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ENHANCING PHOSPHORUS UTILIZATION EFFICIENCY IN SUMMER GROUNDNUT THROUGH MICROBIAL CULTURE

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ABSTRACT

The field experiments were carried out for Enhancing Phosphorus utilization efficiency in summer groundnut through Microbial Culture during Summer season. The experiment consisted of twelve treatment combinations of seed treatment with PSB culture inoculants @ 15g/ kg or seed treatment with DGRC culture inoculants @ 10g/ kg groundnut seed (cv. GJG-31) with different doses of phosphorus (20 kg, 40 kg and 60 kg/ha). Application of 40 kg P_2O_5/ha + PSB (15ml/kg seed) or DGRC culture showed significant increase in the growth and yield parameters of groundnut *viz.*, number of branches per plant (4.04), number of pods per plant (14.52) and pod yield (2590 kg/ ha) as compare to other treatments and it has saved 20 kg P_2O_5/ha by increasing the higher gross return (Rs. 1,33,559/ ha), net return (Rs. 94,829/ha) and B:C ratio (3.45) and the highest nutrient uptake of phosphorus (10.76 kg/ha) and potassium (40.23 kg/ ha) (except nitrogen uptake 4325 kg/ha) in pooled results.

Key words : Groundnut, Microbial culture, Nutrient uptake, Phosphorus, Quality parameters.

Introduction

Groundnut (*Arachis hypogaea* L.) contains high quality edible oil (48 per cent), easily digestible protein (26 per cent) and carbohydrates (20 per cent) therefore considered as "king of oilseed" among the oilseed crops and botanically classified in family Fabaceae (Das *et al*., 2005). Groundnut provides an inexpensive source of high-quality dietary protein and oil to millions of people in world especially in developing counties also it is a source of considerable amounts of mineral elements to supplement the dietary requirements of humans and farm animals. (Asibuo *et al*., 2008). Peanut oil like other vegetable oil is determined on the ester which is made up of straight chain higher fatty acids and glycerine. The fatty acids include the unsaturated; palmitic acid and stearic acid, mono unsaturated fatty acids; such as oleic acid and polyunsaturated fatty acids such as linoleic acid, linolenic acid.

As per estimate, groundnut is grown in India on 4.56 million hectare and production of 6.77 million tonnes with an average productivity of 1486 kg/ha (DAC and FW, 2016). In India, about 80 per cent of the area and 84 per cent of the production of groundnut is confined to the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra. However, it is also grown in Uttar Pradesh, Tamil Nadu, Punjab and west Bengal. Among the groundnut producing states, Gujarat is the topmost state both in area and production. Within Gujarat, the Saurashtra region is considered as "bowl of groundnut". It has been witnessed that the area under groundnut is also increasing in potato growing areas of North Gujarat considerably because of suitable agro-climatic conditions and coarse texture soil. Phosphorus is an indispensable mineral nutrient for legume crops, crucial for enhancing root growth and development, thus optimizing biological nitrogen fixation. It is integral to metabolic activities as a constituent of nucleoproteins and nucleotides, and it plays a pivotal role in forming energy-rich phosphate bonds like those found in ADP and ATP. Bio-fertilizers containing phosphate-solubilizing bacteria (PSB) can effectively meet the phosphorus requirements of crops by solubilizing insoluble phosphorus sources. Plant growth-promoting bacteria (PGPR), a group of free-living microorganisms, employ various methods to enhance plant growth (Glick B.R., 1995). Some of these bacteria, belonging to the group of phosphate-solubilizing bacteria (PSB), increase phosphorus uptake, thereby serving as biological fertilizers to improve plant growth and yield (Chen *et al*., 2006). Aspergillus niger and Penicillium strains are the most common fungi capable of phosphate solubilization. Phosphorus is typically added in the form of phosphatic fertilizers, part of which is utilized by plants, while the remainder is converted into soluble fixed forms. To address phosphorus deficiency, phosphate-solubilizing microorganisms (PSM) could play a crucial role in supplying phosphate to plants in a more environmentally-friendly and sustainable manner. With this perspective, the present investigation was conducted to examine the growth, yield, yield attributes, and economics of *kharif* groundnut influenced by integrated nutrient management strategies.

