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EFFECT OF ORGANIC, INORGANIC AND BIOFERTILIZERS ON PRODUCTIVITY AND ECONOMICS OF GROUNDNUT-PIGEONPEA RELAY INTERCROPPING SYSTEM IN *vertisols* OF GUJARAT

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ABSTRACT

Experiments were conducted at Pulses Research Station, Junagadh Agricultural University, Junagadh during 2009-10 to 2012-13 in *kharif* season with the objective of finding out the effect of various types of fertilizer (organic, inorganic and biofertilizers) on nutrient management in groundnut and pigeonpea relay intercropping system. The results of the study revealed that the application of recommended dose of fertilizers (100 % RDF) to both crops showed significant improvement in the final yield viz groundnut (1299 kg/ha) and pigeonpea (1501 kg/ha). In case of organic matter treatments, first year of the study, organic matters are not showing any significant effect on the improvement of yield as compared to onward years in both the crops. In case of equivalent seed yield, application of 100% RDF recorded highest pigeonpea equivalent (PE) seed yield (2546 kg/ha) which statistically remained on the same bar with 50% RDF + 5 ton FYM/ha + *Rhizobium* + PSB by producing 2350 kg/ha PE seed yield. However, three year study revealed that the reduction in chemical fertilizers upto 50% of RDF gave 7.7% less yield over 100% RDF application. Similarly, higher net return was recorded in 100% RDF to both the crops (Rs. 64.4×10³/ha) than 50% RDF + 5 ton FYM/ha + *Rhizobium* + PSB (Rs. 59.3×10³/ha). From the view point of economics, application of 50% RDF + 5 ton FYM/ha + *Rhizobium* + PSB to groundnut provided an alternate best option of nutrient management in groundnut-pigeonpea relay intercropping system.

Abbreviations : B:C -Benefit-Cost ratio; FYM - Farm Yard Manure; Ha - Hectare; K - Potassium; Kg - Kilogram; N - Nitrogen; P - Phosphorus; PE - Pigeonpea equivalent; PSB - Phosphate Solubilizing Bacteria; RDF - Recommended Dose of Fertilizers; Rs - Rupees (Indian Currency); VC - Vermicompost

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1 Introduction

Use of nutrient for agricultural production is an essential factor to increase food production but continuous use of chemical fertilizers has deleterious effects on soil which in turn cause decline in productivity, low nutrient recovery efficiency and increase in cost of production and environmental pollution (Sarkar et al., 1997). Soil degradation is occurring due to inadequate and imbalanced fertilization. Even though edible oils are an important consumer item and are next to food grain in Indian diet but its per capita consumption is very less as compared to the world scenario (14.5 kg). Despite the poor level of consumption of oils and fats (7.13 kg in India), the demand of these products has been expanding much faster than indigenous availability (Sodhganga, 2014).

Groundnut or peanut (*Arachis hypogaea* L.) which is also known as a 'King' of oilseed (Sathya Priya et al., 2013) is a rainfed crop and grown in *kharif* season (Varghese, 2011). Groundnut oil is edible oil and finds extensive use as a cooking medium both as refined oil and vegetable Ghee. It is also used for soap making, and manufacturing cosmetics and lubricants. Its kernels are also eaten raw, roasted or sweetened. They are rich in protein and vitamins A, B and some members of B_2 group. Their calorific value is 349 per 100 gram seed. It is an important food, fodder and cash crop for the farmers of India. Groundnut also has value as a rotation crop. Being a legume with root nodules, it can synthesize atmospheric nitrogen and therefore improve soil fertility. The residual oilcake contains 7-8% N, 1.5 % P_2O_5 and 1.2% K_2O and is used as an organic fertilizer and it is also used for manufacturing artificial fibre. It is an important protein supplement in cattle and poultry rations. The haulms (plant stalks) are fed (green, dried or silage) to livestock. Groundnut shell is used as fuel for manufacturing coarse boards, cork substitutes etc.

