annual cool-season legume crop that is also known as the "king of fodders." According to Gondal *et al.* (2021), it is one of the most significant legume crops grown in south-east Asia because of its superior vegetative growth, high fodder output, superior palatability, and ability for multiple cuts. When used in crop rotation with cereal crops provides an abundance of green fodder along with enhancement of soil fertility (Salama and Nawaz, 2021). Due to its high crude protein content and forage yield potential, dairy farmers in Bihar widely grow it, making it one of the most significant forage legumes in India during the winter months from November to April (Nanda *et al.,* 2022). One of the most essential macro-nutrients for plants is phosphorus, which plays key role for root growth and, in turn, influences nutrient uptake, plant growth and development (Nanda *et al.* 2023). Since berseem is a legume crop, it requires a lot of phosphorus for nodule formation. P is essential for the transfer of energy (ATP and ADP). Previous research (Godara *et al.,* 2016; Devi and Satpal, 2019; Kumar *et al.,* 2021) indicates that P levels affect the performance of berseem crop. Thus, phosphorus management may have an effect on N-fixation thereby impacting the crude protein content of berseem genotypes. In Bihar's calcareous soils, one of the most important soil fertility factors limiting crop productivity is P availability (Nanda *et al.,* 2022). Therefore, the current research was done to investigate the response of recent berseem genotypes to P management with respect to forage and crude protein yield, production economics and P use efficiency.

MATERIALS AND METHODS

Experimental site

During *Rabi* season 2022-2023, a field experiment was carried out at Forage Research Block of APRI, RPCAU, Pusa, Samastipur, Bihar under AICRP on forage crops and utilisation. The site is located on the banks of the *Budhi Gandak* river and is geographically located in the sub-tropical region of the Indo-Gangetic plains. It is situated at an elevation of 63.9 metres above mean sea level at latitude 25°98′ N and longitude 85°68′ E. Pusa, Samastipur has sub-tropical, humid weather with an average yearly rainfall of 1200 mm, of which 941 mm, or almost 70%, occur between July and September. The monsoon typically begins in the third week of June and lasts until the end of September, or occasionally the first week of

October. The summer months are hot, dry and humid while the winter months are quite cold. The pH of the soil was 8.47 and was silty clay loam in texture. The soil had low levels of available K (90.5 kg/ha), medium levels of available P (15.2 kg/ha), low levels of organic carbon (0.46%) and available nitrogen (196.2 kg/ha).

Experimental design and cultural practices

Six berseem genotypes (PC-114, JB-08-17, JHB-20-1, JHB-20-2, Wardan (national check), and BB-3 (zonal check)) and three phosphorus levels (60, 80, and 100 kg P_2O_5/ha) were evaluated using a split plot design with three replications. Genotypes and P levels were assigned to main-plots, and sub-plots, respectively. 20 kg N/ha and 40 kg K_2O/ha was uniformly to all the plots through urea and MOP, respectively. SSP was the fertilizer source of phosphorus. The experimental plots were 4m × 3 m in size. On December 5, 2022, the trial was manually seeded using a recommended seed rate of 25 kg/ha with a row spacing of 30 cm. All other accepted agronomic procedures for growing berseem were applied consistently across all of the treatments.

Observations and method of analysis

From every experimental plot, three cuts were taken: the first at 60 days after sowing (DAS), and the other two at 30-day intervals subsequently. Green fodder yield (GFY) harvested from net plot were recorded and converted to q/ha. Green fodder samples weighing 500 g were taken from each plot and heated to 70 ± 2°C in a hot air oven until a consistent weight was reached for determination of dry matter content, which was then multiplied by GFY to produce the dry matter yield (DMY). To calculate nitrogen uptake, the total N of the dry matter was determined and multiplied by the DMY. The crude protein (CP) content of dry matter was calculated by multiplying its nitrogen content by a factor of 6.25. Crude protein yield (CPY) was calculated by multiplying CP content (%) by DMY. The output (Rs. 250/q of green fodder) and the input prices as of the current market were used to calculate the production economics of the crop. Using Microsoft Excel software, the overall response of green forage yield of berseem genotypes to P fertilizer levels was fitted to a quadratic equation ($Y= a + bX + cX^2$), where Y represented the green forage yield in q/ha, a served as the intercept, and b and c were the regression co-efficients. The following formula was used to get the economical P fertiliser rate in accordance with Ali and Habib (2022):

