



Performance of groundnut (*Arachis hypogaea*) under different phosphorus management options in semi-arid environment of Rajasthan

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ABSTRACT

The present field investigation was carried out during *kharif* season of 2015, 2016 and 2017 at Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur to evaluate the effect of various phosphorous (P) management options on growth, productivity and economics of groundnut (*Arachis hypogaea* L.). The experiment was carried out in a randomized complete block design with 10 P management practices. Results revealed application of 5 t farmyard manure (FYM) + 50% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-1 increased dry matter accumulation by 47.5% and 48.72% (35 days after sowing, DAS), 38.6% and 34.6% (70 DAS) and 38.9% and 35.1% (at harvest) over no P fertilization. Application of 5 t FYM + 50% chemical P + DGRC-1 enhanced crop growth rate (CGR) by the magnitude of 19. 8%–47. 5% (0–35 DAS), 12. 5%– 36. 3% (35–70 DAS), and 13. 4%–39. 5% (70 DAS–at harvest) compared to control and 5 t FYM, 5 t FYM + DGRC-1 and 5 t FYM + DGRC-2 plots. The maximum number of pods/plant, pod weight/plant, test weight and shelling% were also registered with application of 5 t FYM + 50% chemical P + DGRC-1. With respect to yields, application of 5 t FYM + 50% chemical P + DGRC-1 resulted in the maximum pod (5. 99 t/ha) and kernel (4. 29 t/ha) yields. The maximum net returns and B:C ratio were recorded when the crop was fertilized with 5 t FYM + 50% chemical P + DGRC-1. Finally, it can be concluded that integrated P management in groundnut using 5 t FYM + 50% chemical P + DGRC-1 can be advocated as sustainable P management strategy for enhancing productivity and profitability under semi-arid conditions of Rajasthan.

Key words: Crop productivity, Farm profitability, Groundnut, Phosphorus management

Groundnut (*Arachis hypogaea* L.) is one of the important oilseed crops for small land holding farmers of rainfed areas. Globally, Asia and Africa share around 95% of cultivated area and 87% of production due to their most suitable agro-climatic condition for groundnut cultivation (FAO 2016). In India, it is second most important oilseed with an acreage of ~5.86 Mha, production of ~8.27 million tonnes and an average productivity of 1411 kg/ha (Anonymous 2016). The ever growing population and continuous reduction in available land due to large scale urbanization and rapid setting of industries puts severe pressure on available natural resources in order to meet the increasing food and oil demand (Bruinsma 2009, Yadav *et al.* 2018). To circumvent this challenge, farmers overuse certain inputs such as chemical fertilizers and pesticides which deteriorate environment and soil (Foley *et al.*

2011). The intensive use of these chemicals results in low nutrient–use efficiency which makes fertilizer consumption uneconomical and produces negative effects on environment and groundwater quality (Mueller *et al.* 2012). Results of long-term experiments indicate that application of nutrients solely through chemical fertilizers have adverse effects on soil health leading to unsustainable productivity (Godfray *et al.* 2010).

Therefore, to make the nutrient management system more efficient, the practical way is to mobilize the entire available, accessible and affordable plant nutrients from various sources to optimize the productivity of the system (Prasad *et al.* 2002, Parkinson 2013). Moreover, strategic use of varied nutrient sources, including inorganic fertilizers, organic materials and biofertilizers will help to restore desired agro-ecosystem functions (Zhang *et al.* 2012, Wu and Ma 2015). Application of organics improves soil structure, increases water holding and buffering capacity of soils and ultimately enhances availability of nutrients (Behera *et al.* 2007). Plant growth promoting rhizobacteria (PGPRs) are environmental friendly, low cost and non-bulky agricultural inputs which play a significant role in plant nutrition as a supplementary and complementary factor to mineral nutrition (Peix *et al.* 2015). Balanced use of fertilizers,

