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Full Research Article

Influence of Integrated Nutrient Management in Pigeonpea [*Cajanus cajan* (L.) Millisp.] Based Inter-cropping System under Rainfed Condition

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Abstract

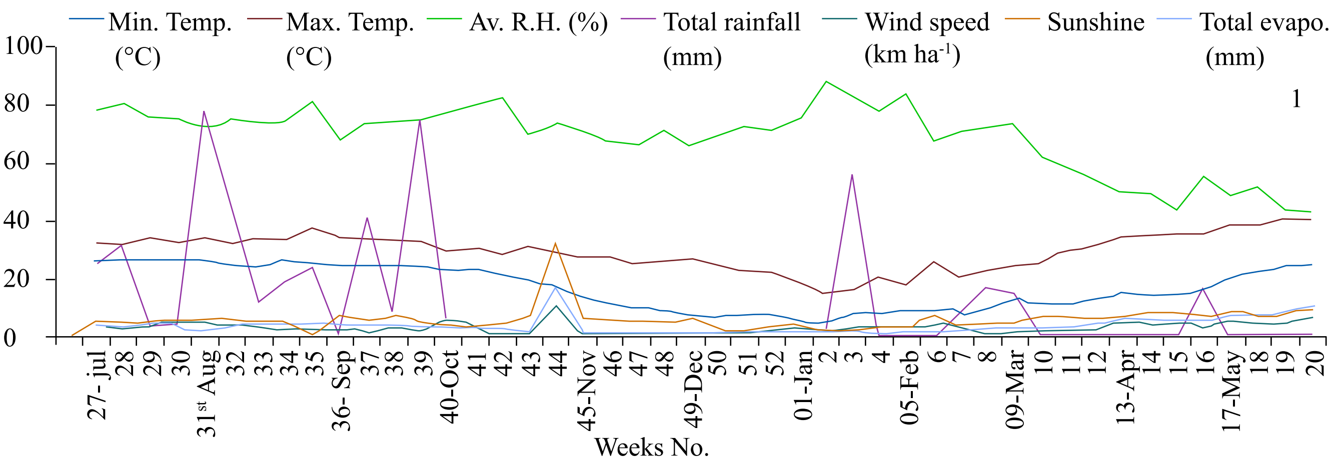
A field experiment was conducted during *kharif* season of 2013−14 and 2014−15 at agronomy research farm, Narendra Dev University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh, India on silty loam soils as influence of integrated nutrient management in Pigeonpea based inter-cropping system. The treatments comprised of three intercropping systems of Pigeonpea sole, Pigeonpea+black-gram and Pigeonpea+maize with four different integrated nutrient management's levels. On the basis of two years results, Pigeonpea with black gram intercropping systems recorded significantly superior Pigeonpea grain yield (18.65 and 15.82 q ha^{-1}), Pigeonpea equivalent yield (25.35 and 23.47 q ha^{-1}), microbial population in cfu g^{-1} dry soil, such as Bacteria (11.65 and 11.62), Actinomyceties (7.62 and 7.50), Fungi 6.07 and 5.92) and Dehydrogenase activity (17.02 and 15.94 µg TPF g^{-1} h^{-1}), gross returns (10460 and 102061 ha^{-1}), net returns (68872 and 70170 ha^{-1}) and B:C ratio (2.18 and 2.20), respectively as compared to sole Pigeonpea and Pigeonpea+maize intercropping. Among the INM practices, application of RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1} prove effective and recorded significantly higher Pigeonpea grain yield and equivalent yield, microbial population and Dehydrogenase activity in soil. Similarly, highest gross returns (92356 and 93467 ha^{-1}), net return (61389 and 52197 ha^{-1}) was found in N_4.

