LR-5297
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RESEARCH ARTICLE Legume Research- An International Journal

Do Groundnut as Preceding Crop Reduce Fertilizer Requirement to the Succeeding Blackgram?-Results of Field Investigation

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10.18805/LR-5297

ABSTRACT

Background: Intensive legume cropping system enhances the soil productivity and reduce the dependance on exterior inputs as legumes are well known for nitrogen (N) fixation by biological means. In addition, inorganic fertilizers, together with the integrated and careful use of FYM, could be an efficient option for increasing the productivity of the legume - legume cropping system. The common use of fertilizer and organics has been shown to have a synergistic effect on crop productivity, while simultaneously improving soil fertility. The residual effects of organic manures applied to previous crops may be available to subsequent crops. As a result, this experiment was designed to shed information on the usage of integrated nutrients from organic and inorganic sources on leguminous groundnut and the residual influence on subsequent blackgram.

Methods: During 2018-19, 2019-20 and 2020-21, a field experiment was undertaken at Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam to investigate the effect of integrated nutrient management on the groundnut-blackgram cropping sequence. Four nutrient combinations for groundnut were tested in a randomized block design and the residual effect on productivity of succeeding blackgram was investigated using four fertilizer levels in a split plot design.

Result: The application of 125% RDF + FYM @ 12.5 t ha^{-1} to groundnut increased growth, yield, quality, economics and soil properties, while the residual effect to succeeding blackgram resulted in significantly higher blackgram seed yield and other important parameters, which was followed by the application of 75% RDF. Among the various levels of fertilizers applied to blackgram, 75% RDF produced the highest blackgram seed yield, economics and soil characteristics compared to the other three levels.

Key words: Blackgram, Farm yard manure, Fertilizers, Groundnut.

INTRODUCTION

The groundnut-blackgram system has played a significant role in bolstering oil and pulses production, contributing to achieving food self-sufficiency and security. The concern for sustainable agriculture with emphasis on eco-friendly inputs had renewed interest to include the nitrogen fixing leguminous crop in the cropping system (Harisudan Chandrasekaran and Manivannan Venkatesan, 2018). Nutrient management on farmlands emerges as a critical factor influencing both crop production and environmental preservation (Prasad, 2009). Oil-bearing crops, being energy-rich, demand substantial nutrition for optimal production. While the use of chemical fertilizers represents a swift response to counteract nutrient depletion from the soil, challenges such as escalating costs, adverse environmental impacts and unpredictable availability deter farmers from employing the necessary nutrients in balanced proportions (Babu *et al*., 2015). On average, a mere 52.5 kg ha^{-1} of nitrogen, phosphorus and potassium (NPK) nutrients are applied in oilseeds, in stark contrast to the 140 kg ha^{-1} for rice and 160 kg ha^{-1} for wheat (Tiwari, 2008). This discrepancy in fertilization practices, coupled with insufficient replenishment of native soil nutrient reserves, has given rise to multinutrient deficiencies, resulting in reduced factor productivity of applied nutrients and a simultaneous decline in the overall productivity of various crops, including oilseeds, in India (Suresh *et al*., 2013).

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How to cite this article: Harisudan, C., Veeramani, P., Allwin, L., Sathiya, K., Sivagamy, K., Karunakaran, V. and Jayakumar, J. (2024). Do Groundnut as Preceding Crop Reduce Fertilizer Requirement to the Succeeding Blackgram?-Results of Field Investigation. Legume Research. DOI: 10.18805/LR-5297.

Submitted: 30-01-2024 **Accepted:** 03-04-2024 **Online**: 06-06-2024

In Tamil Nadu, the groundnut-blackgram cropping sequence has evolved into an established and vital component of the agricultural landscape. Blackgram, with its shallow rooting pattern, demands a generous application of primary nutrients. Conversely, Groundnut exhibits robust growth, efficiently progressing through various phenophases within a short timeframe and effectively utilizing both applied and residual nutrients due to its deep-rooting growth habit. However, the continuous cultivation of such an exhaustive cropping system can lead to the depletion of nutrients from soil reserves, posing a risk to sustainability without adequate restorative practices. It is imperative to assess the nutrient requirements of the entire cropping system as a holistic entity, moving away from the conventional focus on individual crop fertilizer requirements in the current era of exploitative agriculture (Fustec *et al*., 2010).