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organic manures along with bio-fertilizers for improving crop productivity and soil fertility status in cereals and cereal-based rotations is well documented (Garai *et al.* 2014). Thus, substitution of some of the inorganic P requirement of groundnut through farm yard manure (FYM) and PGPRs is important to synthesize low cost nutrient management technology, besides addressing production vulnerabilities. Therefore, the objective of this study was to determine the effects of different P management practices (organic, inorganic and their combinations) on growth behaviour, productivity and economic profitability of groundnut cultivation under semi-arid ecosystem.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2015, 2016 and 2017 at Research farm of All India Coordinated Research Project on Groundnut of Rajasthan Agricultural Research Institute, Durgapura, Jaipur (26° 51' N, 75° 47' E at an altitude of 390 m (symsol) amsl to examine effect of different phosphorus fertility practices on growth, productivity and economics of groundnut. The experimental site is in the semi-arid Eastern plain zone of Rajasthan, characterized by cold winters and hot summers. The average annual rainfall of zone was ~563 mm of which ~90% is received during later half of June–September with erratic distribution over time and space. The soil of the experimental field was loamy sand with pH 8.2, low in organic carbon and nitrogen, medium in available phosphorus and potassium. The experiment was laid out in randomized complete block design with 10 phosphorus management practices, viz. control (no P fertilization) (T_1), 5 t FYM/ha (T_2), 5 t FYM/ha + DGRC-1 (T_3), 5 t FYM/ha + DGRC-2 (T_4), 5 t FYM/ha + 50% chemical P (T_5), 5 t FYM/ha + 50% chemical P + DGRC-1 (T_6), 5 t FYM/ha + 50% chemical P + DGRC-2 (T_7), 5 t FYM/ha + chemical 100% P (T_8), 5 t FYM/ha + 100% chemical P + DGRC-1 (T_9), 5 t FYM/ha + 100% chemical P + DGRC-2 (T_{10}); replicated thrice.

Field preparation included 2 cross harrowings followed by planking. The groundnut variety RG 559-3 was sown during 3rd week of June with seed rate of 150 kg/ha at 30 cm × 15 cm plant geometry. FYM (5 t/ha) was applied ~15 days before sowing as per the treatments and well mixed in the soil. The recommended dose of nitrogen, phosphorus (as per treatment) and potash (20:60:0) was applied through urea (46% N) and single superphosphate (16% P_2O_5). The PGPR (DGRC-1 and 2) used for this study was a specific strain of P solubilizing bacteria (PSB) applied in the form of seed treatment before sowing. For weed management, pendimethalin at 1.0 kg/ha as pre-emergence (PE) was applied to all the experimental plots. In addition to chemical weed management, one hand weeding was also done at 20–35 DAS. The growth and yield attributes were estimated as per the standard procedure by sampling from 3 places in each plot. From the net plots, after leaving the 2 border rows on either side of the plots, groundnut was harvested manually with spade. The produce was kept for sundrying for some days in field and after drying the biological yield was recorded. Stover yield was obtained by subtracting the pod yield from the biological yield of individual plots.

The net returns of groundnut cultivation under various P management options were calculated by subtracting cost of cultivation of individual treatment from gross returns of respective treatments, and finally the benefit:cost ratio was calculated. The recorded data were analysed using analysis of variance (ANOVA) technique (Gomez and Gomez 1984). The least significance test was used to decipher the main and interaction effects of treatments at 5% level of significance ($P < 0.05$).