In India, about 75% of the groundnut area lies in a low to moderate rainfall zone with a short period of distribution. It has been grown over an area of 5.31 million ha and producing 6.93 million tonnes of groundnut (DOAC, 2012) with productivity of 1305 kg/ha in Indian context. Its cultivation is mostly confined to the states of Gujarat, Andhra Pradesh, Maharashtra, Tamil Nadu and Karnataka. The average area under groundnut cultivation in Junagadh district during 2011 was 4.42 lakh hectares with production of 9.57 lakh tonnes and productivity of 2162 kg/ha (DOAC, 2012). One of the important reasons for low productivity of groundnut at national level is vagaries of monsoon and nutrient management. Inadequate and uneven distribution of rainfall along with aberrant weather condition and temperature caused second generation problems in nutrient management. Efficiency in use of natural resources has been central to agricultural practice for over 10,000 years and yield per unit land area is the simplest and most widely used eco-efficiency measure for field crops (Keating et al., 2010). Hence, the most feasible approach to enhance crop yield is growing crops from beginning of monsoon season to post monsoon season by adopting concept of relay intercropping system.

Groundnut contributes about 40 per cent to the total oilseeds production in the country (Sathya Priya et al., 2013). At this level of contribution the projected demand of groundnut by 2020 will reached near about 14 million tonnes while the present production level are around the 6.9 million tonnes. Therefore, a gap of about 7.1 million tonnes needs to be filled and this can be possible if the production rate will increase about 2.2 percent per annum. This growth has to come mainly by the increase in productivity though continuous cropping system. At present, average yield in the *kharif* is around 900 kg/ha and the *rabi* is around 1500 kg/ha. A fair projection for enhanced productivity with sustainability by 2020 will be about 1100 kg/ha (about 22% increase) for *kharif* groundnut and 2000 kg/ha (about 25% increase) for *rabi* groundnut (CRIDA, 2003. Walia et al. (2007) reported that there is an urgent need to explore the possibilities for increasing the productivity through better understanding of the constraints in production of oilseed crops especially in groundnut.

Pigeonpea (*Cajanus cajan*) is a fast growing crop with its extensive root system. Its tap root system allows optimum utilization of soil moisture and soil nutrients and can be an ideal crop in groundnut relay intercropping system. Bidinger (1981) observed that pigeonpea used as a most preferred pulse crop in Indian villages and its consumption patterns differed widely by age group, farm size, and the village. Intercropped annual legumes (pigeonpea) and small amounts of inorganic fertilizer offer a strategy to meet the N needs on smallholder farms (Jeranyama et al., 2000).

Being the area of origin and the principal center of diversity, India had a virtual monopoly in the production of pigeonpea in the total world production. The plants are often intercropped, or grown as hedges or single plants near houses where they contribute to the protein diet (Van der Maesen, 1983). It may be noted that homestead production is quite common in many tribal areas of India. However, because of its multiple uses such as a source of food, fodder, feed, fuel, and fertilizer interest in the cultivation of this crop is increasing in many countries. In addition, the cultivation of pigeonpea brings improvement in the soil structure and because of this it is known as soil plough. Considerable organic matter decomposition also takes place in the soil because of their extensive root system. Pigeonpea, being a deep rooted leguminous crop helps to build up of soil fertility. Therefore, any improvement in the productivity of this plant would be a great blessing to the rural community (Anon, 1981).

To stabilize crop production and to provide insurance against aberrant weather situation, relay intercropping could be a viable agronomic option for risk minimizing, more profit and sustainable venture. To elevate yield of a cropping system, the most feasible approach is continuous cropping from beginning of the monsoon season to post monsoon by adopting concept of mixed/inter/relay cropping system. It provides an opportunity to use per unit land, water, nutrient and money invested efficiently. Substantial yield advantage can be achieved through inter/relay cropping as compared to sole cropping. Singh et al., (2006) reported that nutrient balance of N, P and K in the soil after harvest of crops was highest at recommended dose of fertilizer applied to pigeonpea and groundnut in intercropping system.

