RESEARCH ARTICLE Legume Research- An International Journal, Volume 47 Issue 9: 1567-1572 (September 2024)

Residual Effect of Rice-fish Based Organic Nutrient Management Approaches on Rice Fallow Blackgram Productivity Enhancement in Cauvery Delta Zone of Tamil Nadu

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10.18805/LR-5337

ABSTRACT

Background: A field experiment was conducted during the rice fallow season of 2023 and 2024 (January to March) at Tamil Nadu Rice Research Institute (TRRI), Aduthurai, Tamil Nadu to study the residual effect of rice-fish-based organic nutrient management practices adopted in rice on succeeding blackgram grown as rice fallow.

Methods: The experiment was carried out using randomized block design (RBD) with eleven treatments *viz*., T_1- No Green manure- Rice crop alone (RDF), T_2- Green manure- Rice crop alone (PSB+KSB+ZSB), T_3- T_2+Nanourea, T_4-Green manure- Rice crop (PSB+KSB+ZSB) + Fish, T_5- T_4+ Nano urea,T_6- Green manure- Rice crop (PSB+KSB+ZSB) + Fish + Azolla, T_7-T_6 + Nano urea, T_8- Green manure-Rice crop (PSB+KSB+ZSB) + Fish + Duck, T_9- T_8+Nano urea, T_{10}- Green manure- Rice crop (PSB+KSB+ZSB)+ Fish + Azolla + Duck, T_{11}- T_{10}+Nano urea. The treatments were replicated thrice. The blackgram variety ADT 6 was used as a test crop.

Result: The results revealed that among the different organic nutrient management approaches followed in the rice-fish based farming system, the residual effect of Green manure- Rice (solubilizing bacteria such as PSB, KSB and ZSB) + Fish + Azolla + Duck (T_{10}) resulted in higher plant height, DMP, LAI and SPAD value in blackgram. Similarly, the highest root length (19.43 cm), root dry weight (1.10 g), root volume (10.68 g/cc), nodule plant^{-1} at 20 DAS (13.82) and nodule plant^{-1} at 40 DAS (22.97) were also obtained with the same treatment. By virtue of higher growth and yield parameters, more number of pods plant^{-1} (26.88) and seeds pod^{-1} (7.73), grain yield (789 kg ha^{-1}) and halum yield (2136 kg ha^{-1}) of blackgram were obtained in the residual treatment of the residual effect of Green manure- Rice (solubilizing bacteria such as PSB, KSB and ZSB) + Fish + Azolla + Duck (T_{10}). The available soil nutrients at 20 DAS of blackgram were higher in Green manure- Rice (solubilizing bacteria such as PSB, KSB and ZSB) + Fish + Azolla + Duck (T_{10}). Due to higher blackgram yield, the same treatment achieved higher gross return (Rs.41561 ha^{-1}), net return (Rs.30156 ha^{-1}) and BCR (3.64). The study also indicated that the trench (300 m^3) dug in rice fields for fish rearing provided sufficient moisture for rice fallow blackgram and thereby evaded the terminal stress.

Key words: Blackgram, Fish trench, Residual, Rice fallow, Rice-fish.

INTRODUCTION

Traditionally, Rice is normally grown in puddled conditions, which implies a large quantity of water. Fish rearing is suggested under the low-lying rice fields since it will improve yield, economic benefits and soil and nutritional security. Research reports have indicated that rice-fish co-culture significantly increases rice yields more than rice monoculture (Wang *et al.,* 2023). Pulses are an important source of protein in India. In addition to serving as a significant source of protein, they also support promising sustainable agriculture and increase soil fertility through biological N fixation (Lal, 2017). India produced 4.63 million tonnes of blackgram in an area of 2.77 million ha with an average productivity of 599 kg ha^{-1}. The area, production and productivity of blackgram in Tamil Nadu are 4.07 lakhs ha, 2.68 lakhs tonnes and 660 kg ha^{-1} respectively (India Stat, 2022-23). The rice-fallow pulses cropping system of Cauvery delta zone has 1.76 lakh ha of area. In the Cauvery delta zone, rice fallow pulses are mostly grown under a no-tillage condition with the use of residual moisture and nutrients in proceeding rice crops (Nagarajan *et al.,* 2004). At the time of harvesting rice, the available soil moisture presents in the soil profile ranged from 150 to 200 mm, which would be sufficient to cultivate a short-duration pulse under rice fallow conditions (Das *et al.,* 2017). Unlike other