RESULTS AND DISCUSSION

Growth parameters and phosphorous fertilization: The P management had significant effect on plant height and dry matter accumulation (Table 1). The crop fertilized using 5 t FYM + 50% chemical P + DGRC-1 attained significantly maximum plant height (21.1, 39.1 and 54.4 cm) and dry

Table 1 Effect of phosphorous management on periodic plant height and dry matter accumulation and crop growth rate (CGR) of groundnut (average of 3 years)

Treatment	Plant height (cm)			Dry matter (g/plant)			CGR (g/plant/day)		
	35 DAS	70 DAS	At harvest	35 DAS	70 DAS	At Harvest	0–35 DAS	35–70 DAS	70 DAS–Harvest
Control (no P) (T_1)	13.63	22.95	33.76	4.16	25.58	37.99	0.11	0.61	0.35
5 t FYM/ha (T_2)	16.19	29.75	41.65	5.63	32.28	47.55	0.16	0.76	0.43
5 t FYM/ha+DGRC-1 (T_3)	18.23	33.58	47.84	6.35	35.81	53.70	0.18	0.84	0.51
5 t FYM/ha+DGRC-2 (T_4)	16.86	31.06	43.60	5.87	33.32	49.57	0.16	0.78	0.46
5 t FYM/ha+50% (T_5)	18.29	33.68	47.20	6.40	36.00	53.67	0.18	0.84	0.50
5 t FYM/ha+50% P+DGRC-1 (T_6)	21.18	39.12	54.40	7.92	41.65	62.25	0.22	0.96	0.58
5 t FYM/ha+50% P+DGRC-2 (T_7)	17.90	33.98	48.65	6.22	35.20	54.00	0.17	0.82	0.53
5 t FYM/ha+100% P (T_8)	18.23	34.43	49.68	6.35	37.23	55.42	0.18	0.88	0.52
5 t FYM/ha +100% P +DGRC-1 (T_9)	19.95	37.49	52.88	7.39	39.10	58.50	0.21	0.90	0.55
5 t FYM/ha+ 100% P+DGRC-2 (T_{10})	18.06	34.20	49.28	6.27	37.82	54.49	0.17	0.90	0.47
LSD($P=0.05$)	2.80	5.14	7.19	0.97	4.97	8.20	0.028	0.11	0.092

matter (7.92, 41.65 and 62.25 g/plant) at 35 DAS, 70 DAS and at harvest, respectively. However, application of 5 t FYM + 100% chemical P, 5 t FYM + 100% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-2 produced statistically similar plant height and dry matter accumulation compared to 5 t FYM + 50% P + DGRC-1 at all the growth stages. Application of 5 t FYM + 50% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-1 increased the plant height by 35.6% and 31.7% (at 35 DAS), 41.3% and 38.8% (at 70 DAS) and 37.9% and 36.2% (at harvest) and dry matter accumulation by 47.5% and 48.7% (at 35 DAS), 38.6% and 34.6% (at 70 DAS) and 38.96 and 35.05% (at harvest), respectively compared to control. Application of 5 t FYM + 50% chemical P + DGRC-1 resulted in significantly maximum CGR, which was enhanced by the magnitude of 19.79–47.47% (0–35 DAS), 12.53–36.31% (35–70 DAS) and 13.35–39.52% (70 DAS–at harvest) over control, 5 t FYM, 5 t FYM + DGRC-1 and 5 t FYM + DGRC-2. However, application of 5 t FYM + 100% chemical P, 5 t FYM + 100% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-2 recorded statistically similar CGR compared to 5 t FYM + 50% chemical P + DGRC-1 at all the crop growth stages. The optimum availability of macro and micro nutrient with the integrated use of organic and inorganic nutrient sources might speed up the growth and development processes especially related to source system and their efficiency for photosynthesis leading to higher dry matter production (Raychaudhury *et al.* 2003, Ramana *et al.* 2002). Moreover, integration of both organic and inorganic nutrient sources might improve fixation of nitrogen and reduce the fixation of soil P which could be one of the reasons for higher dry matter production and growth of groundnut.

Yield attributes and phosphorous fertilization: The maximum pod weight/plant (36.4 g), test weight (85.5 g) and shelling % (71.2%) were registered with integrated application of 5 t FYM + 50% chemical P + DGRC-1.