Groundnut-pigeonpea is an emerging most important relay intercropping system in India, especially in Gujarat and Maharashtra (AICRP, 2002-07). A report on research achievements of All India Coordinated Research Project on Crop Science reported that in Groundnut + Pigeonpea inter cropping system, maintaining 100% plant density in groundnut and 75% in pigeonpea or 75% of groundnut and pigeonpea, and fertilizing with 50% of RDF to both the crops found most optimal combination and remunerative at Dharwad, Jalgaon and Junagadh (AICRP, 2002-07). Use of farm derived organic sources can be an ideal option to reduce not only the expenditure on inorganic fertilizers in groundnut-pigeonpea cropping system but also for raising farm produce for small land holders.

Organic farming is not new term for Indian community and it has been successfully used by the Indian farmers from hundreds of the years. Like other parts of India, it is also very common in the rainfed areas of south Gujarat. Even today, the farmers do not have enough funds to purchase costly chemical fertilizers and other agricultural chemicals and use lesser amount of organic fertilizers. Farmers apply chemical fertilizers to both the crops with poor application of organic sources of fertilizers. It has been observed that farmers can reduce the dosage of costly chemical fertilizers by adopting organic sources in combination with inorganic fertilizers.

Use of efficient strains of bio-fertilizers are environment friendly, low cost agricultural inputs that have an important role in improving nutrient supply to crops but also reducing the cost of production (Kumar, 2013). Integrated approach of nutrient management by chemical fertilizers along with organic manures and bio-fertilizers is gaining importance but there is no information to replace costly chemical fertilizers for the groundnut-pigeonpea relay intercropping system. Hence, the present investigation was conducted to find out the effect of organic, inorganic and bio-fertilizers on yield trends and an alternate nutrient management option in groundnut-pigeonpea relay intercropping system in *vertisols* of south Gujarat.

Uses of fertilizers are considered as a barometer for agricultural production; no doubt it played a key role in agricultural production. But short in supply and escalating prices of chemical fertilizers, increasing the awareness in favour of adopting biological routes of fertilizer management. This can prevent the soil from degradation and can increase the efficiency of applied fertilizers. Palaniappan & Annadurai (2007) reported that combining of organic and inorganic fertilizer with biofertilizers gave high production than the individual application of both. The organic manure and bio-fertilizers on the other side provide a good substrate for crop growth and favourable nutrient supply environment to the crops. The application of available organic sources with N, P_2O_5 and K_2O obtained maximum productivity under the fine textured *Vertisols* (Behara et al., 2007).

2 Materials and Methods

Experiments were carried out at Pulses Research Station, JAU, Junagadh during crop years 2009-10, 2010-11 and 2012-13 to evaluate the effect of various types of fertilizer (organic, inorganic and biofertilizers) on nutrient management in groundnut-pigeonpea relay intercropping system. The soil was *Vertisol* with pH 7.8 and medium in organic carbon (0.65%) with clay loam texture. It was low in alkaline permanganate oxidizable available N (202.8 kg/ha), medium in Olsen's available P (44.4 kg/ha) and high in 1 M ammonium exchangeable K (294.4 kg/ha). The experiment consisted of seven treatments, each replicated thrice in randomized block design in individual gross plot size of 10 m × 7.2 m. The treatments were RDF1 (100% Recommended Dose of Fertilizers), FYM1 (@10 ton/ha), VC1 (@ 1 ton/ha), RDF2 + FYM2 (@ 50% RDF + 5 ton FYM/ha), RDF2 + VC1 (@ 50% RDF + 1 ton VC/ha), RDF2 + FYM2 + *Rhizobium* + PSB (@ 50% RDF + 5 ton FYM/ha + *Rhizobium* @ 25 g/kg seed + PSB @ 30 g/kg seed) and RDF2 + FYM3 + *Rhizobium* + PSB (@ 50% RDF + 1 ton FYM/ha + *Rhizobium* @ 25 g/kg seed + PSB @ 30 g/kg seed). RDF1 (100%) was applied to both crops while the rest of treatments were applied to groundnut crop only. Among crop varieties Gujarat Groundnut 20 for groundnut and Gujarat Tur 101 for pigeonpea were grown during the experimental period. The recommended doses of fertilizers for groundnut and pigeonpea are 12.5-25-00 and 25-50-00 kg NPK/ha, respectively. Full dose of Phosphorus and Potash were applied at the time of sowing of both the crops as di-ammonium phosphate. Seeds of groundnut were treated with *Rhizobium*/ PSB (10^8 cfu/g) @ 25/30 g/kg seed. All the agronomical practices were carried out as per recommendations of the crops. The pigeonpea crop was sown in mid of August each year as a rely crop keeping 2:1 row ratio of groundnut-pigeonpea. Groundnut and pigeonpea crops were sown at 2: 1 ratio keeping row and plant distance 60-cm × 10-cm for groundnut and 120-cm × 30-cm for pigeonpea. Two hand weeding and two interculture operations were done at suitable intervals.