The current practice of uniformly applying fertilizers represents a generalized approach, neglecting the vital carryover effects of manures and fertilizers to subsequent crops. To enhance fertilizer use efficiency, a more targeted strategy involves adopting nutrient management practices that consider the entire cropping system rather than individual crops. The groundnut-blackgram cropping system, known for its high productivity, resource use efficiency (Subrahmaniyan *et al*., 2018) and economic returns. This is crucial not only for increasing productivity but also for fostering sustainability, eco-friendliness and comparative profitability. In response to these imperatives, efforts have been directed towards developing an integrated nutrient supply system. This initiative aims to optimize the utilization of residual and cumulative soil nutrient balances, combined with judicious applications of added fertilizers within the groundnut-blackgram cropping sequence. The objective is to establish a sophisticated nutrient management approach that reflects the comparative capability of the system, paving the way for a more productive, sustainable and economically rewarding agricultural paradigm.

MATERIALS AND METHODS

The field experiment was carried out from 2018-19, 2019-20 and 2020-21 at the Regional Research Station of Tamil Nadu Agricultural University in Vridhachalam (110°30′N, 79°26′E, 42.67 m altitude) to determine the effect of integrated nutrient management on the growth, yield, quality, economics and soil properties of the groundnut-blackgram crops. The yearly rainfall ranges from 950 to 1240 millimeters. The soil of the experimental field was sandy loam. The chemical composition showed that the soil had low nitrogen availability (215 kg ha^{-1}), moderate phosphorus availability (11.5 kg ha^{-1}) and high potassium availability (218 kg ha^{-1}). The soil pH was 6.7, with an organic carbon concentration of 0.23%.

The *Kharif* groundnut cv. VRI 2 experiment was set out in a randomized block design with four levels of fertilizer: control, 100% RDF (25:50:75 kg NPK ha^{-1}) + FYM at 12.5 t ha^{-1}, 125% RDF+ FYM @ 12.5 t ha^{-1} and 150% RDF+ FYM @ 12.5 t ha^{-1}. With five replications and after the harvest of groundnut, each plot of groundnut was divided into four equal sub plots for sowing rabi blackgram cv. VBN 3 with four levels of fertilizer, *viz*., Control, 50% RDF, 75% RDF and 100% RDF (25:50:25 kg NPK ha^{-1}) in split plot design to test the residual effect of groundnut treatments on blackgram.

Seed treatment with Rhizobium biofertilizer was integrated into the integrated nutrient management (INM) practices. During the Kharif season, groundnut was sown in mid-July with a spacing of 30 cm (intra-row) × 10 cm (intra-plant) and a seed rate of 120 kg ha. Harvesting occurred in the last week of October. Following this, the experimental site was irrigated for field preparation and blackgram (VBN 3) was sown in the Rabi season at a spacing of 30 cm × 10 cm with a seed rate of 20 kg ha. Crop management practices adhered to the assigned treatments. At harvest, various growth and yield components were assessed, including plant height (cm), dry matter production (DMP) at harvest, number of mature pods per plant, test weight (g), shelling percentage, pod yield (kg ha^{-1}), protein content (%), protein yield (kg ha^{-1}) available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}), available potassium (kg ha^{-1}), NPK uptake, gross income (Rs./ha), net income (Rs./ha) and benefit-cost (B:C) ratio. These metrics provided a comprehensive evaluation of the cropping system's performance. Before and after harvest of crops, soil samples were taken for determination of available nitrogen (Subbiah and Asija, 1956), phosphorus (Olsen *et al*., 1954), potassium (Merwin and Peech,1950). The uptake of nutrients by seeds and haulm were calculated by multiplying per cent nutrient content of the individual crop with its respective dry matter of seeds and haulm. The statistical analysis of the experimental data was done as per the methods suggested by Gomez and Gomez (1983).

RESULTS AND DISCUSSION

Growth and yield of groundnut

Growth-related characteristics (Table 1) showed that 125% RDF + FYM @ 12.5 t ha-1 resulted in the maximum pod production (2657 kg ha^{-1}). Among the four fertilizer levels, 125% RDF + FYM @ 12.5 t ha^{-1} produced the highest growth and production of groundnut. The significant increase in yield under 125% RDF was ascribed to a greater number of ripe pods per plant (27.3). The use of both organic and inorganic fertilizer sources improved total crop growth, including dry matter production, morphological and photosynthetic components and nutrient accumulation. This increase in nutrient availability and metabolites most likely aided the growth and development of reproductive structures, resulting in better individual plant productivity. The nutrient applied to the preceding crop makes e easy availability and efficient utilization by the succeeding crops (Harisudan and Nish Sapre, 2019). These findings, which are consistent with prior research by Premalatha and Angadi (2017); Singh and Singh (2018) and Kiran Kumar *et al.* (2020), highlight the benefits of integrated nutrient management for agricultural productivity.