Materials and Methods

The field experiments were conducted during *summer* season of 2019, 2020 and 2021 at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India. The soil of the experimental plot having pH 7.65. The soil was low in available nitrogen 215 kg/ha, medium in phosphorus 29.60 kg/ha and potash 289 kg/ha. The experiment was laid out in randomized block design with three replications. The experiment consisted of twelve treatment combinations of seed treatment with DGRC culture inoculants @ 10g/ kg or seed treatment with PSB culture inoculants @ 15g/ kg groundnut seed (cv. GJG-31) with different doses of phosphorus (20 kg, 40 kg and 60 kg/ha) the treatment details viz., Control (no application of P), application of 20 kg/ha of P, application of 40 kg/ha of P, application of 60 kg/ha of P, application of 20 kg/ha of P+DGRC culture, application of 40 kg/ha of P+DGRC culture, application of 60 kg/ha of P+DGRC culture, application of FYM @ 2.5 t/ha, application of FYM @ 2.5 t/ha + DGRC culture, application of DGRC culture enriched FYM@100 kg/ha, application of FYM @ 5 t/ha + PSB culture and application of 40 kg/ha of P+ PSB culture. Application of recommended dose of farmyard manure, nitrogen, potash and seed rate was applied. The cultural practices, irrigation and plant protection measures were taken as and when required.

Results and Discussion

Growth Parameters and Phosphorous Fertilization

Three years pooled data presented in Tables 1, 2 and 3 revealed that the growth and yield attributes significantly influenced by different treatments. Significantly higher plant height (21.30 cm) was observed in application of FYM @ 5 t/ha + PSB (15ml/kg seed) and which is on par with the application of 40 kg/ha of P + PSB, application of 40 kg/ha of P + DGRC culture (15g/kg seed), application of DGRC culture (2 kg) enriched FYM@100 kg/ha, application of FYM @ 2.5 t/ha+ DGRC culture (10g/kg seed) and application of 60 kg/ha of P + DGRC culture (10g/kg seed). Whereas, number of branches per plant (4.04), number of pods per plant (14.52) and 100 kernel weights (43.10g) were significantly recorded by application of 40 kg/ha of P + DGRC culture (15g/kg seed). Number of branches per plant (4.04) and number of pods per plant (14.52) were also at par with all the treatments except control (no application of P), application of 20 kg/ha of P, application of 20 kg/ha of P + DGRC culture (10g/kg seed), application of DGRC culture (2 kg) enriched FYM@100 kg/ha and application of 60 kg/ha of P in case of number of branches per plant. The optimum availability of P to sustain crop growth. Further, P is a key component of molecules necessary for root growth and development, respiration, nucleic acid synthesis, N fixation, plant maturity and seed production (Raychaudhury *et al*., 2003). Phosphorus is required in greater amounts for pulse crops than many other crops due to its high demand in energy transfer molecules used in nitrogen fixation. Moreover, integration of both organic and inorganic nutrient sources might improve fixation of nitrogen and to reduce the movement of P to non-liable pools in the soil solution and also reduce the adsorption and immobilization of P (Ramana *et al*., 2002), which could be one of the reasons for higher dry matter production and growth of groundnut.

Effect of different P management options with PSB cultures on groundnut productivity

Three years pooled data presented in Table 4, Significantly year wise higher pod yield (2128 kg/ha, 3167 kg/ha), haulm yield (3380 kg/ha, 5135 kg/ha), kernel yield (1466 kg/ha, 2207 kg/ha) and oil yield (721 kg/ha, 1105 kg/ha) was recorded by application 40kg/ha of P + PSB culture @ 15 ml/kg or DGRC culture inoculated seeds in both the years of 2019 and 2020 and which was remained at par with application of 40 kg/ha of P (T_3), application of 60 kg/ha of P (T_4), application of 40 kg/ha of P + DGRC culture(15g/kg seed) (T_6), application of 60 kg/ha of P + DGRC culture (10g/kg seed) (T_7) and application of FYM @ 5 t/ha+ PSB (15ml/kg seed) (T_{11}). The Application of 20 kg/ha of P also at par in the year of 2020. In the year of 2021, non-significant effects were observed on pod yield, haulm yield, kernel yield and oil

Table 1 : Effect of different Treatments on Plant height, Number of branches, Number of pods and Shelling percentage of Groundnut.