The total rainfall received during *kharif* (July to October) was 844.6, 1449.3 and 425 mm during 2009-10, 2010-11 and 2012-13, respectively.

Table 1 Mean monthly air temperature and total monthly precipitation during 2009-10 to 2012-13 and long-term* (1965 to 2010).

Month	Long-term average (1965-2010)			2009-10			2010-11			2012-13		
	Maxi. Temp. (°C)	Mini. Temp. (°C)	Rainfall (mm)	Maxi. Temp. (°C)	Mini. Temp. (°C)	Rainfall (mm)	Maxi. Temp. (°C)	Mini. Temp. (°C)	Rainfall (mm)	Maxi. Temp. (°C)	Mini. Temp. (°C)	Rainfall (mm)
July	35.8	26.4	88.4	37.0	26.8	163.0	36.1	26.9	37.5	37.5	36.4	86.0
August	31.9	25.1	401.1	30.6	25.2	589.6	31.0	25.1	464.1	32.8	26.1	70.5
September	31.2	23.8	167.4	30.5	24.9	401.1	30.5	25.2	221.7	32.3	24.9	87.6
October	33.2	23.0	118	31.6	23.7	240.4	30.8	24.1	239.4	31.9	24.5	180.9
November	36.3	20.9	50.7	35.1	22.2	55.2	35.9	22.9	0.0	36.8	19.8	0.0
December	33.9	17.0	19.0	31.5	20.3	0.0	34.6	19.6	0.0	33.4	14.8	0.0
Total	-	-	844.6	-	-	1449.3	-	-	962.7	-	-	425.0
Mean	33.7	22.7	-	32.7	23.8	-	33.2	23.9	-	34.1	24.4	-

**Source*: Department of Meteorology, Junagadh.

The average monthly temperature during the growing period in the experimental years (respectively maximum 33.7, 32.7 and 34.1°C) was lower than climatic data of long-term period (maximum 33.7 and minimum 22.7°C). The amount of precipitation during the growing period was higher in the first two seasons but lower in the third season compared to long-term average rainfall (Table 1).

The experiment was conducted as rainfed with assured irrigation facilities.Two irrigations were applied to pigeonpea crop every year after harvest of the groundnut crop. For comparison between treatments, the yield of crop was converted into pigeonpea equivalent yield on prevailing price (Tomar & Tiwari, 1990). The cost of cultivation was calculated at the prevailing prices of 2012-13. The data were subjected to statistical analysis by adopting appropriate analysis of variance as described by Cochran & Cox (1967).