1. Introduction

Pulses are equally important for maintaining soil health and sustainability of different cropping systems. By virtue of being a restorer of soil fertility, pulses have a unique position in cropping systems and dry land rainfed agriculture. pigeonpea, a deep rooted crop with slow initial growth rate between 45 and 60 days after sowing is well suited for intercropping. Intercropping is an intensive land use system with an objective to utilize the space between the rows of main or base crop and to produce more produce $unit^{-1}$ area. The space between the rows could be effectively utilized by growing a short duration crop, which may generate an additional income without adversely affecting the yield of pigeonpea Jat and Ahlawat (2010). To enhance the productivity of this crop, use of balanced fertilization by application of organic manures, NPK along with biofertilizers viz., *Rhizobium* and PSB is of great importance. Inoculation of pulses with PSB, *Rhizobium* and Harit Vardan causes growth stimulation of plant and enhances crop yields. The synergism has also been reported between *Rhizobium* spp. and PSB in soybean Dubey (1997). Organic matter inputs through organic amendments, in addition to supplying nutrients, stimulate microbial diversity and activity and improved soil aggregation, which had positive effects on soil water content, temperature, aeration and mechanical impedance Ferreras et al. (2006). Harit Vardan protect crop plants under water stress conditions by making regular supply of moisture and nutrient throughout the crop season and increase water and fertilizer use efficiency. It has been considered as "Sanjivani" for plants, "boon" for farmers and "Ram ban" for agriculture Singh (2011).

2. Materials and Methods

The field experiment was conducted during *kharif* season of 2013−14 and 2014−15 at agronomy research farm, NDUA&T, Kumarganj Faizabad, Uttar Pradesh, India situated in subtropical sub humid climate in indo-gangatic plains and lies between 26.47° North latitude and 81.12° East longitude with is an elevation of about 113 m. The temperature, rainfall and humidity were represented in Figure 1 and 2. The treatment comprised three inter cropping (C_1-pigeonpea sole, C_2-pigeonpea+black-gram and C_3-pigeonpea+maize) and four INM (N_1-RDF, N_2-RDF+PSB+*Rhizobium,* N_3-RDF+PSB+*Rhizobium*+FYM @ 3



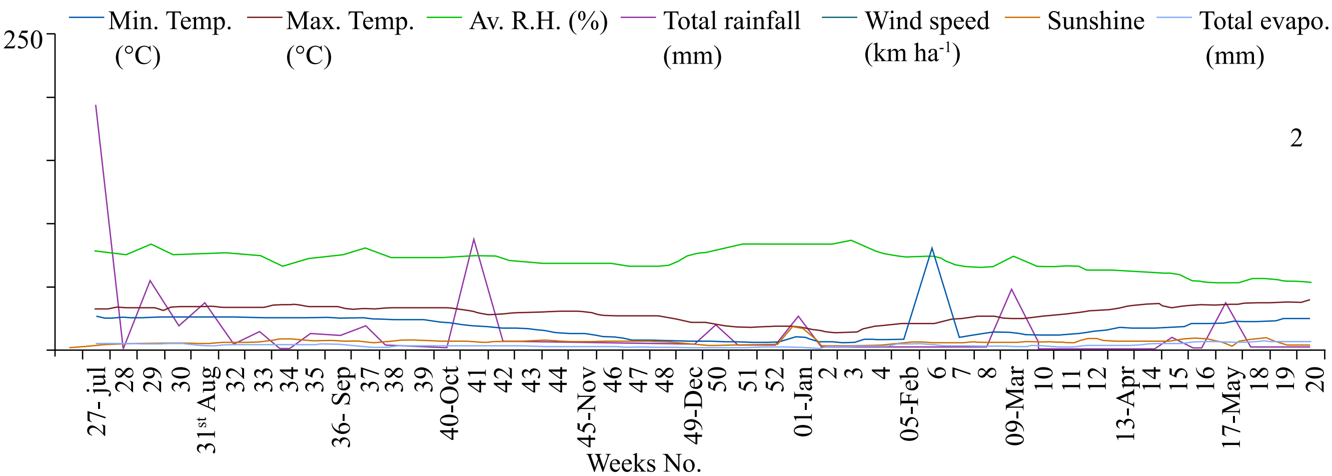


Figure 1 & 2: Mean weekly meteorological data received during July-2013−14 and 2014−15