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How to cite this article: Ranjith, R. Subrahmaniyan, K., Elamathi, S., Manimaran, R., Manikandan, K. and Sivasankari Devi, T. (2024). Residual Effect of Rice-fish Based Organic Nutrient Management Approaches on Rice Fallow Blackgram Productivity Enhancement in Cauvery Delta Zone of Tamil Nadu. Legume Research. 47(9): 1567-1572. doi: 10.18805/LR-5337.

Submitted: 16-04-2024 **Accepted:** 01-07-2024 **Online:** 20-08-2024

pulses, blackgram is well suited for rice fallow conditions, because of their better adaptability to limited soil moisture and tolerance to water logging during an early stage of crop growth (Raja and Sathish, 2018). The yield potential of rice fallow blackgram is lower than that of irrigated blackgram, with an average yield of 300 to 500 kg ha^{-1} (Umamageshwari *et al.,* 2019). ADT 6 blackgram is a recently released blackgram variety suitable for rice fallow conditions. It is high-yielding, short duration and matured in 60-65 days duration to make use of residual soil moisture. Furthermore, it is highly suitable for the Cauvery Delta zone of Tamil Nadu (Shanthi *et al.,* 2019).

In rice fallow condition, soil moisture and nutrients availability are major limiting factor and it ultimately led to decline crop productivity. The soil moisture is sufficient to crop due to presence of water in micro farm pond created in a corner of the field to mitigate the terminal moisture stress in blackgram under rice fallow conditions (Subrahmaniyan *et al.,* 2023). In the green manure-rice-black gram cropping sequence, practices of pre-season green manure cultivation and rice-fish along with azolla and duck systems provide sufficient nutrients to the current rice crop and also supply nutrients to succeeding crop. Adoption of various integrated farming system components like fish, azolla and ducks in rice field enhanced the organic matter content and nutrient availability (Meena *et al.,* 2020). Azolla incorporation and dual culturing provide organic matter, which improves soil quality and provides nutrients to rice and subsequent crops (Kimani *et al.,* 2022). Rice integrated with duck effectively increased organic matter and total nitrogen content of soil. Keeping above points in view, an experiment was conducted to evaluate the residual effect of rice-fish based organic nutrient management approaches to increase the rice fallow blackgram productivity.