Other growth and yield parameters, including as plant height and dry matter production (DMP) at harvest, improved significantly with the use of 150% RDF. At harvest, this treatment resulted in a higher plant height (78 cm) and more DMP (57.1 g per plant). The significant increase in plant height attributed to the application of recommended nitrogen doses in conjunction with FYM is most likely due to cell and internodal elongation, which promotes vegetative growth and correlates positively with the plant's productive potential, as highlighted in previous studies by Bharath *et al.* (2017) and Srinivasa Rao *et al.* (2019) in groundnuts. However, in terms of protein, the use of general RDF resulted in significantly higher protein content (22.8%) and yield (587.1 kg ha^{-1}) in groundnut.

Growth and yield of blackgram

In this experiment, several fertilizer amounts were tested on Kharif groundnut, but on the same treatments, blackgram treatments were superimposed with four levels of fertilizer and three years of pooled data (Table 2). The maximum seed yield for blackgram was achieved with 125% + FYM @12.5 t ha^{-1}, equal to 710 kg ha^{-1}, followed closely by 100% RDF + FYM @ 12.5 t ha^{-1}, yielding 671 kg ha^{-1}. The substantial increase in yield with 125% + FYM @ 12.5 t ha^{-1} was linked to superior growth and yield parameters, such as the number of branches per plant (7.7), pods per plant (34.2), test weight (4.6 g) and shelling percentage (74.2). The robust growth, characterized by increased plant height and branch numbers, ensured an ample supply of photosynthates for sink development, reflecting overall enhanced growth performance and higher values of yield attributes under this treatment. Thus, the percentage yield of blackgram over control is shown in the following order: 50% RDF (37.4), 75% RDF (58.9) and 100% RDF (56.1). The control group had the lowest blackgram growth and yield characteristics. Higher yields in blackgram in the rotation could be attributed to improved soil physicochemical properties and increased nutrient availability with the addition of FYM to the preceding groundnut crop, as well as further mineralization of required nutrients to the succeeding blackgram crop, resulting in a yield effect. These findings are consistent with those of Chavan *et al*. (2014), who found that the combined usage of organic manures resulted in higher seed yields than inorganic fertilizers alone. Ahiwale *et al.* (2013) also supported the notion that combining organics with inorganics results in the highest yields. The cumulative effects of improved growth and yield parameters, along with enhanced nutrient uptake, likely contributed to the increased grain yield potential of the crop. Furthermore, an increase in RDF fertilizer levels during Kharif groundnut cultivation resulted in a gradual and significant increase in the seed yield of *Rabi* blackgram.

The application of 75% RDF to blackgram subplots resulted in significantly higher growth characters, yield contributing characters and seed yield (823 kg ha^{-1}), number of branches per plant (7.8), number of pods per plant (34.6), test weight (4.7 g) and shelling percentage (74.2). This could be owing to the combined residual effect of nutrients applied to groundnut and the whole package of nutrients applied to blackgram. The control treatment showed the fewest growth characters, yield-contributing characters and yield.

Table 1: Growth and yield attributes at harvest of *kharif* groundnut as influenced by different treatment (Pooled mean of 3 years).

Treatments	Plant height (cm)	DMP at harvest (g plant^{-1})	No. of mature pods plant^{-1}	Test weight (g)	Shelling (%)	Pod yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
***Kharif* groundnut**										
Control	48.3	40.6	20.2	42.6	71.5	1372	16.4	225.1	28430	1.60
100% RDF + FYM @12.5 t ha^{-1}	58.6	46.0	24.6	44.2	72.9	2557	21.7	554.8	92573	2.89
125% RDF + FYM @ 12.5 t ha^{-1}	64.5	48.6	27.3	44.7	74.2	2657	22.8	587.1	95634	2.93
150% RDF + FYM @ 12.5 t ha^{-1}	71.7	52.5	22.7	45.4	74.0	2107	22.1	480.3	65260	2.29
S.Ed.	1.07	0.85	0.48	0.73	1.94	40.65	0.14	18.9	-	-
CD (0.05)	2.67	2.12	1.25	NS	NS	101.40	0.29	38.1	-	-

Table 2: Growth and yield attributes at harvest of rabi blackgram as influenced by different treatment (Pooled mean of 3 years).