$$\text{Economical P fertilizer rate (kg/ha)} = \frac{\text{Cost of P fertilizer per kg}}{\text{Price of green fodder per quintal}} \times \left(\frac{1}{2c}\right) - \left(\frac{b}{2c}\right)$$

Further, P fertilizer rate for maximum green forage yield was obtained as follows:

$$\text{P fertilizer rate for maximum yield (kg/ha)} = \frac{-b}{2c}$$

Data were subjected to Analysis of Variance for split plot design (Gomez and Gomez, 1984). To compare treatment means, the critical difference (CD) at the 5% level of significance was computed.

RESULTS AND DISCUSSION

Effect of genotypes

Average plant height, leaf:stem ratio and CP content varied significantly due to genotypes and P level (Table 1). BB-3 (62.3 cm) had the maximum plant height which was similar to Wardan (61.2 cm), PC-114 (60.4 cm) and JB-08-17 (58.9 cm). Except PC-114 (0.71), average L:S ratio of the berseem genotype JHB-20-2 was significantly higher than the other genotypes (Table 1). Similarly, the CP contents of the genotypes JHB-20-2, PC-114 and BB-3 were statistically comparable to that of Wardan (17.99%). Variations in plant height, leaf:stem ratio and CP content among varieties may be attributed to their inherent characteristics. Genotypic differences in plant height, L:S ratio, and CP content were also observed for berseem genotypes by Nanda *et al.* (2022) and Godara *et al.* (2016). BB-3 produced the highest green forage production (526.6 q/ha), which was similar to PC-114 and Wardan (Table 2). But Wardan (69.6 q/ha) and JHB-20-2 (69.6 q/ha) had the highest DMY (Table 2). The trend of production efficiency in terms of GFY and DMY was consistent with GFY and DMY, respectively. JHB-20-2 and BB-3 had the highest partial factor productivity of P fertilizer (PFPP) in terms of DMY and GFY, respectively. Wardan had the greatest CPY (12.54 q/ha) which was similar to that of BB-3 and JHB-20-2. Similar results were also reported by Godara *et al.* (2016), Devi and Satpal (2019), Kumar *et al.* (2021) and Nanda *et al.* (2022). BB-3 had the

TABLE 1
Effect of different P levels on plant height, L:S ratio and crude protein of Berseem genotypes.

Treatments	Plant height (cm)	L:S ratio	CP (%)
Genotypes			
JB-08-17	58.9	0.59	17.52
JHB-20-1	54.1	0.60	17.12
PC-114	60.4	0.71	17.78
BB-3 (NEZC)	62.3	0.66	17.71
Wardan (NC)	61.1	0.64	17.99
JHB-20-2	57.6	0.80	17.93
SEm ±	1.4	0.03	0.14
CD (P= 0.05)	4.4	0.09	0.45
P levels (kg P_2O_5/ha)			
60	55.9	0.60	17.47
80	60.4	0.69	17.73
100	60.9	0.71	17.82
SEm ±	0.7	0.02	0.14
CD (P= 0.05)	2.0	0.05	NS
Interaction	NS	NS	NS

highest gross return (Rs. 1311639/ha), net return (Rs. 82492/ha), and B: C ratio (2.68) which was comparable to PC-114 and Wardan.