MATERIALS AND METHODS

A field experiment on rice fallow blackgram was conducted at Tamil Nadu Rice Research Institute (TRRI), Aduthurai, Tamil Nadu during the rice fallow season (January to March) of 2023 and 2024 with an objective to study the residual effect of rice-fish based organic nutrient management approaches on rice fallow blackgram. The experimental site was located at 11°01′N latitude and 79°48′E longitude, with a height of 19.5 meters above sea level. The experimental field has a clayey soil with a pH of 7.6, EC of 0.32 dSm^{-1}, low organic carbon (0.20%), medium available nitrogen (275 kg ha^{-1}), high available phosphorus (45 kg ha^{-1}) and medium available potassium (324 kg ha^{-1}). During first season, the experiment was carried out using randomized block design (RBD) in rice with eleven treatments *viz*., T_1- No Green manure- Rice alone (RDF), T_2-Green manure- Rice alone (PSB+KSB+ZSB), T_3-T_2+Nano urea,T_4- Green manure- Rice (PSB+KSB+ZSB) + Fish, T_5-T_4+ Nano urea, T_6-Green manure-Rice (PSB+KSB+ZSB) + Fish + Azolla, T_7- T_6 + Nano urea, T_8- Green manure- Rice (PSB+KSB+ZSB)+ Fish+ Duck, T_9- T_8+ Nano urea, T_{10}- Green manure- Rice (PSB+KSB+ZSB) + Fish + Azolla + Duck, T_{11}- T_{10} + Nano urea. The treatments were replicated thrice. In the respective treatment of rice, nano urea foliar spray was done with 4ml per litre of water twice at 20 DAT and one week before flowering. The recommended dose of NPK was 150:50:50 kg ha^{-1} for rice crops and the sources of nitrogen, phosphorus and potassium were urea, single super phosphate and muriate of potash, respectively. The rice crop was transplanted at spacing of 20 × 15 cm. The treatments were imposed only to rice crop and rice fallow blackgram was raised as a relay crop to make use of residual soil moisture and residual nutrients. A trench was dug at a dimension of 300m × 1m × 1m (L × B × D) in three sides of the experimental field with the objective of rearing the fish during rice cultivation. Subsequently, the water level of the trench is maintained in RFP season, because fish rearing is done on the field up to the pulses harvest. Furthermore, the fish trench ensured the soil moisture availability and helpful to pulse crop for their growth and development. The practice of preseason rice fish-based farming system approaches was added nutrients through duck excreta as 20.99 kg of N, 11.93 kg of P and 8.19 kg of K and nutrients added through fish excreta as 2.09 kg of N, 1.87 kg of P and 0.14 kg of K. Azolla incorporation were also added 21.5, 3.4 and 10.5 kg of N, P and K respectively. The blackgram variety ADT 6 was used as a test crop and a seed rate of 30 kg ha^{-1} was broadcasted in the rice field 7 days before harvest to study the residual effect of treatment applied to rice crop. During time of broadcasting, the available soil moisture was noticed as around 65% in rice fields. The experiment was conducted on the same site without changing the randomization of the treatments for the successive year to assess the residual effects.

The SPAD-502 chlorophyll meter, a rapid, non-destructive and hand-held spectral device was used for estimating leaf chlorophyll content. SPAD values of the 5 fully expanded uppermost leaves were determined on 40 DAS and the results are reported as SPAD units. Ten plants were excavated along with soil at a dimension of 15 cm × 15 cm × 30 cm (L × B × D) from each experimental plot in three replications at 20 and 40 DAS and the extent of nodulation was estimated by carefully washing the roots and detaching the nodules before counting (Khan *et al.,* 2006). Further, those roots were taken and used for root length measurement. The length of the root was determined in centimeters from base to the tip of root using a measuring scale. For, root dry weight, after taking the fresh weight of the roots they are kept in butter paper and kept in oven for drying at 80°C for 24 hrs and then dry weight of root is expressed in grams (g). In order to measure root volume, the root masses were placed into a water-filled measuring cylinder. The increase in water level was measured and expressed as (g/cc). The data on growth, root parameters and yield attributes were observed at the time of harvest randomly from 5 plants in each treatment.

The seed yields were measured as total yield per plot and converted to kg ha^{-1}. The experimental data were analyzed statistically as per the method suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters

The data on growth attributes of blackgram (Table 1) indicated that the plant height at harvest stage differed under residual effect of rice-fish based organic nutrient management approaches. The integrated application of Green manure - Rice (PSB + KSB + ZSB) + Fish + Azolla + Duck (T_{10}) significantly improved the plant height (57.74 cm) at harvest which is a critical factor for increasing biomass and yield, which was comparable with rice alone along with no green manure (T_1) (42.46 cm). The higher nutrient availability due to the integration of green manure, fish, azolla and duck in rice field, would have benefitted the succeeding black gram and as a result, taller plants were observed. Similarly, Baigi (2013) reported earlier that N fixing fern Azolla and fish and ducks excreta enhances soil fertility, allowing them to focus on plant growth.

The excreta of fish and ducks, along with the microbial breakdown of azolla would have improved the soil structure and fertility and thus created a conducive environment for root expansion and leaf growth in rice fallow condition. As a result, higher LAI (2.56) was observed with the same treatment T_{10}. Residuals of microbial consortia (PSB + KSB + ZSB) might have further enhanced the nutrient availability

Table 1: Residual effect of rice-fish based organic nutrient management approaches on growth parameters of rice fallow blackgram (Mean of two years).