Table 2 Effect of phosphorous management on yield attributes of groundnut (average of 3 years)

Treatment	Pods/plant	Pod weight/plant	Test weight (g)	Shelling (%)
Control (No P) (T ₁)	12.84	27.43	76.73	65.86
5 t FYM/ha (T ₂)	15.54	30.02	77.76	67.47
T ₃ +DGRC-1	14.67	31.93	78.95	68.72
T ₄ + DGRC 2	14.42	29.20	78.65	68.55
T ₅ + 50% P	15.05	31.95	80.98	69.69
T ₆ + 50% P+DGRC-1	16.70	36.40	85.49	71.17
T ₇ + 50% P+DGRC-2	16.75	33.94	83.01	69.19
T ₈ + 100% P	17.45	32.13	82.32	70.69
T ₉ + 100% P + DGRC-1	17.34	35.25	84.23	70.97
T ₁₀ + 100% P + DGRC-2	17.49	34.61	83.33	71.13
SEM +	105	0.96	1.17	0.72
LSD(P=0.05)	2.25	2.88	3.51	2.16

Combined application of 50% chemical P along with FYM and DGRC-1 enhanced the number of pods/plant by 27.9, 16.3, 13.7 and 17.5% and pod weight/plant by 24.6, 17.5, 12.3 and 19.8% over control, 5 t FYM, 5 t FYM + DGRC-1 and 5 t FYM + DGRC-2, respectively (Table 2). Optimal and balanced supply of nutrients (macro and micronutrients) from inorganic and organic fertilizers led to higher growth and development of plants. Moreover, integrated use of organic and inorganic sources of P improved the physical (soil structure and water-holding capacity), chemical (buffering capacity, cation exchange capacity, macro and micro nutrients availability and reduce phosphate fixation) and biological properties of soil (organic matter, soil microbial biomass and soil microorganisms) which further provided an optimum environment for higher growth and development of plants and led to higher yield attributes of plants (Kachot *et al.* 2001).

Effect of different P management options on groundnut productivity: The maximum pod (5.99 t/ha) and kernel yield (4.29 t/ha) was recorded with combined application of 5 t FYM + 50% chemical P + DGRC-1 (Table 3). However, application of 5 t FYM + 100% chemical P, 5 t FYM + 100% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-2 resulted in statistically similar pod and kernel yields compared to 5 t FYM + 50% chemical P+DGRC-1. The application of 5 t FYM + 50% chemical P + DGRC-1 enhanced the pod yield by 10.8%–24.0% and kernel yield by 12.8%–29.3% compared to control, 5 t FYM, 5 t FYM + DGRC-1 and 5 t FYM + DGRC-2. Similarly, the maximum haulm yield (6.90 t/ha) was also recorded with 5 t FYM + 50% P+DGRC-1. Application of 5 t FYM + 50% chemical P + DGRC-1 enhanced the haulm yield by 24.1, 16.3, 9.0 and 9.55% compared to control, 5 t FYM, 5 t FYM + DGRC-2 and 5 t FYM + 50% chemical P + DGRC-2, respectively. However, with exception to control, 5 t FYM, 5 t FYM + DGRC-2 and 5 t FYM + 50% P + DGRC-2, rest P management treatments remained statistically similar

Table 3 Effect of phosphorous management on groundnut productivity (average of 3 years)

Treatment	Pod yield (q/ha)	Haulm yield (q/ha)	Kernel yield (q/ha)
Control (No P) (T ₁)	4.55	5.24	3.04
5 t FYM/ha (T ₂)	5.02	5.78	3.35
T ₃ + DGRC-1	5.34	6.28	3.74
T ₄ + DGRC 2	5.19	5.74	3.58
T ₅ + 50% P	5.39	6.27	3.79
T ₆ + 50% P + DGRC-1	5.99	6.90	4.29
T ₇ + 50% P + DGRC-2	5.49	6.24	3.73
T ₈ + 100% P	5.88	6.58	4.08
T ₉ + 100% P + DGRC-1	5.98	6.89	4.29
T ₁₀ + 100% P + DGRC-2	5.86	6.55	4.10
LSD (P=0.05)	0.28	0.65	0.31

with respect to haulm yield (Table 3).