	Treatments	Plant height(cm)				No. of branches				No. of pods/plant				Shelling %			
		2019	**2020**	**2021**	**Pooled**	**2019**	**2020**	**2021**	**Pooled**	**2019**	**2020**	**2021**	**Pooled**	**2019**	**2020**	**2021**	**Pooled**
T_1	Control (no application of P)	18.22	17.55	16.78	17.52	3.22	3.55	3.22	3.33	8.22	12.78	14.44	11.81	66.10	66.92	67.06	66.69
T_2	Application of 20 kg/ha of P	18.89	18.11	17.44	18.15	3.44	3.33	3.44	3.41	9.22	12.22	15.11	12.18	66.77	67.77	67.91	67.48
T_3	Application of 40 kg/ha of P	18.89	19.22	14.67	17.59	3.56	4.00	3.56	3.70	9.67	15.11	15.00	13.26	66.05	69.00	68.49	67.85
T_4	Application of 60 kg/ha of P	19.33	19.22	18.78	19.11	3.44	3.66	3.56	3.55	9.55	13.11	16.44	13.04	66.27	68.52	68.66	67.82
T_5	Application of 20 kg/ha of P + DGRC culture(10g/kg seed)	20.00	20.11	15.89	18.67	3.33	3.44	3.67	3.48	9.22	12.67	16.44	12.78	68.67	68.65	68.80	68.71
T_6	Application of 40 kg/ha of P+ DGRC culture(15g/kg seed)	20.11	22.22	18.89	20.41	4.11	4.11	3.89	4.04	10.89	16.00	16.66	14.52	69.57	68.57	68.71	68.95
T_7	Application of 60 kg/ha of P+ DGRC culture(10g/kg seed)	19.33	21.11	17.78	19.41	4.11	4.11	3.78	4.00	10.78	15.45	16.22	14.15	67.67	67.93	68.03	67.87
T_8	Application of FYM@2.5t/ha	18.44	20.67	18.67	19.26	3.33	3.89	3.56	3.59	9.44	14.78	16.22	13.48	66.85	67.60	67.78	67.41
T_9	Application of FYM@2.5t/ha + DGRC culture(10g/kg seed)	19.44	21.22	18.26	19.64	3.33	4.00	3.67	3.67	9.56	14.89	16.44	13.63	67.33	68.08	68.83	68.08
T_{10}	Application of DGRC culture (2 kg) enriched FYM @100kg/ha.	18.45	22.67	19.67	20.26	3.44	3.66	3.44	3.52	9.11	13.89	15.11	12.70	66.56	67.31	68.25	67.38
T_{11}	Application of FYM @ 5 t/ha + PSB (15ml/kg seed)	19.11	24.89	19.89	21.30	4.00	4.22	3.78	4.00	10.78	15.00	16.11	13.96	68.92	69.80	69.90	69.54
T_{12}	Application of 40 kg/ha of P + PSB	20.22	23.11	19.78	21.04	4.11	4.22	3.66	4.00	10.67	16.55	16.11	14.44	68.83	69.72	69.81	69.45
	S.Em. ±	0.84	1.24	1.33	0.67	0.17	0.17	0.31	0.13	0.51	0.78	1.34	0.54	0.61	0.59	0.65	0.35
	C.D. at 5%	NS	3.62	NS	1.89	0.50	0.48	NS	0.37	1.48	2.29	NS	1.54	1.78	1.74	NS	0.99
	C.V. %	7.6	10.26	12.81	10.35	8.16	7.43	14.88	10.57	8.97	9.41	14.68	12.26	1.56	1.51	2.11	1.56
	Y S.Em. ±	-	-	-	0.36	-	-	-	0.05	-	-	-	0.20	-	-	-	0.17
	C.D. at 5 %	-	-	-	1.01	-	-	-	0.14	-	-	-	0.57	-	-	-	0.47
	YXT S.Em. ±	-	-	-	1.16	-	-	-	0.23	-	-	-	0.94	-	-	-	0.61
	C.D. at 5%	-	-	-	NS	-	-	-	NS	-	-	-	NS	-	-	-	NS

Table 2 : Effect of different treatments on 100 kernel weight, oil percentage, number of nodules per plant and dry weight of nodules.