Treatments	Plant height at harvest (cm)	LAI at harvest	SPAD value	DMP at harvest (kg ha^{-1})
T_1- No Green manure- Rice alone (RDF)	42.46	1.55	29.60	2334
T_2- Green manure- Rice alone (PSB+KSB+ZSB)	45.72	1.73	31.42	2440
T_3- T_2+ Nano urea (foliar spray @ 0.4 %)	45.20	1.72	31.37	2436
T_4- Green manure- Rice +Fish (PSB+KSB+ZSB)	48.85	1.94	33.21	2569
T_5- T_4+ Nano urea (foliar spray @ 0.4 %)	48.43	1.92	33.17	2564
T_6- Green manure-Rice+Fish+Azolla (PSB+KSB+ZSB)	52.40	2.14	35.00	2678
T_7- T_6+ Nano urea (foliar spray @ 0.4 %)	52.08	2.12	34.95	2673
T_8- Green manure- Rice+ Fish+ Duck (PSB+KSB+ZSB)	55.31	2.35	36.81	2789
T_9- T_8+ Nano urea (foliar spray @ 0.4 %)	54.74	2.33	36.75	2783
T_{10}- Green manure-Rice+Fish+Azolla+Duck (PSB+KSB+ZSB)	57.74	2.56	38.60	2928
T_{11}- T_{10} + Nano urea (foliar spray @ 0.4%)	57.56	2.54	38.55	2923
SEd	0.88	0.04	0.59	44.99
CD (p=0.05)	1.83	0.08	1.29	93.3

Table 2: Residual effect of rice-fish based organic nutrient management approaches on root parameters of rice fallow blackgram (Mean of two years).

Treatments	Root length (cm)	Root dry weight (g)	Root volume (g/cc)	Nodule $plant^{-1}$ 20 DAS	Nodule $plant^{-1}$ 40 DAS
T_1- No Green manure- Rice alone (RDF)	14.01	0.56	7.80	6.64	7.63
T_2- Green manure- Rice alone (PSB+KSB+ZSB)	15.06	0.67	8.37	8.04	17.39
T_3- T_2+ Nano urea (foliar spray @ 0.4%)	15.03	0.65	8.33	8.01	16.26
T_4- Green manure- Rice +Fish (PSB+KSB+ZSB)	16.20	0.78	8.94	9.49	18.91
T_5- T_4+ Nano urea (foliar spray @ 0.4%)	16.15	0.76	8.89	9.45	17.75
T_6- Green manure- Rice + Fish + Azolla (PSB+KSB+ZSB)	17.18	0.89	9.59	10.90	20.35
T_7- T_6+ Nano urea (foliar spray @ 0.4%)	17.14	0.88	9.55	10.85	19.27
T_8- Green manure- Rice+ Fish+ Duck (PSB+KSB+ZSB)	18.40	1.00	10.13	12.36	21.79
T_9- T_8+ Nano urea (foliar spray @ 0.4%)	18.36	0.99	10.11	12.31	21.10
T_{10}- Green manure- Rice+ Fish+Azolla+Duck (PSB+KSB+ZSB)	19.43	1.10	10.68	13.82	22.97
T_{11}- T_{10} + Nano urea (foliar spray @ 0.4%)	19.37	1.08	10.66	13.78	22.29
SEd	0.29	0.02	0.16	0.21	12.73
CD(p=0.05)	0.62	0.03	0.34	0.44	0.52

Table 3: Residual effect of rice-fish based organic nutrient management approaches on yield parameters and yield of rice fallow blackgram (Mean of two years).

Treatments	Pods plant^{-1}	Seeds pod^{-1}	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1- No Green manure-Rice alone (RDF)	17.13	4.52	586	1699
T_2- Green manure-Rice alone (PSB+KSB+ZSB)	19.03	5.15	634	1790
T_3- T_2 + Nano urea (foliar spray @ 0.4%)	18.96	5.09	627	1780
T_4- Green manure-Rice + Fish (PSB+KSB+ZSB)	21.02	5.88	668	1876
T_5- T_4 + Nano urea (foliar spray @ 0.4%)	20.89	5.83	664	1871
T_6- Green manure-Rice + Fish + Azolla (PSB+KSB+ZSB)	23.06	6.52	707	1962
T_7- T_6+ Nano urea (foliar spray @ 0.4%)	22.95	6.47	700	1956
T_8- Green manure-Rice + Fish + Duck (PSB+KSB+ZSB)	24.97	7.12	746	2046
T_9- T_8+ Nano urea (foliar spray @ 0.4%)	24.92	7.06	740	2041
T_{10}- Green manure-Rice + Fish + Azolla + Duck (PSB+KSB+ZSB)	26.88	7.73	789	2136
T_{11}- T_{10}+ Nano urea (foliar spray @ 0.4%)	26.83	7.68	783	2129
SEd	0.41	0.11	12.0	32.89
CD (p=0.05)	0.85	0.25	24.9	68.21