t ha^{-1} and N_4-RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1}) alone with sole cropping of pigeon-pea, black gram and maize. The experiment was laid out in factorial randomized block design (2 Factors) with three replications. The experimental soil was silty loam in textural having low in organic carbon (0.39%), available N, P, and K was 155.96, 16.00 and 238.60 kg ha^{-1}, respectively with pH (7.86). The varieties namely pigeonpea (Narendra Arhar-1), Blackgram (Narendra Urd-1) and Maize (MM-1107) were sown in first week of August. Black gram and maize were harvested during October and November (2013−14, 2014−15) respectively. Seeds of pigeon-pea and black-gram were inoculated with *Rhizobium* and PSB before sowing. The Soil samples up to 15 cm depth were collected from individual plot after harvesting the pigeonpea crop. One soil sample of each plot was air dried; proceed to pass through 2 mm sieve. Soil samples was stored at low temperature in the deep freezer and used for estimation of different soil biological properties. The population of bacteria, actinomyceties and fungi in soil was determined by cereal dilution pour plate using Thornton's medium for bacteria Thornton's (1922), Ken Knight and Munaier's medium for actinomyceties Subba Rao (1986) and Martin's Rose-Bengal streptomycin agar medium for fungi Martin (1950), respectively. Dehydrogenase activity of soil (2, 3, 5 triphenyl tetrazolium chloride) was determined by Ross (1970).

3. Results and Discussion

3.1. Growth characters

Results on growth pattern of pigeonpea, black gram and maize are presented in Table 1. Among the intercropping systems, pigeonpea+black gram recorded significantly maximum values of growth pattern of pigeonpea viz., plant height (294.14 and 288.24 cm), number of branches plant^{-1} (26.58 and 15.60) and dry matter production plant^{-1} (411.21 and 345.88) than pigeonpea sole intercropping followed by pigeonpea+maize during both years. It may be attributed to well distribute rainfall resulting favorable condition for proper growth of pigeonpea+Black gram during 2013−14 as compared to 2014−15. The similar results were found by Kumar (1993). Here it may be pointed out that the competition between pigeonpea and maize for space sunlight, nutrient and water etc. was more than black gram which resulted poor growth and development of pigeonpea under pigeonpea+maize intercropping system Singh and Pal (2003). Further, black gram crop also improved the fertility status and physical condition of soil which augmented growth and development of pigeonpea under pigeonpea+black gram intercropping system has also be reported by Kumar et al. (2003).

Application of FYM @ 5 t ha^{-1} along with RDF+PSB+*Rhizobium* culture+harit vardan were also significantly higher plant height, No. of branches and dry matter production as compared to RDF alone and its parts during both the years due to higher availability of nutrients and sufficient nodulation that ultimately

Table 1: Growth parameter of pigeonpea, black gram and maize as influenced by intercropping and INM levels

Treatments	Pigeonpea						Black gram						Maize					
	Plant height (cm)		No. of branches $plant^{-1}$		Dry matter production $plant^{-1}$ (g)		Plant height (cm)		No. of branches $plant^{-1}$		Dry matter production $plant^{-1}$ (g)		Plant height (cm)		No. of leaves $plant^{-1}$		Dry matter production $plant^{-1}$ (g)	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
Intercropping system																		
C_1-PP sole	270.34	271.42	24.15	14.96	377.19	309.11	-	-	-	-	-	-	-	-	-	-	-	-
C_2- PP+Black gram	294.14	288.24	26.57	15.6	411.21	345.88	-	-	-	-	-	-	-	-	-	-	-	-
C_3- PP+Maize	250.18	237.51	17.28	9.86	283.49	246.84	-	-	-	-	-	-	-	-	-	-	-	-
SEm±	6.46	5.53	0.42	0.27	0.18	7.02	-	-	-	-	-	-	-	-	-	-	-	-
CD (*p*=0.05)	18.95	16.2	1.22	0.8	0.53	20.58	-	-	-	-	-	-	-	-	-	-	-	-
Integrated nutrient management system																		
N_1-RDF	232.93	227.09	19.6	10.31	303.96	250.76	52.21	63.24	9.33	9.302	12.18	13.45	148.3	142.40	9.5	9.12	285.2	268.03
N_2- N_1+PSB+*Rhizobium*	261.53	254.38	21.82	12.65	341.77	284.22	59.47	67.83	10.82	12.07	15.12	16.96	154.21	154.21	10.23	9.93	309.34	295.82
N_3- N_2+FYM @ 3 t ha^{-1}	289.11	283.94	24.2	15.15	382.75	326.68	63.24	71.35	11.9	14.17	17.77	20.07	163.63	163.63	11.87	11.48	360.23	347.39
N_4-N_3+Harit Vardan @ 5 kg ha^{-1}	302.64	297.48	25.04	15.78	400.69	340.79	65.12	72.89	12.22	15.10	18.87	21.47	165.12	165.12	12.02	11.6	364.99	353.43
SEm±	7.46	6.38	0.48	0.32	0.21	8.1	1.88	3.05	0.4	0.43	0.57	0.74	5.54	7.65	0.73	0.33	16.37	12.20
CD (*p*=0.05)	21.88	18.71	1.41	0.93	0.61	23.76	6.52	10.57	1.4	1.50	1.97	2.58	NS	NS	NS	1.14	56.63	42.23