	Treatments	100 kernel weights(g)				Oil %				No of nodules/plant				Dry weight of nodules/plant(mg)			
		2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled
T_1	Control (no application of P)	38.43	38.14	41.05	39.21	48.24	49.24	45.09	47.52	26.50	21.56	17.89	21.98	32.58	32.89	33.02	32.83
T_2	Application of 20 kg/ha of P	39.10	38.80	43.48	40.46	48.44	49.21	49.70	49.12	33.50	27.44	24.11	28.35	42.09	36.67	43.76	40.84
T_3	Application of 40 kg/ha of P	38.39	38.18	43.14	39.90	48.50	48.95	49.83	49.10	34.61	28.22	21.78	28.20	70.50	38.39	39.24	49.38
T_4	Application of 60 kg/ha of P	38.60	39.30	43.94	40.62	48.56	48.97	48.45	48.66	34.61	25.44	20.67	26.91	67.08	42.56	37.69	49.11
T_5	Application of 20 kg/ha of P + DGRC culture(10g/kg seed)	41.00	40.70	41.23	40.98	48.69	49.65	47.63	48.66	38.61	26.89	24.11	29.87	78.33	45.44	43.54	55.77
T_6	Application of 40 kg/ha of P+ DGRC culture(15g/kg seed)	42.80	41.82	44.67	43.10	48.96	47.34	49.02	48.44	43.14	29.67	26.44	33.08	77.54	55.92	47.66	60.37
T_7	Application of 60kg/ha of P+ DGRC culture(10g/kg seed)	42.37	42.04	42.76	42.39	49.51	49.23	49.20	49.31	41.31	26.33	22.78	30.14	54.25	47.81	42.80	48.29
T_8	Application of FYM @ 2.5 t/ha	40.85	40.53	42.19	41.19	48.88	49.18	45.41	47.82	46.86	26.89	19.00	30.92	71.00	44.70	36.96	50.89
T_9	Application of FYM @ 2.5 t/ha+ DGRC culture(10g/kg seed)	41.33	41.01	41.74	41.36	49.21	49.62	47.29	48.71	45.72	26.67	27.22	33.20	66.53	49.61	51.47	55.87
T_{10}	Application of DGRC culture (2 kg) enriched FYM@100 kg/ha.	40.56	40.24	41.50	40.77	49.39	49.63	50.16	49.73	39.42	23.11	25.22	29.25	69.89	37.74	48.03	51.88
T_{11}	Application of FYM @ 5 t/ha + PSB (15ml/kg seed)	42.92	42.02	43.58	42.84	49.54	50.21	49.22	49.65	46.75	35.00	30.33	37.36	72.50	65.33	57.53	65.12
T_{12}	Application of 40 kg/ha of P + PSB	42.57	42.19	43.36	42.71	49.18	50.07	47.81	49.02	45.28	31.11	28.56	34.98	68.00	60.03	54.28	60.77
	S.Em.±	0.86	0.99	1.60	0.69	0.32	0.87	1.88	0.70	3.70	3.07	1.65	1.69	4.60	5.15	3.33	4.36
	C.D. at 5%	2.53	2.92	NS	1.95	NS	NS	NS	NS	10.86	NS	4.85	4.79	13.48	15.10	9.75	12.79
	C.V. %	3.67	4.26	6.48	5.02	1.14	3.07	6.75	4.30	16.16	19.41	11.92	16.75	12.40	19.21	12.90	14.80
	Y S.Em.±	-	-	-	0.30	-	-	-	0.30	-	-	-	0.89	-	-	-	1.28
	C.D. at 5 %	-	-	-	0.84	-	-	-	NS	-	-	-	2.51	-	-	-	3.75
	YXT S.Em.±	-	-	-	1.20	-	-	-	1.21	-	-	-	2.94	-	-	-	4.42
	C.D. at 5 %	-	-	-	NS	-	-	-	NS	-	-	-	NS	-	-	-	12.50

Table 3 : Effect of Different Treatments on Nutrients Uptakes by plant.