Table 4: Residual effect of rice-fish based organic nutrient management approaches on soil available N, P and K of rice fallow blackgram (Mean of two years).

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1- No Green manure- Rice alone (RDF)	206	29	245
T_2- Green manure- Rice alone (PSB +KSB +ZSB)	227	33	270
T_3- T_2 + Nano urea (foliar spray @ 0.4%)	224	32	268
T_4- Green manure- Rice + Fish (PSB+KSB+ZSB)	248	37	294
T_5- T_4 + Nano urea (foliar spray @ 0.4%)	245	36	293
T_6- Green manure- Rice + Fish + Azolla (PSB+KSB+ZSB)	269	42	318
T_7- T_6 + Nano urea(foliar spray @ 0.4%)	266	40	317
T_8- Green manure- Rice + Fish + Duck (PSB+KSB+ZSB)	272	47	343
T_9- T_8 + Nano urea (foliar spray @ 0.4%)	270	45	341
T_{10}- Green manure- Rice+ Fish + Azolla + Duck (PSB+KSB+ZSB)	293	51	367
T_{11}- T_{10}+ Nano urea (foliar spray @ 0.4%)	290	50	366
SEd	7.9	0.9	10.3
CD (p=0.05)	17.0	2.0	22.1

by decomposing organic matter and releasing nutrients to soil, which resulted in maximizing photosynthetic efficiency and reflected in the higher SPAD value (38.60). Increased plant height, LAI and photosynthesis efficiency in the residual of Green manure - Rice + Fish + Azolla + Duck (PSB + KSB + ZSB) (T_{10}) led to increased Dry matter production (DMP) (2928 kg ha^{-1}) as well.

The increased DMP was due to the effective utilization of available nutrients obtained from the residues of rice, remnant nutrients from the wastes of duck and fish and biological nitrogen fixation by Azolla (Meena *et al.,* 2020).

Root parameters

The data on root parameters of the blackgram (Table 2) indicated that the root length, root dry weight and root volume differed under the residual effect of rice-fish-based organic nutrient management approaches. The residual effect of Green manure - Rice (PSB + KSB + ZSB) + Fish + Azolla + Duck (T_{10}) had significantly increased the root length (19.43 cm), root dry weight (1.10) and root volume (10.68) due to the leftover residues of rice, mineralized droppings of fish and duck and oxygenic photosynthesis in the root system by Azolla which was quite comparable with root length (14.01), root dry weight (0.56) and root volume (7.8) observed with rice alone along with no green manure (T_1). Similar result was also reported by Paramesh *et al.,* (2021) who stated that the atmospheric nitrogen fixation of N by azolla, increased microbial activity and soil organic carbon from the fish and duck droppings and the rapid decomposition of residues of rice had increased the root parameters.

The residual effect of Green manure - Rice (PSB + KSB + ZSB) + Fish + Azolla + Duck (T_{10}) support healthier root systems by creating more favorable environment for

Table 5: Residual effect of rice-fish based organic nutrient management approaches on economicsof rice fallow blackgram (Mean of two years).