enhance the height of plants Singh (2007); Rameshwar and Singh (1998). The results was also supported by Reddy et al. (1991), dry matter accumulation were increased because more availability nutrient that promoted the metabolic activities, accelerated cell division and of metabolic tissues, ultimately enhance the number of branches plant^{-1} Tomar (1998).

3.2. *Yield of component crop and pigeonpea equivalent*

The higher grain yield of pigeonpea (18.65 and 15.82 q ha^{-1}) was recorded under pigeonpea+blackgram intercropping system which was significantly higher to pigeonpea sole (17.07 and 14.03 q ha^{-1}) and pigeonpea+maize (12.58 and 10.98 q ha^{-1}) in both the years (Table 2). Sizable reduction in pigeonpea yield under pigeonpea+maize intercropping system was due to more competition between maize and pigeonpea for space, nutrients, soil moisture and solar energy of Joshi et al. (1999). Pulses crop seed Inoculated with PSB+*Rhizobium* culture along with RDF and FYM increased the grain yield of pigeonpea, black gram and maize. Significantly higher pigeonpea equivalent yield (PEY) (25.35 and 23.47 q ha^{-1}) and Rain Water Use Efficiency (5.92 kg ha^{-1} mm^{-1}) was recorded under pigeonpea+black gram intercropping system over pigeonpea sole and pigeonpea+maize. Inclusion of black gram and intercrop with pigeonpea attributed to less exhaustion of soil fertility, reduced early stage of crop weed competition due to their smothering effect on weeds compared to sole pigeonpea and pigeonpea+maize intercropping, thereby increased the yield indices and finally the grains equivalent yield of pigeonpea Panday et al. (2003). Inoculation of pigeonpea and blackgram seeds with PSB and *Rhizobium* culture significantly increased PEY (19.49 and 17.58 q ha^{-1}) and RWUE (3.78 and 4.44 kg ha^{-1} mm^{-1}) over RDF alone. Similarly addition of FYM @ 5 t ha^{-1} along with RDF+PSB+*Rhizobium* culture were also significantly increased the PEY (21.98 and 20.32 q ha^{-1}) over rest of the nutrient management system while at par with addition of Harit Vardan biofertilizer during 2013-14

Table 2: Yield component and pigeonpea equivalent yield as influenced by pigeonpea based intercropping and INM levels