	Treatments	N uptake(kg/ha)				P uptake(kg/ha)				K uptake(kg/ha)			
		2019	**2020**	**2021**	**Pooled**	**2019**	**2020**	**2021**	**Pooled**	**2019**	**2020**	**2021**	**Pooled**
T_1	Control (no application of P)	96.4	116.9	114.4	109.3	6.27	11.38	6.52	8.06	22.58	30.14	28.20	26.97
T_2	Application of 20 kg/ha of P	98.3	136.6	128.6	121.2	6.97	11.80	7.14	8.64	23.84	35.96	31.24	30.35
T_3	Application of 40 kg/ha of P	111.8	104.4	138.0	118.1	7.50	12.75	7.08	9.11	29.20	40.01	29.90	33.04
T_4	Application of 60 kg/ha of P	114.0	128.8	146.9	129.9	9.78	14.26	7.94	10.66	28.40	40.28	34.52	34.40
T_5	Application of 20 kg/ha of P + DGRC culture(10g/kg seed)	97.8	137.2	157.7	130.9	9.09	12.91	7.47	9.82	25.21	40.13	29.62	31.65
T_6	Application of 40 kg/ha of P + DGRC culture(15g/kg seed)	120.2	166.4	189.3	158.6	9.18	15.54	10.06	11.59	28.64	44.73	34.37	35.91
T_7	Application of 60 kg/ha of P + DGRC culture(10g/kg seed)	124.2	151.9	157.8	144.6	10.61	18.02	9.00	12.54	32.57	51.28	34.97	39.61
T_8	Application of FYM @ 2.5 t/ha	104.7	147.8	142.1	131.5	8.20	13.00	8.63	9.94	24.40	37.09	35.84	32.44
T_9	Application of FYM@2.5 t/ha+DGRC culture(10g/kg seed)	106.7	155.0	169.8	143.8	7.34	13.84	9.79	10.33	23.19	38.51	33.90	31.87
T_{10}	Application of DGRC culture (2 kg) enriched FYM@100 kg/ha.	105.3	118.3	158.5	127.3	6.91	11.92	10.92	9.91	26.18	38.13	36.54	33.62
T_{11}	Application of FYM @ 5 t/ha+ PSB (15ml/kg seed)	122.7	170.8	153.5	149.0	9.10	16.24	9.06	11.46	30.22	48.45	42.50	40.39
T_{12}	Application of 40 kg/ha of P + PSB	133.2	167.2	153.8	151.4	10.39	16.39	10.76	12.52	32.39	49.83	38.48	40.23
	S.Em.±	6.5	14.7	13.9	7.1	0.97	1.25	0.83	0.61	1.94	3.47	4.03	1.90
	C.D. at 5%	19.2	NS	NS	20.0	2.92	3.61	2.50	1.71	5.69	10.14	NS	5.37
	C.V. %	10.1	18.0	15.9	15.8	19.63	15.86	17.23	17.52	12.19	14.77	19.59	16.67
	Y S.Em.±	-	-	-	3.6	-	-	-	0.33	-	-	-	0.80
	C.D. at 5 %	-	-	-	10.2	-	-	-	0.93	-	-	-	2.27
	YXT S.Em.±	-	-	-	12.3	-	-	-	1.05	-	-	-	3.29
	C.D. at 5 %	-	-	-	NS	-	-	-	NS	-	-	-	NS

Table 4 : Effect of different treatments on pod yield, haulm yield, kernel yield and oil yield of groundnut.

