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Significance of integrated plant nutrition system (IPNS) practices on biological yield and NPK uptake of groundnut and redgram in legume based intercropping system

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Abstract
An integrated plant nutrition system (IPNS) practice has a significant potential to counterbalance the growing nutrient demands and to sustain the crop productivity on long term basis. A field experiment was conducted at Chandirambadi village of Thiruvannamalai District, Tamil Nadu during April – August, 2019 (Chithirai Pattam) to study the effect of IPNS on biological yield and NPK uptake of groundnut and redgram. The experiments were laid out in a Randomized Block Design and were replicated thrice with 13 treatment combinations *viz*., T_1 - Farmer's practice, T_2 - 75% RDF to Groundnut, T_3 – 100% RDF to Groundnut, T_4 – 125% RDF to Groundnut, T_5 - 75% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut, T_6 - 100% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut, T_7 - 125% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut, T_8 – 75% RDF to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_9 – 100% RDF to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_{10} - 125% RDF to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_{11} - 75% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_{12} - 100% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm) and T_{13} - 125 % RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm). The results revealed that the integrated application of 75 per cent RDF (12.75: 25.5: 40.5 kg N, P_2O_5 and K_2O ha^{-1}) along with vermicompost (5 t ha^{-1}) to groundnut and foliar spray to redgram @ 2% DAP and NAA 40 ppm at flowering stage can be attributed the highest biological yield (5.81 3.79 t ha^{-1} for groundnut and redgram, respectively) and NPK uptake (148.00, 18.4 and 118 kg ha^{-1} for groundnut and 58.17, 9.07 and 42.25 kg ha^{-1} for redgram), agronomic efficiency (75.45, 37.72 and 25.65 kg kg^{-1}) and unit area efficiency (59.02 g m^{-2} day^{-1}) of groundnut + redgram intercropping system.

Keywords: agronomic efficiency, foliar fertilization, growth regulators, intercropping, legumes

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crop of tropical and subtropical regions. Groundnut is a predominant commercial oilseed crop in India and it is widely cultivated in rainfed regions (Bhosale *et al.*, 2017)[3]. Being a legume with root nodules, it can fix atmospheric nitrogen and therefore improve soil fertility. Commercially, groundnut is the world's fourth most important sources of edible oil and third most important sources of vegetable protein. The groundnut crop is grown over an area of 26.62 million ha spread over 84 countries with an annual production of 35.66 million tonnes of pods with a productivity of 1348 kg ha^{-1}. In India, it is being cultivated in an area of 4.90 million ha and 8.26 million tonnes of total production with an average productivity of 1074 kg ha^{-1} (Anon, 2018). The national average productivity of groundnut is 1380 kg ha^{-1} in India which is less than the world average of 1600 kg ha^{-1}. In Tamil Nadu, groundnut is cultivated in an area of 1.1 million ha with production 1.23 lakh tonnes with an average productivity of 1713 kg ha^{-1}.

Pigeonpea (*Cajanus cajan* (L) Millsp.) is an important pulse crop of India, grown in an area of 3.63 million ha with a production of 2.12 million tonnes and productivity of 584 kg ha^{-1}.

Integrated plant nutrition system (IPNS) is the maintenance of soil fertility and supply of plant nutrients to an optimum level for sustaining desired crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner. The success of IPNS depends on the judicious use of different components of IPNS *viz*., integration of legumes, organics, fertilizer nutrients and growth hormones. Legume based inter cropping system is one of the key components of sustainable farming system as it serves as a component of IPNS, for sustaining the productivity of the system through efficient nutrient cycling (Legodi and Ogola, 2020) [12]. Groundnut - pigeonpea is an emerging most important intercropping system in India. Groundnut and pigeonpea intercropping proved advantageous because groundnut is a short duration crop which utilizes resources effectively in the early season and pigeonpea being medium/long duration, slow-growing and indeterminate type can utilize the resources effectively during post monsoon season. Growing of pigeonpea as an intercrop even in high input agriculture to enhance total pulses besides increasing system productivity and profitability (Praharaj and Blaise, 2016[15]; Saxena *et al.*, 2018[19]).