Effect of Phosphorus levels

Plant height and the L:S ratio increased with increasing phosphorus (P) levels from 60 kg P_2O_5/ha to 100 kg P_2O_5/ha; however, applying 80 kg and 100 kg resulted in similar plant height and L:S ratio (Table 1). Godara *et al.* (2016), Devi and Satpal (2019) and Nanda *et al.* (2022) also noted that the highest plant height of Berseem genotypes was recorded with the treatment of 100 kg P_2O_5/ha. Similar results were also reported by Kumar *et al.* (2021) and Roy *et al.* (2015) who found that P application had a substantial impact on the L: S ratio. Different P levels could not influence CP content (Table 1). The GFY, DMY and production efficiency was significantly impacted due to application of different P levels. The highest GFY, DMY and production efficiency in terms of GFY and DMY was registered with application of the highest dose of phosphorus (100 P_2O_5/ha) but it was comparable with 80 kg P_2O_5/ha (Table 2). Similar results were also reported by Devi and Satpal (2019), Kumar *et al.* (2021) and Nanda *et al.* (2022). PFPP in terms of GFY and DMY evidenced significant decline with increase in P levels and the lowest P level *i.e.* 60 kg P_2O_5/ha recorded the highest PFPP in terms of GFY (732.6 kg GFY/kg P_2O_5 applied) and DMY (91.5 kg DMY/ kg P_2O_5 applied). CPY was the highest with application of 100 kg P_2O_5/ha (11.77 q/ha) and was significantly superior over its lower levels. The application of 100 kg P_2O_5/ha yielded the highest gross return (Rs. 118944/ha) and net return (Rs. 68747/ha) which was comparable to 80 kg P_2O_5/ha. However, the treatment of 80 kg P_2O_5/ha resulted in the highest B:C ratio (2.38).

TABLE 2
Effect of different P levels on forage yield, production efficiency, phosphorus use efficiency of Berseem genotypes

Treatments	GFY (q/ha)	DMY (q/ha)	Production efficiency (q/ha/day)		PFPP (kg forage yield/kg P_2O_5 applied)		CPY (q/ha)
			GFY	DMY	GFY	DMY	
Genotypes							
JB-08-17	401.6	55.3	3.65	0.50	521.6	71.2	9.69
JHB-20-1	384.7	48.1	3.50	0.44	489.8	60.5	8.25
PC-114	508.0	61.8	4.62	0.56	658.4	78.8	10.97
BB-3	526.6	64.7	4.79	0.59	685.7	83.2	11.45
Wardan	489.3	69.6	4.45	0.63	635.5	89.6	12.54
JHB-20-2	455.4	69.6	4.14	0.63	594.6	90.8	12.48
SEm ±	14.1	2.3	0.13	0.02	19.5	3.2	0.45
CD (P= 0.05)	44.4	7.4	0.40	0.07	61.3	10.0	1.43
P levels (kg P_2O_5/ha)							
60	439.5	54.9	4.00	0.50	732.6	91.5	9.60
80	467.5	63.7	4.25	0.58	584.4	79.7	11.32
100	475.8	65.9	4.33	0.60	475.8	65.9	11.77
SEm ±	6.0	0.8	0.05	0.01	8.6	1.1	0.13
CD (P= 0.05)	17.5	2.2	0.16	0.02	25.2	3.3	0.37
Interaction	NS	S	NS	S	S	S	S

TABLE 3
Effect of different P levels on production economics of Berseem genotypes.