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	Test weight (g)	Shelling %	Seed yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
***Kharif* groundnut**										
Control	20.1	6.0	21.4	4.4	71.5	443	17.3	77	11955	1.49
100% RDF + FYM @12.5 t ha^{-1}	27.0	7.4	29.6	4.6	72.9	671	20.1	135	30094	2.27
125% RDF + FYM @ 12.5 t ha^{-1}	30.3	7.7	34.2	4.6	74.2	710	20.8	148	31437	2.24
150% RDF + FYM @ 12.5 t ha^{-1}	33.1	7.4	28.4	4.6	74.0	640	20.9	134	25433	1.98
S.Ed.	0.45	0.16	0.53	0.08	1.94	12.79	0.12	9.14	-	-
CD (0.05)	1.15	0.44	1.23	NS	NS	32.09	0.28	21.03	-	-
***Rabi* blackgram**										
Control	22.1	5.7	20.1	4.4	72.2	338	17.8	60	5992	1.28
50% RDF	27.4	7.3	26.9	4.6	72.8	540	19.7	106	19258	1.82
75% RDF	29.4	7.8	34.6	4.7	74.2	823	20.4	168	40128	2.57
100% RDF	30.5	7.7	32.1	4.7	73.5	771	20.9	161	33746	2.22
S.Ed.	0.74	0.25	0.77	0.13	2.92	17.57	0.13	10.34	-	-
CD (0.05)	1.55	0.53	1.60	NS	NS	36.45	0.29	22.10	-	-
Interaction										
S.Ed.	1.12	0.43	1.21	0.21	5.10	32.4	0.24	20.21	-	-
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	-	-

Table 3: Soil status after harvest of rabi green gram (completion of third cropping cycle) as influenced by different treatment.

Treatments	Bulk density (Mg cm^{-3})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
***Kharif* groundnut**								
Control	1.32	0.23	207	12.1	196	63	7.5	51.1
100% RDF + FYM @12.5 t ha^{-1}	1.39	0.26	231	14.6	219	108	10.4	64.8
125% RDF + FYM @ 12.5 t ha^{-1}	1.40	0.27	236	15.3	225	126	13.7	83.7
150% RDF + FYM @ 12.5 t ha^{-1}	1.41	0.31	239	16.1	230	119	11.1	71.2
S.Ed.	0.019	0.008	4.04	0.26	3.80	2.10	0.39	2.01
CD (0.05)	0.053	0.021	10.09	0.66	9.49	4.31	0.76	4.15
***Rabi* blackgram**								
Control	1.41	0.24	198	11.8	191	38	6.4	34
50% RDF	1.38	0.28	222	13.8	213	53	8.1	49
75% RDF	1.37	0.30	242	15.7	233	62	10.7	59
100% RDF	1.37	0.31	265	17.8	243	57	9.8	51
S.Ed.	0.016	0.005	6.10	0.39	5.79	2.78	0.31	2.11
CD (0.05)	0.047	0.017	12.63	0.81	12.02	5.04	0.69	4.24
Interaction								
S.Ed.	0.035	0.013	10.11	0.65	9.57	4.89	0.74	4.28
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Initial	1.37	0.23	215	11.5	218	-	-	-