Vermicompost has been reported to increase availability of major nutrients and nutrient use efficiency of crops (Sudhagar Rao *et al.*, 2019)[21]. Soil application of vermicompost exhibited higher nutrient use efficiency and the increased the soil organic carbon which holds more moisture in soil and creates appropriate condition for better

root growth to provide an opportunity to extract more nutrient uptake. NPK nutrients are essential and an significant determinant of plant growth and development. The addition of nitrogen fertilizer generally increases the proportion of shoot root. On the other hand, phosphorus is an imperative food component for legumes and constitutes an essential component of ATP and plays an important role in energy shifts in plants and also in different roles in seed formation. In addition, K has a beneficial effect on the transformation of photosensitites from leaves to root nodules

Foliar application of nutrients play a key role in pulses production compare to soil application. It has ability to improve the efficiency and rapidity of utilization of a nutrient urgently required by the plant for maximum growth and yield (Kandil and Eman, 2017) [8]. Foliar spray of DAP met constant requirement of nitrogen and phosphorous at reproductive stage of the crop which in turn favoured photosynthetic ability and increased accumulation and efficient portioning of photosynthates towards sink (Suhathiya and Ravichandran, 2018 [22]; Priyanka *et al*., 2019 [16]). Likewise foliar application of growth regulators such as Naphthalene Acetic Acid (NAA) at flowering stage to enhance the source – sink relationship and stimulate the translocation of photo- assimilates to sink there by helping in effective flower formation, seed development and ultimately enhancing the productivity of crop (Gnyandev *et al.*, 2019) [4]. Considering these facts, the present experiment was under taken to evaluate the integrated plant nutrition system (IPNS) practices for the biological productivity and to find out the nutrients uptake of groundnut + redgram intercropping system.

Materials and Methods

A field experiment was conducted at Chandirambadi village of Thiruvannamalai District, Tamil Nadu during April, 2019 (Chithirai Pattam) to study the effect of IPNS on biological yield and NPK uptake of groundnut + redgram intercropping system. The farm is geographically located at 12º 57' North latitude and 79º 43' East longitude with an altitude of +168 m above mean sea level.

The weather of Chandirambadi village is moderately warm with hot summer months. The weekly mean maximum temperature during cropping period ranges from 25.2^{0}C to 40.8^{0}C with mean of 35.6^{0}C and the weekly mean minimum temperature fluctuates between 22.7^{0}C and 28.3^{0}C with a mean of 25.9^{0}C. The relative humidity ranged from 52 to 85 per cent with a mean of 68 per cent. The study area received the rainfall is 401mm distributed over 23 rainy days during cropping period. The texture of the experimental field was clay loam which is high in nitrogen (301 kg ha^{-1}) and medium in phosphorus (11.9 kg ha^{-1}) and high in potassium (290 kg ha^{-1}).

The experiments were laid out in a Randomized Block Design and were replicated thrice with 13 treatment combinations *viz*., T_1 - Farmer's practice, T_2 - 75% RDF to Groundnut, T_3 – 100% RDF to Groundnut, T_4 – 125% RDF to Groundnut, T_5 - 75% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut, T_6 - 100% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut, T_7 - 125% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut, T_8 – 75% RDF to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_9 – 100% RDF to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_{10} - 125% RDF to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_{11} - 75% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm), T_{12} - 100% RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm) and T_{13} - 125 % RDF + Vermicompost (5 t ha $^{-1}$) to Groundnut + Foliar Spray to Redgram (2% DAP & NAA 40 ppm).

A pilot survey was conducted among the farmers (25 Farmer's) of Chandirambadi village in Thiruvannamalai District for nutrient management practices in groundnut cultivation. According to pilot survey biannually they use the 4 t ha^{-1} of Farm Yard Manure (FYM) and for groundnut 25: 10: 0 kg NPK ha^{-1}. For the base crop of groundnut variety TMV 7 was selected for this study and Redgram (VBN (Rg) 3) used as an intercrop. The vermicompost was prepared in farmer's field by using local organic inputs such as paddy straw, sorghum, other leaf litters and farm yard manure. The recommended fertilizer schedule of groundnut *viz.,* 17 kg N, 34 kg P_2O_5, and 54 kg K_2O ha^{-1} was adopted in this study. Urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) fertilizers were used to supply N, P and K nutrients, respectively. A half dose of nitrogen was applied basally and the remaining half doses of nitrogen were applied by top dressing. In addition, as per the treatment schedule the prescribed quantity of organic manure (vermicompost) @ 5 t ha^{-1} was applied. Two per cent DAP solution was uniformly sprayed using hand operated knapsack sprayer at flowering stage. NAA 40 ppm was also applied as per the treatment schedule.