Treatments	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
Genotypes				
JB-08-17	49147	100389	51242	2.04
JHB-20-1	49147	96176	47029	1.95
PC-114	49147	127009	77862	2.58
BB-3	49147	131639	82492	2.68
Wardan	49147	122333	73186	2.49
JHB-20-2	49147	113861	64714	2.32
SEm ±		3526	3526	0.07
CD (P= 0.05)	-	11111	11111	0.23
P levels (kg P_2O_5/ha)				
60	48097	109884	61787	2.28
80	49147	116875	67728	2.38
100	50197	118944	68747	2.37
SEm ±	-	1496	1496	0.03
CD (P= 0.05)	-	4367	4367	NS
Interaction	-	NS	NS	NS

Interaction effect of genotypes and phosphorus levels

Berseem genotypes responded differently to studied P levels with respect to DMY (Fig. 1), CPY (Fig. 2), PE DMY (Fig. 3), PFPP in terms of GFY (Fig. 4) and PFPP in terms of DMY (Fig. 5). The highest DMY was noted with JHB-20-2 with 80 kg P_2O_5/ha (73.4 q/ha) which was at par with Wardan and BB-3 along with 80 kg P_2O_5/ha and Wardan, JHB-20-2 and PC-114 along with 100 kg P_2O_5/ha (Fig. 1). Similarly, the highest CPY was noted with Wardan with 100 kg P_2O_5/ha (13.3 q/ha) which was at par with Wardan and JHB-20-2 at 80 kg P_2O_5/ha (Figure 2). Production efficiency in terms of DMY was the highest with Wardan along with 100 kg P_2O_5/ha and JHB-20-2 along with 80 kg P_2O_5/ha being at par with Wardan and BB-3 at 80 kg P_2O_5/ha and JHB-20-2, BB-3 and PC-114 at 100 kg P_2O_5/ha (Figure 3). The highest PFPP in terms of GFY was noted with BB-3 along with 60 kg P_2O_5/ha (859.3 kg GFY/ kg P_2O_5 applied) which was comparable with PC-114 (801.9 kg GFY/ kg P_2O_5 applied) (Fig. 4). However, the highest PFPP in terms of DMY was noted with JHB-20-2 (112.7 kg DMY/ kg P_2O_5 applied) (Fig. 5).

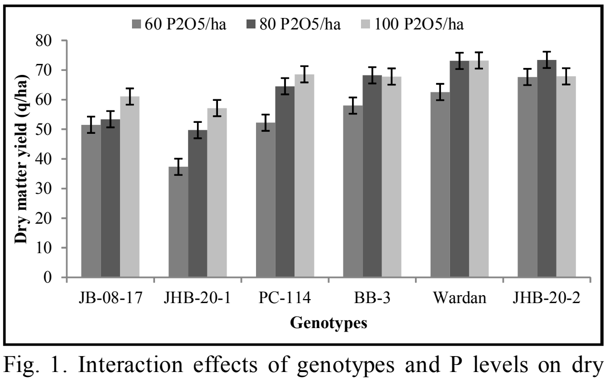

Fig. 1. Interaction effects of genotypes and P levels on dry matter yield of berseem. Error bars indicate CD values (p<0.05).

Determination of economic optimum and agronomic maximum dose of phosphorus for berseem genotypes

The fitted quadratic response equation for

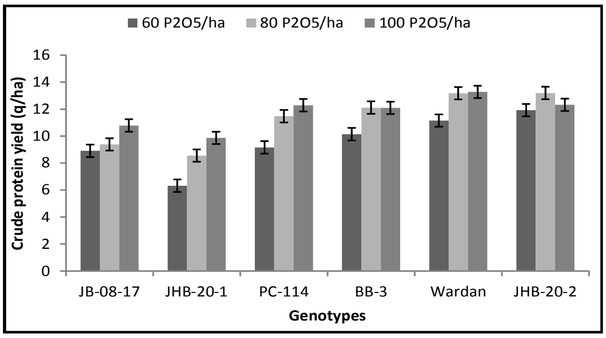

Fig. 2. Interaction effects of genotypes and P levels on crude protein yield of berseem. Error bars indicate CD values (p<0.05).