3 Results and Discussion

3.1Growth and yield of groundnut

Different fertilizer combination had a significant effect on pod yield of groundnut. Among the various tested combination highest pod yield was reported in the treatment containing RDF1 (100%) through chemical fertilizers (Table 2). The results are in close conformity reported by Shankaranarayana et al. (2002) that application of 100% recommended dose of fertilizer was the best treatment for increasing the growth, yield and yield attributes of the pigeonpea intercrop in groundnut-pigeonpea intercropping system in Karnataka. Yield attributes viz. test weight, shelling percentage and haulm yield showed a non significant effect in different nutrient management practices.

3.2 Growth and yield of pigeonpea

Different composition had a significant effect on plant height, branches/plant, pods per plant and seed and stalk yield of pigeonpea. Tallest plant (116.1 cm) of pigeonpea was reported in the crop fertilized with RDF1 (100%) then the rest of the treatments. Similarly, the maximum number of branches/plant (9.6) was recorded in the same treatment (RDF1) but it is statistically not differ that the RDF2 + FYM2 + *Rhizobium* + PSB treatments (8.9).

Significantly the maximum pigeonpea seed yield (1501 kg/ha) was recorded with RDF1 (100%) and remained at par with RDF2 + FYM2 + *Rhizobium* + PSB (1382 kg/ha). The beneficial effect of organic nutrients on yield and yield attributes the fact that after proper decomposition and mineralization, not only increase the plant yield characters but also had solubilizing effect on fixed forms of nutrients in soil (Singh et al., 2006). The higher seed yield attributed due to higher number of pods/plant. Significantly the maximum number of pods per plant (202 pods/plant) was recorded with RDF1 (100%) but were at par with RDF2 + FYM2 + *Rhizobium* + PSB (180.2 pods/plant) and RDF2 + FYM3 + *Rhizobium* + PSB (170 pods/plant).

Yield is the manifestation of various yield components. The higher seed yield of pigeonpea under inorganic sources of nutrient (Kumari et al., 2010; Choudhary et al., 2011) might be due to immediate release and availability of nutrients compared with combined use of inorganic and organic sources, but may achieve the yield stability in the long run (Subhashini et al., 2007).

Table 2 Effect of different organic, inorganic and biofertilizers on growth and yield attributes of groundnut and pigeonpea (Data pooled over three years).

Treatment	Groundnut				Pigeonpea					PE yield (kg/ha)	
	100 seed weight (g)	Shelling %	Pod yield (kg/ha)	Haulm yield (kg/ha)	Plant height (cm)	Branches/plant	Pods / plant	Seed yield (kg/ha)	Stalk yield (kg/ha)	Seed	**Stalk**
RDF1 for both crops	41.7	68.7	1299	1708	116.1	9.6	202.0	1501	1681	2546	**2657**
FYM1	41.1	67.3	1009	1428	102.5	8.2	150.6	1122	1334	1969 (-22.6)	**3477**
VC1	41.4	68.1	991	1463	95.0	7.9	146.7	1075	1228	1900 (-25.3)	**3422**
RDF2 + FYM2	41.3	69.6	1037	1475	98.7	7.1	131.3	1091	1289	1960 (-23.0)	**3503**
RDF2 + VC1	42.0	69.0	983	1414	98.8	8.1	144.8	1174	1372	1990 (-21.8)	**3493**
RDF2 + FYM2 + *Rhizobium* +PSB	42.0	69.1	1162	1632	102.2	8.9	180.2	1382	1520	2350 (-7.7)	**3968**
RDF2 + FYM3+ *Rhizobium* +PSB	41.5	67.6	1102	1631	103.8	8.8	170.0	1287	1439	2182 (-14.3)	**3887**
SEm±	0.40	0.70	40.5	83.8	3.1	0.24	10.7	59.2	61.1	69.6	**211.0**
CD (P=0.05)	**NS**	**NS**	**115.3**	**NS**	**8.7**	**0.7**	**32.6**	**168**	**173**	**198**	**650**

Figure in parenthesis indicate the percentage changes over inorganic. Value given in table are mean of three replicates, RDF 1 (100% Recommended dose of fertilizers); RDF2 (50% of the Recommended dose of fertilizers); FYM1 (10 ton/ha application of Farm Yard Manure); FYM2 (5 ton/ha application of Farm Yard Manure); FYM3 (1 ton/ha application of Farm Yard Manure); VC1 (1ton/ha application of Vermicompost); PSB (Phosphate Solubilizing Bacteria).