The adequate and balanced use of nutrient inputs from inorganic and organic fertilizers is of fundamental importance for plant growth and crop productivity. Moreover, the use of organics with inorganic fertilizers leads to better soil moisture utilization, nutrient uptake and less fluctuation in the soil temperature and improves soil organic matter which increase the soil water holding capacity, soil aggregation, microbial activity and soil porosity ultimately leading to higher crop productivity (Badole *et al.* 2003). Similar results were also reported by many other researchers which state that integration of chemical and organic sources led to higher crop productivity (Biswas *et al.* 2003, Soumare *et al.* 2003).

Effect of different P management options on farm profitability: The highest cost of cultivation of groundnut (₹ 43740) was recorded with 5 t FYM + 100% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-2 over others treatments (Table 4). Similarly, the highest gross return (₹ 226881) was recorded with T₂ + 100% chemical P + DGRC-1. However, application of 5 t FYM + 50% chemical P + DGRC-1 fetched similar gross returns (₹ 226322) with T₂ + 100% chemical P + DGRC-1. The maximum net returns (₹ 183434) and B:C ratio (4. 27) was reported with 5 t FYM + 50% chemical P + DGRC-1. However, application of 5 t FYM + 100% chemical P + DGRC-1 with net return of ₹ 183341 and B:C ratio 4.19 proved second best P management option for farmers after 5 t FYM+50% chemical P+DGRC-1. The application of 5 t FYM+50% chemical P + DGRC-1 and 5 t FYM + 100% chemical P + DGRC-1 enhanced the gross returns with magnitude of 10. 44–23. 66%, net returns by 12. 53–25.90% and B:C ratio by 9.01–13.72 over control, 5 t FYM, 5 t FYM + DGRC-1 and 5 t FYM + DGRC-2. Thus, supply of P through 5 t FYM+50% chemical P + DGRC-1 provided additional net returns of ₹ 47516 over control. The combined use of inorganic fertilizers and organic manures along with PGPRs might improve physical, chemical and

biological properties of soil which inturn improves its nutrient supplying capacity (Hao and Chang 2002) and promotes better rooting, higher nutrient uptake by the crop and also enhances seed yield of peanut. Moreover, integrated P management using chemical 50% P fertilizer + FYM + DGRC-1 led to reduction in plant requirements for inorganic P fertilizer which is likely to save farmers' money by avoiding of use costly chemical P fertilizer. The replacement of 50% of chemical P fertilizer requirement of crop with low cost P inputs (FYM and Microbial PSB) and higher crop productivity might be the principal reasons for higher net returns under integrated P management tailored with 5 t FYM + 50% P + DGRC-1. The results are in close agreement with the findings of many researchers (De Jager *et al.* 2001, Palm *et al.* 2001, Ouedraogo *et al.* 2001). The present study revealed that application of 5 t FYM + 50% chemical P + DGRC-1 effective in improving the growth, productivity and profitability of groundnut.

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Table 4 Effect of phosphorous management on farm profitability of groundnut cultivation (average of 3 years)

Treatment	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Control (No P) (T ₁)	36836	172754	135918	3.68
5 t FYM/ha (T ₂)	41836	190457	148621	3.55
T ₂ +DGRC-1	42236	202673	160437	3.79
T ₂ +DGRC 2	42236	196963	154727	3.66
T ₂ +50% P	42488	204416	161928	3.81
T ₂ +50% P+DGRC-1	42888	226322	183434	4.27
T ₂ +50% P+DGRC-2	42888	208214	165326	3.85
T ₂ +100% P	43140	222822	179678	4.16
T ₂ +100% P +DGRC-1	43740	226881	183341	4.19
T ₂ +100% P+DGRC-2	43740	221968	178228	4.07

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