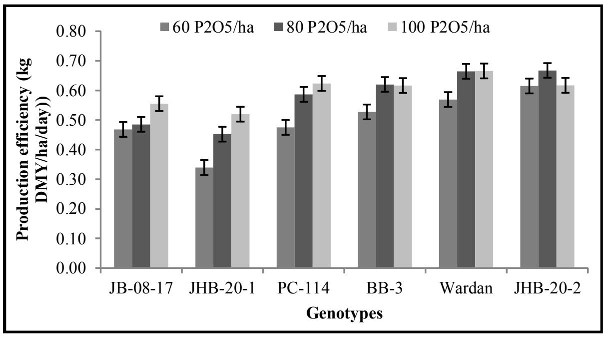

Fig. 3. Interaction effects of genotypes and P levels on production efficiency (in terms of DMY) of berseem.

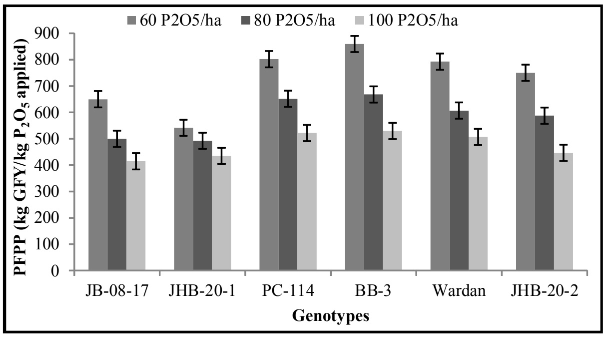

Fig. 4. Interaction effects of genotypes and P levels on partial factor productivity of P fertilizer (in terms of GFY) of berseem. Error bars indicate CD values (p<0.05).

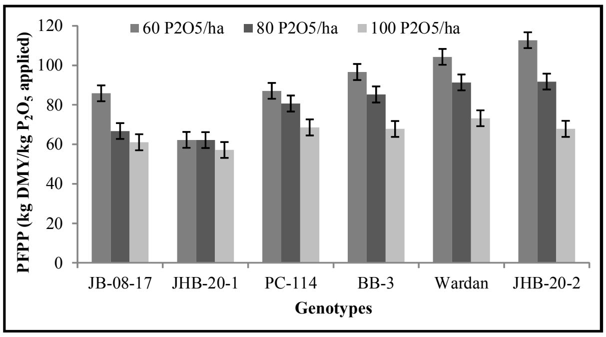

Fig. 5. Interaction effects of genotypes and P levels on partial factor productivity of P fertilizer (in terms of DMY) of berseem. Error bars indicate CD values ($p<0.05$).

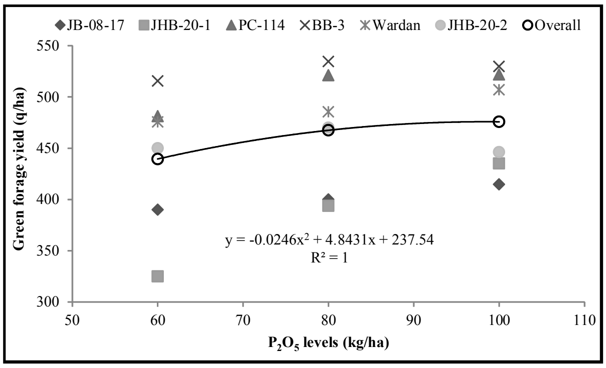

Fig. 6. Economic optimum and agronomic maximum dose of phosphorus for berseem genotypes.

green forage yield across genotypes as a function of P application was $y = -0.024x^2 + 4.843x + 237.5$ (Figure 6). The calculated P fertilizer rate for obtaining maximum green forage yield and economical P fertilizer rate was found to be 101 and 97 kg/ha, respectively.

CONCLUSION

The present study revealed that growing Bundel berseem-3 with application 100 kg P_2O_5/ha resulted in higher green forage yield, crude protein yield and net return. The P fertilizer rate for obtaining maximum green forage yield and economical P fertilizer rate was found to be 101 and 97 kg/ha, respectively.

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