	Treatments	Pod yield (kg/ha)				Haulm yield (kg/ha)				Kernel yield (kg/ha)				Oil yield (kg/ha)			
		2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled
T_1	Control (no application of P)	1667	2094	1774	1845	2627	3463	3113	3068	1099	1401	1191	Pooled	531	690	529	583
T_2	Application of 20 kg/ha of P	1736	2528	1963	2076	2717	4004	3603	3441	1159	1714	1336	1230	562	844	664	690
T_3	Application of 40 kg/ha of P	2079	2767	1946	2264	3292	4377	3604	3758	1373	1909	1334	1403	666	935	663	755
T_4	Application of 60 kg/ha of P	2045	2831	1831	2236	3243	4481	3386	3703	1355	1940	1257	1539	658	950	610	739
T_5	Application of 20 kg/ha of P + DGRC culture(10g/kg seed)	1956	2992	2016	2321	3045	4726	3734	3835	1345	2053	1386	1517	655	1019	660	778
T_6	Application of 40 kg/ha of P + DGRC culture(15g/kg seed)	2116	3159	2463	2579	3310	5103	4561	4325	1401	2162	1691	1595	721	1021	828	857
T_7	Application of 60 kg/ha of P + DGRC culture(10g/kg seed)	2120	3149	2150	2473	3264	5096	4072	4144	1435	2137	1459	1775	711	1051	719	827
T_8	Application of FYM@2.5t/ha	1852	2639	2106	2199	2848	4322	3896	3689	1238	1784	1427	1677	605	877	652	711
T_9	Application of FYM @ 2.5 t/ha+ DGRC culture (10g/kg seed)	1759	2759	2129	2216	2731	4511	4236	3826	1184	1876	1465	1483	583	931	698	737
T_{10}	Application of DGRC culture (2 kg) enriched FYM@ 100 kg/ha.	1731	2368	2116	2072	2685	3907	4210	3601	1153	1593	1446	1509	570	790	725	695
T_{11}	Application of FYM @ 5 t/ha + PSB (15ml/kg seed)	2075	3102	2208	2462	3194	5145	4395	4245	1430	2165	1543	1397	708	1087	758	851
T_{12}	Application of 40 kg/ha of P + PSB	2128	3167	2476	2590	3380	5135	4233	4249	1466	2207	1727	1713	721	1105	829	885
	S.Em. ±	113	221	213	109	185	362	441	200	77	146	145	1800	39	74	77	38
	C.D. at 5%	330	648	**NS**	308	543	1062	**NS**	565	226	427	**NS**	73	115	216	**NS**	107
	C.V.%	10.06	13.69	17.57	14.35	10.59	13.87	19.48	15.69	10.21	13.2	17.41	206	10.59	13.54	19.09	14.91
	Y S.Em. ±	-	-	-	45	-	-	-	82	-	-	-	14.12	-	-	-	15
	C.D. at 5 %	-	-	-	127	-	-	-	231	-	-	-	31	-	-	-	42
	YXT S.Em. ±	-	-	-	189	-	-	-	346	-	-	-	86	-	-	-	65
	C.D. at 5 %	-	-	-	NS	-	-	-	NS	-	-	-	127	-	-	-	NS

Table 5. : Economics of different treatments.

	Treatments	GMR (Ra./ha)	CoC (Ra./ha)	NMR (Ra./ha)	BCR
T_1	Control (no application of P)	95297	36908	58389	2.58
T_2	Application of 20 kg/ha of P	107174	37477	69697	2.86
T_3	Application of 40 kg/ha of P	116906	38046	78859	3.07
T_4	Application of 60 kg/ha of P	115412	38616	76796	2.99
T_5	Application of 20 kg/ha of P + DGRC culture(10g/kg seed)	119799	38046	81752	3.15
T_6	Application of 40 kg/ha of P + DGRC culture(10g/kg seed)	133358	38616	94743	3.45
T_7	Application of 60 kg/ha of P + DGRC culture(10g/kg seed)	127854	39185	88669	3.26
T_8	Application of FYM @ 2.5 t/ha	113714	38616	75098	2.94
T_9	Application of FYM @ 2.5 t/ha+ DGRC culture(10g/kg seed)	115007	39185	75822	2.93
T_{10}	Application of DGRC culture (2 kg) enriched FYM@100 kg/ha.	107633	37545	70087	2.87
T_{11}	Application of FYM @ 5 t/ha+ PSB (15ml/kg seed)	127762	41006	86755	3.12
T_{12}	Application of 40 kg/ha of P + PSB (15ml/kg seed)	133559	38729	94829	3.45

yield.