Treatments	Yield (q ha^{-1})								RWUE kg ha^{-1} mm^{-1}	
	Pigeonpea		Black gram		maize		Pigeonpea equivalent			
	2013−14	2014−15	2013−14	2014−15	2013−14	2014−15	2013−14	2014−15	2013−14	2014−15
A. Inter-cropping system										
Pigeonpea sole	17.07	14.03	-	-	-	-	17.26	14.03	3.30	3.54
Pigeonpea+ Black gram	18.65	15.82	6.71	7.74	-	-	25.35	23.47	4.87	5.92
Pigeon pea+maize	12.58	10.98	-	-	-		19.17	18.59	3.71	4.69
SEm±	0.33	0.39	-	-	26.28	25.32	0.34	0.58	-	-
CD (p=0.05)	0.98	1.15	-	-	-	-	1.00	1.72	-	-
B. Integrated nutrient management levels										
RDF (20:40:0) kg^{-1}	13.73	11.28	4.92	5.96	22.54	21.34	11.25	15.41	3.34	3.89
RDF+PSB+ *Rhizobium*	15.42	12.76	6.06	7.32	24.72	23.72	19.49	17.58	3.78	4.44
RDF+PSB+ *Rhizobium*+ FYM @ 3 t ha^{-1}	17.2	14.72	7.10	8.46	28.91	27.88	21.98	20.32	4.26	5.13
RDF+PSB+ *Rhizobium*+ FYM @ 3 t ha^{-1}+ Harit Vardan @ 5 kg ha^{-1}	18.05	15.69	7.76	8.83	29.36	28.35	23.08	21.48	4.47	5.42
SEm±	0.39	0.45	0.25	0.30	0.98	0.88	0.39	0.66	-	-
CD (p=0.05)	1.13	1.32	0.87	1.03	3.39	3.04	1.60	1.94		

and 2014−15, respectively. The higher grain equivalent yield user intercropping system might be attributing to additional advantage of intercrop yield and their support price Reddy et al. (2007). Similarly, integrated nutrient application also increased the pigeonpea equivalent yield also reported by Kumar and Rana (2007) and

3.3. *Microbial population in soil*

Intercropping of pigeonpea+black gram maintained significantly higher microbial population (bacteria, actinomyceties and fungi cfu10^6 g^{-1} dry soil) as compared to sole and pigeonpea+maize intercropping in both the years (Table 3). This is possibilityd ue to decomposing roots nodules and root tissues also provide carbon and energy to the soil microbes resulting in to increased microbial population Geethakumari and shivashankar (1991).

The application of RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1} +Harit Vardan @ 5 kg ha^{-1} resulted in maximum microbial population of bacteria (11.79 and 11.66 cfu10^6 g^{-1} dry soil), actinomyceties (7.95 and 7.29 cfu10^6 g^{-1} dry soil) and fungi (6.26 and 6.15 cfu10^6 g^{-1} dry soil), respectively. There was increased in microbial population such as bacteria 6.60, 15.18 and 15.81%, actinomyceites 10.24, 28.94 and 29.26% and fungi 16.87, 16.59 and 29.42% during first year. While during second year, bacteria 9.76, 16.07 and 18.61%, actinomyceties 10.88, 26.16 and 30.80% and fungi 16.59, 15.47 and 29.74 were observed respectively as compared to RDF alone. This might be due to availability of more nutrients for growth of rhizospheric microbial population and key role of PSB, *Rhizobium,* FYM and Harit Vardan which could exhibition both direct and indirect effect in increasing microbial population in soil. Similar results were reported by Bhardwaj and Omanwar (1992) and Patil and Varade (1998). The incorporation of FYM, Harit-vardan with biofertilizer which is increased the soil microbial biomass than the chemical fertilizers. Better plant growth also contributes to higher microbial biomass as reported by Manna and Ganguly (2001).

3.4. *Dehydrogenase enzyme activity*

The maximum activity of dehydrogenase activity (DHA) was observed in pigeonpea with black gram in soil during both the years, which was significantly higher than all the other treatments during both the years (Table 3). In generally DHA of pigeonpea+black gram was 6.50 and 6.89%, 6.10 and 12.50% greater than pigeonpea sole followed by 42.54 and 43.22% and 28.66 and 27.13% during 2013-14 and 2014-15, respectively. It might be due to buildup of their population in the rhizosphere.