Table 3 Effect of different organic, inorganic and biofertilizers on yield of groundnut and pigeonpea (Data pooled over three years).

Treatment	Pigeonpea equivalent yield (kg/ha)		Gross return (Rs. $\times 10^3$/ha)		Total gross return (Rs. $\times 10^3$/ha)	Cost of cultivation (Rs. $\times 10^3$/ha)	Net return (Rs. $\times 10^3$/ha)	B:C ratio
	Seed	Stalk	Seed	Stalk				
RDF1 for both crops	2546	2657	95.5	3.9	99.4	35.0	64.4	**1.84**
FYM1	1969	3477	73.8	5.2	79.0	36.8	42.2	**1.15**
VC1	1900	3422	71.3	5.1	76.4	33.1	43.2	**1.30**
RDF2 + FYM2	1960	3503	73.5	5.2	78.7	34.5	44.2	**1.28**
RDF2 + VC1	1990	3493	74.6	5.2	79.8	33.8	46.0	**1.36**
RDF2 + FYM2 + *Rhizobium* +PSB	2350	3968	88.1	5.9	94.0	34.7	59.3	**1.71**
RDF2 + FYM3+ *Rhizobium* +PSB	**2182**	**3887**	**81.8**	**5.8**	**87.6**	**32.3**	**55.3**	**1.71**

Market price: (Rs./kg) taken for 2012-13: Pigeonpea seed - 37.50; Pigeonpea stalk - 1.5; DAP – 25.00; Urea - 5.84; FYM - 0.60 and Vermicompost - 2.30

3.3 Pigeonpea equivalent yield

The pigeonpea equivalent yield was influenced significantly due to application of different nutrient management options to *kharif* groundnut and pigeonpea crops (Table 2). Among the different treatments application of RDF1 to both crops recorded maximum pigeonpea equivalent seed yield (2546 kg/ha) than the rest of the treatments but statistically not differ than the RDF2 + FYM2 + *Rhizobium* + PSB (2350 kg/ha). Application of RDF2 + FYM2 + *Rhizobium* + PSB gave 7.7% lesser yield than the RDF1 application to both crops. However, RDF2 + FYM3 + *Rhizobium* + PSB gave 14.3% lower yield than the RDF1 application.

3.4 Economic analysis

In agreement with grain and stalk yields the gross and net returns as well as benefit cost ratio were highest for treatment RDF1 for both crops. The highest total gross return (Rs. 99.4×10^3/ha) as well as benefit–cost ratio (1.84) was recorded with treatment RDF1 (Table 3). The results are in close conformity that earlier reported by Shankaranarayana et al. (2002). Similarly, despite of lesser yield than RDF1, application of RDF2 + FYM2 + *Rhizobium* + PSB produced next best option by fetching gross and net return to the tune of Rs. 94.0×10^3 and Rs. 59.3×10^3/ha, respectively with a benefit–cost ratio of 1.71. However, application of RDF2 + FYM2 + *Rhizobium* + PSB gave 7.9% less gross and net return benefits than RDF1 meanwhile the same time reduced 50% requirement of chemical fertilizers.

It can be concluded that adoption of a balanced fertilizer management approach will safeguard the higher productivity and returns from money spent, not only on nutrients but also on relay cropping enterprise. Inorganic crop receiving recommended dose of fertilizers gave the highest productivity and profits. However, it enhanced the cost of production than combined use of RDF and organic sources. Over the years, combined application of RDF and organic fertilizers expected to match or excel the fertilizer based production structure in the groundnut-pigeonpea relay intercropping system.

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