In pooled results, application of 40 kg/ha of P + PSB or DGRC culture @ 15 ml/kg seed, was revealed significantly higher pod yield (2590 kg/ha), haulm yield (4249 kg/ha), kernel yield (1713 kg/ha) and oil yield (885 kg/ha), which was remained at par with application of 20 kg/ha of P + DGRC culture(10g/kg seed) T_5, Application of 40 kg/ha of P + DGRC culture(15g/kg seed) T_6, Application of 60 kg/ha of P + DGRC culture(10g/kg seed) T_7 and application of FYM @ 5 t/ha+ PSB (15ml/kg seed) T_{11}. A substantial quantity of applied P becomes unavailable to plants through complexation under calcareous and alkaline soil conditions with highly reactive Ca^{2+}. It has also been documented that P anions are very reactive, forming metal complexes with metal cations such as calcium in calcareous and alkaline soil. These reactions reduce the efficiency of applied P fertilizers by approximately 80% (Salvagiotti, 2017). Microorganisms such as phosphate solubilizing bacteria have been reported to modify phosphorus nutrition and increase its Solubilization in soil through many processes such as, they may decrease the pH of the soil by the producing organic (gluconic acid) and mineral acids, alkaline phosphatases, phytohormones and H^+ protonation, anion exchange, chelation and siderophores production which promote P solubilisation in soil (Rodriguez and Fraga, 1999). 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 matters 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 and Soumare *et al.*, 2003).

Effect of different P management options with PSB cultures on farm profitability and nutrient uptake

Economics of different treatments are presented in Table 5. Gross realization, cost of cultivation, net realization and B:C ratio of different treatments was worked out on the basis of current market prices of groundnut and inputs used. The results indicated that application of 40 kg/ha of P + PSB (15ml/kg seed) was recorded higher gross return (Rs. 1,33,559/ha), net return (Rs. 94,829/ha) and B:C ratio (3.45). Similarly, highest nutrient uptake of phosphorus (12.52 kg/ha) and potassium (40.23 kg/ ha) in groundnut after harvest was noticed with the application of 40 kg P_2O_5/ha PSB (15ml/kg seed). In case of nitrogen uptake (158.6 kg/ha) was higher with the application of 40 kg/ha of P + DGRC culture (15g/kg seed) (Table 3). Integrated application of P exits in the soil in several organic and inorganic forms in soil organic matter, minerals and in the soil solution. Plants taken up as orthophosphate ions from the soil solution. To maintain equilibrium, P moves from more available organic and inorganic pools to the soil solution. This more available or liable P includes mineralizable organic P, readily exchangeable adsorbed P moves from less available pools which include stable organic P and is strongly absorbed to soil minerals and compounds into liable pools to maintain P equilibrium status in the soils, thereby increases the nutrient uptake and biological yield of crops (Hao and Chang, 2002). Moreover, integrated P management using chemical 40 kg/ha P fertilizer + PSB culture or DGRC culture led to reduction in plant requirements for inorganic P fertilizer which is likely to reduce cost of cultivation by reducing the dependent as on chemical P fertilizer. The results are in close agreement with the findings of many researchers (De Jager *et al*., 2001; Palm *et al*., 2001 and Ouedraogo *et al*., 2001). The present study revealed that application of 40 kg/ha P_2O_5/ha + DGRC culture effective in improving the growth, productivity and profitability and nutrient uptake of groundnut.

Conclusion

From the present study authors conclude that, application of 40 kg P_2O_5/ha + PSB (15 ml/kg seed) or DGRC culture showed significant increase in the growth and yield parameters of groundnut *viz*., plant height (21.04 cm), number of branches per plant (4.0), number of pods per plant (14.44) and pod yield (2590 kg/ ha) as compare to other treatments and it has saved 20 kg P_2O_5/ha by increasing the higher gross return (Rs. 1,33,559/ ha), net return (Rs. 94,829/ha) and B:C ratio (3.45) and the highest nutrient uptake of phosphorus (12.52 kg/ha) and potassium (40.23 kg/ ha) in pooled results.

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