Five plants per plot were uprooted from the sampling row at at harvest of the crop and air dried in hot air oven at the temperature of 80 ± 5º C for 24 hours. After oven drying plant biological yield was recorded and expressed in kg ha^{-1}. The oven dried plant samples at harvest were cut into small pieces and powdered in Willey mill. The powdered material was used for the NPK analysis. Nitrogen uptake in the samples was estimated by Microkjeldahl method (Jackson, 1973) [7]. Phosphorus uptake in the samples was estimated colorimetrically using the acid, using the method described by Jackson (1973) [7]. Potassium uptake in the samples was estimated by flame Photometer-Elico Model-CL 22D as suggested by Jackson (1973) [7].

The agronomic efficiency is the response in yield per unit inputs as indicated by the following equation (Yoshida, 1976) [24] and expressed in kg kg^{-1}.

$$AE = G_F – G_U / Na$$

Where, G_F – Grain yield in fertilized plot (kg ha^{-1}); G_U – Grain yield in unfertilized plot (kg ha^{-1}); N_a - Quantity of fertilizer nutrients applied (kg ha^{-1}) like N, P and K alone.

The unit area efficiency for seed yield and total dry matter production were calculated by using the formula and the values are expressed in g m^{-2} day $^{-1}$.

$$UAE = \frac{Bioogical\ Yield}{Land\ area} \times \frac{1}{Duration\ of\ a\ crop}$$

The statistical analysis of the data was carried out as suggested by Panse and Sukhatme (1989). The critical differences were worked out at 5 per cent probability level, wherever the results were significant. Treatment differences which were not significant were denoted as "NS".

Results

Biological yield

In groundnut, the treatment T_{12} (100 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm)) recorded the highest biological yield of 5.81 t ha^{-1}, and it was on par with 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{11}) (Table 1). In these treatments, percent biological yield increase over the farmers practice was 69 and 64 per cent, respectively (Fig 1). The least biological yield of 236.27, 1271.54 and 3.44.00 t ha^{-1} was recorded with farmer's practice (T_1).

In redgram also, 100 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm (T_{12}) recorded the highest biological yield of 3.79 t ha^{-1} and it was on par with 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40ppm) (T_{11}) (Table 2). In both the treatments, percent biological yield increase over the farmers practice was 118 and 117 per cent, respectively (Fig 2). The least biological yield of 1.74 t ha^{-1} was recorded with farmer's practice (T_1).

Table1: Effect of IPNS practices on the biological yield and NPK uptake of groundnut

Treatment	Biological yield (t/ha)	N Kg ha^{-1}	P Kg ha^{-1}	K Kg ha^{-1}
T_1	3.44	109.37	12.60	82.51
T_2	3.72	115.39	14.10	87.49
T_3	3.90	120.16	14.19	89.98
T_4	3.81	118.14	14.15	88.60
T_5	4.73	132.77	16.18	101.59
T_6	4.89	134.27	16.23	103.09
T_7	4.45	127.26	15.25	96.33
T_8	5.28	140.89	17.21	109.80
T_9	5.38	141.93	17.24	111.82
T_{10}	4.27	125.25	15.21	95.00
T_{11}	5.64	146.98	18.25	116.50
T_{12}	5.81	148.00	18.40	118.00
T_{13}	5.22	139.57	17.18	108.30
SEm±	0.07	2.43	0.34	2.27
CD (P=O.05)	0.24	4.90	0.70	4.58

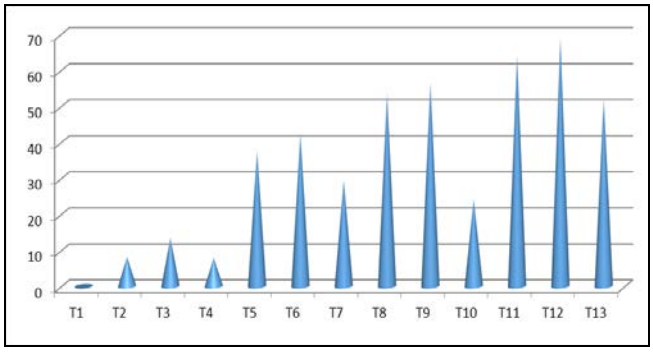

Fig1: Per cent biological yield increase over the farmers practice (Groundnut)

NPK uptake

The observations recorded on NPK uptake due to integrated plant nutrition system (IPNS) practices to groundnut are furnished in Table 1. Among the treatments, application of 100 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{12}) excelled all other treatments by recording the highest NPK uptake of 148.00, 18.4 and 118 kg ha^{-1}. However, it was statistically on par with the application of 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2 % DAP and NAA 40 ppm) (T_{11}). The farmer's practice (T_1) recorded the lowest NPK uptake of 109.37, 12.6 and 82.51 kg NPK ha^{-1}.