Treatments	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
T_1- No Green manure- Rice alone (RDF)	13100	30974	17874	2.36
T_2- Green manure- Rice alone (PSB + KSB + ZSB)	11405	33465	22060	2.93
T_3- T_2+ Nano urea (foliar spray @ 0.4%)	11405	33130	21725	2.90
T_4- Green manure- Rice + Fish (PSB + KSB + ZSB)	11405	35276	23871	3.09
T_5- T_4+ Nano urea (foliar spray @ 0.4%)	11405	35046	23641	3.07
T_6- Green manure- Rice + Fish + Azolla (PSB + KSB + ZSB)	11405	37287	25882	3.27
T_7- T_6+ Nano urea (foliar spray @ 0.4%)	11405	36931	25526	3.24
T_8- Green manure- Rice + Fish + Duck (PSB + KSB + ZSB)	11405	39321	27916	3.45
T_9- T_8+ Nano urea (foliar spray @ 0.4%)	11405	39041	27636	3.42
T_{10}- Green manure- Rice+ Fish + Azolla + Duck (PSB+ KSB +ZSB)	11405	41561	30156	3.64
T_{11}- T_{10} + Nano urea (foliar spray @ 0.4%)	11405	41254	29849	3.62

the rhizobia-legume symbiosis, resulting in more effective nodulation at both 20 DAS, 40 DAS of (13.82 nodules plant^{-1}), (22.97 nodules plant^{-1}) respectively, which were crucial for nitrogen fixation and plant growth. Residual nutrients from the preceding rice would have been effectively utilized in rice fallow blackgram, where the soil moisture of rice-fish system adopted was conducive for the uptake of left over nutrients.

Yield parameters and yield

Integrated application of Green manure - Rice (PSB + KSB + ZSB) + Fish + Azolla + Duck increased the grain yield (789 kg ha^{-1}) due to the enhanced growth and yield parameters (Table 3), which was achieved due to better nutrient availability and continuous supply of nutrients to the succeeding blackgram crop (Bochalya *et al.,* 2022) and The lower availability of nutrients to the succeeding crop might be reason for poor black gram yield in the rice alone treatment.

Geetha Jebarantham, (2023) reported that the symbiotic relationship between azolla and its cyanobacterial partner not only fixes nitrogen but also promotes a balanced ecosystem that supports plant growth, leading to increased pods plant^{-1}, seeds pod-1 and ultimately grain yield which are critical factors for crop productivity. Sapna and Lingaraju (2022) also observed the presence of microbial consortia residual in the soil can lead to improved soil health and increased microbial activity. Similarly, the haulm yield was also highest with the same treatment (T_{10}) as compared with rice alone (T_1). The poor nutrient uptake from the residues of rice and slower decomposition crop residues might be the reason for blackgram yield reduction in rice alone (Kumar *et al.,* 2021).

Soil available nutrients

The soil available nutrients were analyzed at 20 DAS of blackgram to verify the nutrient availability by application of IFS components, green manure and solubilizing bacteria in the preceding rice crop. Significantly higher available nitrogen (293 kg ha^{-1}), phosphorus (51 kg ha^{-1}) and potassium (367 kg ha^{-1}) were obtained in the treatments that received green manure, fish, azolla, duck, solubilizing bacteria in preseason (Table 4). Similar result was also reported by (Ramesh *et al.,* 2016).

Economic analysis

The highest gross return (Rs. 41561), net return (Rs.30156 ha^{-1}) and BCR of 3.64 achieved with green manure- Rice (PSB + KSB + ZSB) + Fish + Azolla + Duck was mainly due to higher grain yield obtained with this treatment (Table 5), which was closely followed by Green manure- Rice + Fish + Azolla + Duck (PSB + KSB + ZSB) + Nano urea (Rs. 41254 ha^{-1}, Rs.29849 ha^{-1} and 3.62). The gross return (Rs. 30974 ha^{-1}), net return (Rs. 17874) and BCR (2.36) was lowest in No-Green manure-Rice alone (RDF).

CONCLUSION

From the two years of field investigation, the results confirmed that the residual effect of green manure- Rice (PSB+KSB+ZSB) + Fish+ Azolla+ Duck had enhanced the crop yield of blackgram. Hence, it could be concluded that rice-fish based organic nutrient management approaches can be adopted to improve the yield of succeeding blackgram sown as relay cropping in rice-based cropping systems besides improving the soil physical condition, nutrients availability and soil moisture content.

Conflict of interest

I would like to inform on behalf of all the authors that all the authors disclose that there is no potential conflicts of interest related to the publication of the work.

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