The application of RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1} also recorded significantly higher values of dehydrogenease activity in soil, although it was statically at par with the application of RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1} treatments. The effect of FYM and Harit vardan on dehydrogenease activity might be more easily decomposition of FYM on the metabolism of the microorganism Pancholy and Rice, (1973). Dehydrogenase activity was also impacted

Table 3 : Microbial population as influenced by pigeonpea based intercropping and integrated nutrient levels

Treatments	Viable counts (cfu g^{-1} dry soil)						Dehydrogenase activity (µg TPF g^{-1} h^{-1})	
	Bacteria (×106)		Actinomycetes (×104)		Fungi (×103)			
	2013−14	2014−15	2013−14	2014−15	2013−14	2014−15	2013−14	2014−15
A. Inter-cropping system								
Pigeonpea sole	11.31	11.10	7.31	7.17	5.77	5.72	15.98	14.94
Pigeonpea+Black gram	11.65	11.62	7.62	7.50	6.07	5.92	17.02	15.97
Pigeonpea+maize	10.36	10.04	6.69	6.29	5.22	5.20	11.94	11.15
SEm±	0.141	0.176	0.16	0.154	0.142	0.121	0.136	0.172
CD (p=0.05)	0.415	0.517	0.46	0.452	0.416	0.356	0.397	0.506
B. Integrated nutrient management levels								
RDF	10.14	9.83	6.15	5.97	4.86	4.64	14.22	12.68
RDF+PSB+Rhizobium	10.81	10.79	6.78	6.62	5.68	5.41	14.81	13.37
RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}	11.68	11.41	7.93	7.53	6.20	6.02	15.47	14.77
RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1}	11.79	11.66	7.95	7.81	6.29	6.15	15.63	15.26
SEm±	0.163	0.204	0.18	0.178	0.164	0.140	0.157	0.199
CD (p=0.05)	0.479	0.597	0.54	0.522	0.480	0.411	0.459	0.584

by changes in soil organic carbon Aon et al. (2001) as higher level of organic carbon stimulated microbial activity.

3.5. Economics

pigeonpea+black gram intercropping system recorded significantly higher gross returns (₹ 100460 and ₹ 102061 ha^{-1}), net returns (₹ 68872 and ₹ 70170 ha^{-1}) and B:C ratio (2.18 and 2.20) as compared to the gross returns (₹ 76657 and ₹ 80888 ha^{-1}), net returns (₹ 43869 and ₹ 47796 ha^{-1}) and B:C ratio (1.34 and 1.44) obtained from pigeonpea+maize intercropping system in both the years (Table 4). Similar reports were obtained by Rathod et al. (2004), when frenchbean, soybean and greengram were intercropped with pigeonpea. Among the different fertility levels, application of RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1} recorded significantly higher gross returns (₹ 92356 and ₹ 93467 ha^{-1}) and net returns (₹ 61389 and ₹ 52197 ha^{-1}) over other fertility levels, but it was at par with application of RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1} respectively. Similar results were also reported by Rajkhowa et al. (2002) in greengram and Sharma (2009) in pigeonpea.

Table 4: Economical yield of pigeonpea as influenced by pigeonpea based intercropping and integrated nutrient levels

Treatments	Cost of cultivation (₹ ha^{-1})		Gross return (₹ ha^{-1})		Net return (₹ ha^{-1})		Benefit: Cost	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
Inter-cropping system								
Pigeonpea sole	25688	25989	68220	58407	42532	32418	1.66	1.25
Pigeonpea+Black-gram	31588	31891	100460	102061	68872	70170	2.18	2.20
Pigeonpea+maize	32788	33092	76657	80888	43869	47796	1.34	1.44
Integrated nutrient management levels								
RDF	29100	29402	68987	63521	39887	34119	1.37	1.16
RDF+PSB+*Rhizobium*	29175	29480	77933	76458	48758	46978	1.67	1.59
RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}	30175	31145	87840	88364	57665	57219	1.91	1.84
RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1}	30967	31270	92356	93467	61389	52197	1.98	1.98

4. Conclusion

Combined application of (T_4) RDF+PSB+*Rhizobium*+FYM @ 3 t ha^{-1}+Harit Vardan @ 5 kg ha^{-1} was found economically beneficial for obtaining higher productivity and economic return of pigeonpea+black gram intercropping over sole pigeonpea and pigeonpea+maize under rain fed condition during both the years.

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