The same trend was also observed in redgram. Application of 100 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{12}) recorded highest NPK uptake of 58.17, 9.07 and 42.25 kg ha^{-1} and it was statistically on par with 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + redgram (2% DAP and NAA 40 ppm) (T_{11}). The lowest uptake of nitrogen of 43.25, 7.01 24.62 kg ha^{-1} at harvest was recorded in farmer's practice (T_1).

Table2: Effect of IPNS practices on the biological yield and NPK uptake of redgram

Treatment	Biological yield (t/ha)	N Kg ha^{-1}	P Kg ha^{-1}	K Kg ha^{-1}
T_1	1.74	43.25	7.01	24.62
T_2	2.18	46.28	7.35	27.12
T_3	2.28	47.84	7.49	28.35
T_4	2.15	47.30	7.40	28.00
T_5	2.82	52.03	8.15	33.80
T_6	2.94	52.21	8.18	34.79
T_7	2.63	50.11	7.83	31.60
T_8	3.24	54.93	8.61	38.21
T_9	3.35	55.51	8.70	39.06
T_{10}	2.40	49.73	7.78	30.65
T_{11}	3.61	57.54	9.01	41.27
T_{12}	3.79	58.17	9.07	42.25
T_{13}	3.21	54.30	8.49	37.22
SEm±	0.08	0.69	0.09	0.76
CD (P=O.05)	0.22	1.63	0.27	2.02

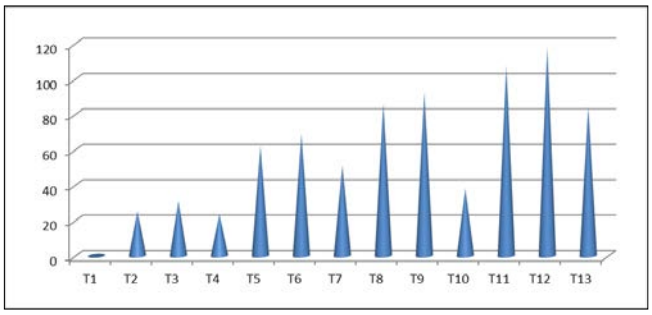

Fig2: Percent biological yield increase over the control (Redgram)

Agronomic efficiency and Unit area efficiency

The highest agronomic efficiency of nitrogen, phosphorous and potassium resulted in application of 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{11}) by registering the value of 75.45, 37.72 and 25.65 kg kg^{-1} respectively.. The least agronomic efficiency was noticed under application of 125 per cent RDF (T_4) with the value of 7.76, 3.88 and 2.64 kg kg^{-1}, respectively.

The unit area efficiency also highest in application of 100 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{12}) by registering the value of 59.02 g m^{-2} day^{-1}. This treatment was statistically on par with application of 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to

redgram (2% DAP and NAA 40 ppm) (T_{11}) by registering value of 57.80 g m^{-2} day^{-1}. The least unit area efficiency (total DMP) of 34.36 g m^{-2} day^{-1} was recorded under farmer's practice (T_1).

Table3: Effect of IPNS practices on agronomic efficiency (kg kg^{-1}) and unit area efficiency under groundnut + redgram intercropping system

Treatment	N (kg kg^{-1})	P (kg kg^{-1})	K (kg kg^{-1})	Unit area efficiency (g m^{-2} day^{-1})
T_1	-	-	-	34.36
T_2	10.19	5.09	3.46	37.50
T_3	10.88	5.44	3.70	39.98
T_4	7.76	3.88	2.64	38.92
T_5	36.75	18.35	12.48	46.63
T_6	32.00	16.00	10.88	48.95
T_7	15.67	7.83	5.32	43.81
T_8	59.86	29.93	20.35	53.23
T_9	48.82	24.41	16.60	54.17
T_{10}	14.82	7.41	5.04	42.90
T_{11}	75.45	37.72	25.65	57.80
T_{12}	62.00	31.00	21.08	59.02
T_{13}	33.23	16.61	11.29	52.36

Discussion

Intercropping is popular among the farmers of small and marginal holdings because of flexibility of sowing and planting dates, profit maximization, risk minimization, soil conservation, soil fertility maintenance, weed control and nutritional reason. Among the legume based intercropping system, groundnut (*Arachis hypogaea* L.) with redgram (*Cajanus cajan* (L.) Millsp) intercropping system performs better in terms of productivity when good cultivars are sown under appropriate nutrient management practices. Under intensive cropping the nutrient removal by these crops are varies considerably, depending upon crop variety and soil fertility. It depletes the soil nutrient rapidly unless the soil and crop is adequately fertilized.