Effect on bulk density, organic carbon, available nutrients and uptake

The results for bulk density and organic carbon of the soil at 0-15 cm depth revealed values ranging from 1.32 to 1.41 Mg cm^{-3} and 0.23 to 0.31%, respectively, at the end of the third year of inquiry under various fertilization levels (Table 3). 150% RDF + FYM at 12.5 t ha^{-1} had significantly lower bulk density (1.41) and higher organic carbon (0.31) values, followed by 125% RDF + FYM @ 12.5 t ha^{-1} (1.40 Mg cm^{-3} and 0.27%, respectively). These findings are superior than the initial values of bulk density (1.37 Mg cm-3) and organic carbon (0.23%). Kar *et al.* (2012) included legumes in groundnut fallow during the season, which not only supplemented the N demand of the following legume crop, but also improved soil structure that groundnut had degraded. In this experiment, the use of organic manures improved pore space, soil aggregation and soil organic carbon. Mitran *et al.* (2017) and Gudadhe *et al.* (2018) report comparable results. It can be stated that the use of organic manures in conjunction with chemical fertilizers to the preceding crop groundnut and chemical fertilizers to the succeeding crop blackgram greatly increased the soil's available NPK levels. The application of 150% RDF + FYM @ 12.5 t ha^{-1} to groundnut resulted in the highest accessible NPK (239, 16.1 and 230 kg ha^{-1} respectively) in the soil (Table 3), which was followed by other treatments. In this experiment enhancement, available N in soil might be due to the release of NPK after decomposition of FYM and mineralization from native sources during decomposition processes again contributed to the maximum build up of available nutrients over control and initial soil nutrient status. These findings align with the research of (Shubhangi *et al.,* 2014 and Banik and Sharma, 2009). The application of RDF and FYM resulted in a significantly higher seed yield, implying that excess assimilates deposited in the leaves were later translocated into seeds during senescence, contributing to the observed increase in seed output. It can also be claimed that the biomass introduced through blackgram was high in nitrogen, which may have increased nitrogen fixation by free living organisms (Chauhan *et al*., 2001). Groundnut residual treatments on blackgram resulted in considerably increased NPK absorption (126, 13.7 and 83.7 kg ha^{-1}, respectively) when 125% RDF + FYM @ 12.5 t ha^{-1} was applied. This could be owing to the additional nutrients provided by organic manures, as well as the beneficial effects of organic matter decomposition, which positively altered the physical and chemical qualities of the soil. Similar results were reported by Ramesh *et al.* (2009) in rapeseed-greengram-rice. The nutrient management in groundnut would have an astounding impact on the succeeding blackgram crop (Ramesh *et al*., 2019).

Subplot treatments to blackgram showed considerably higher NPK uptake (62, 10.7 and 59 kg ha^{-1}, respectively) with 75% RDF application. The lowest values of NPK uptake were discovered with control. This could develop due to increased nutrient availability and more efficient nutrient transfer from preceding seasons to subsequent seasons in the presence of FYM. Increased nutrient uptake occurred as a result of improved soil conditions, which stimulated luxuriant root growth and the absorption of nutrients and moisture from a larger region. Soil nutrient stores were sufficient, allowing crops to absorb and utilize nutrients more efficiently. The productivity and profitability of groundnut-based cropping systems cannot be sustained indefinitely if we continue to add fewer organic and more inorganic nutrients at the same time (Sharma *et al*., 2013).

Economics of groundnut-black gram cropping sequence

After analyzing three years of average data from the groundnut-blackgram cropping sequence among four main plots of groundnut and four subplots of blackgram, it was discovered that applying 125% RDF + FYM @ 12.5 t ha^{-1} to groundnut crop resulted in the highest net monetary returns (Rs. 95634 ha^{-1}) and benefit cost ratio (2.93). Among four alternative subplots to blackgram, the application of 75% RDF yielded the highest net monetary returns (Rs. 40128 ha^{-1}) and benefit cost ratio (2.57), followed by 100% RDF to blackgram. The highest groundnut-blackgram system profitability was achieved with the application of 75% RDF to blackgram, which provided the nutrients required for nitrogen fixation, as well as the residual effect of organic nutrients supplied to groundnut, which contains a variety of micronutrients. This also served to improve the yield and economics of the blackgram, as well as the whole system.

CONCLUSION

Based on a comprehensive three-year study, it is evident that both the direct and residual effects of Farm Yard Manure (FYM) and inorganic fertilizer sources play a pivotal role in significantly increasing pod yield and seed yield. Notably, the treatment that stood out was the one receiving 125% Recommended Dose of Fertilizer (RDF), applied in conjunction with FYM @ 12.5^{-1} in groundnut cultivation. In the case of blackgram, the application of 75% RDF yielded the most favorable results. Conversely, the control group exhibited the lowest pod and seed yields. These findings highlight the critical importance of optimizing nutrient management practices. Specifically, the synergistic application of 125% RDF along with FYM proves to be highly beneficial for enhancing groundnut pod yield. Simultaneously, the application of 75% RDF demonstrates positive effects on subsequent blackgram seed yield. In conclusion, the study underscores the significance of tailored nutrient management strategies, emphasizing the need for a balanced approach involving both inorganic fertilizers and organic inputs such as FYM. These insights can guide farmers and agricultural practitioners in maximizing crop yields and ensuring sustainable and efficient farming practices.

ACKNOWLEDGEMENT

The author thankfully acknowledge the Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam, Tamil Nadu for providing all the necessary and required facilities to conduct the research.

Conflict of interest

All authors declared that there is no conflict of interest.

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