Boosting the yield, reducing production cost and improving soil health are the three interlinked components of the sustainable triangle (Latha *et al*., 2019) [11]. But the modern agriculture especially in the chemical era concentrates on maximum output but overlooks input efficiency. There is increasing evidence that fertilizers alone cannot sustain yields for long periods because crops utilize hardly 30 to 40 per cent of the applied fertilizer nutrients and the rest is lost through various pathways like leaching, surface runoff, volatilization, denitrification, soil erosion and fixation in soil (Sainju, 2017) [17].

Nutrient use efficiency can be improved by checking the path ways of nutrient losses from soil-plant system, making integrated set of nutrients from all possible sources, optimal allocation of nutrients to crops and maximizing the utilization of applied and native nutrients by the crops (Sarkar, 2015) [18]. Integrated Plant Nutrition System (IPNS) practices maintain or adjust of soil fertility and supply of plant nutrient to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible resources of plant nutrients in an integrated manner (Gyeltshen and Sharma, 2019) [6].

The biological yield, nutrient uptake, agronomic efficiency and unit area efficiency were significantly influenced by the application of 100 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{12}) being at on par with 75 per cent RDF + vermicompost (5 t ha^{-1}) to groundnut + foliar spray to redgram (2% DAP and NAA 40 ppm) (T_{11}) recorded significantly higher uptake of N, P and K. The enhanced values of biological yield of groundnut and redgram could be due to the integrated use of vermicompost and inorganic nutrition which sustained the availability of all nutrients throughout the groundnut growth period. It contains higher nitrate, which is more available form of N to promote luxury growth and also enriched in certain metabolites and vitamins that belongs to the B group or pro-vitamin D which helps to enhance the growth parameters like plant height, LAI, number of leaves, root elongation and number of effective root nodules $plant^{-1}$. The present findings are in line with Bekele *et al*. (2019) [2].

Higher uptake of nutrients by groundnut might be attributed to higher nutrient availability due to higher biological production which enhanced microbial activity leading to mineralization and rapid release of nutrients matching with crop demand. The application of vermicompost reduces N losses and conserves soil N by N fixation, thus maintaining a continuous availability of N in the entire life cycle of groundnut which would result in the increase of total N uptake. Further it also enhanced the greater availability of P which enhanced the cambial activity of root hairs, involved in root cell development and enhanced the root proliferation and root biomass. It helps to allowing the plants to absorb required quantity of essential nutrients such as N, P and K from sub soil layers also. These results are in conformity with findings of Kumawat *et al.* (2015) [10], Mallesha *et al*. (2017) [13] and Ananda *et al*. (2018) [1].

In redgram, application of vermicompost during initial stages increases nodulation activity which involved in N fixation. Moreover, application of N, P and K fertilizers and foliar nutrients such as DAP and NAA might have resulted in increased availability of these nutrients which in turn has influenced DNA and protein synthesis leading to vigorous growth. It augments the production of metabolites and their translocation to different parts which ultimately increases the uptake of N, P and K. This is in line with the findings of Gopali Yadav *et al*. (2017) [5] and Mallesha *et al*. (2017) [13]. The more efficient use of resources in addition to the cumulative, synergistic and complementary effect of legume and integrated application of essential plant nutrients to improve the biological productivity and nutrient uptake this result in improved agronomic efficiency and unit area efficiency. Similar results were obtained by Yadav *et al*. (2017) [23] and Kiwia *et al*. (2019) [9].

Conclusion

Integrated plant nutrition system (IPNS) practices sustain soil fertility and plant nutrient supply to achieve the maximum level of crop production. The present study uses all the components of IPNS such as legumes in the cropping system, optimal quantity of chemical fertilizers, organic manures and foliar nutrients. It can be concluded that application of 100 per cent RDF along with vermicompost (5 t ha^{-1}) to groundnut and foliar spray to redgram (2% DAP and NAA 40 ppm) was impressive treatment and had a remarkable effect on growth biological yield, nutrient uptake, agronomic efficiencies and unit area efficiency. However, it was statistically comparable with the integrated application of 75 per cent RDF along with vermicompost (5 t ha^{-1}) to groundnut and foliar spray to redgram (2% DAP and NAA 40 ppm). It save 25 per cent NPK fertilizer and

hence, integrated plant nutrition system (IPNS) practice with 75 per cent RDF (12.75: 25.5: 40.5 kg N, P_2O_5 and K_2O ha^{-1}), vermicompost @ 5 t ha^{-1} to groundnut and foliar spray to redgram @ 2% DAP and NAA 40 ppm can be considered as an optimum IPNS practice for groundnut + redgram intercropping system.

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