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RESEARCH ARTICLE

Influence of duck integration, green manure and fertilizer levels on weed dynamics, productivity and profitability in rice ecosystems

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Abstract

The main staple food of the Indian subcontinent is rice and the careless use of chemical pesticides and fertilizers has negatively impacted rice production. In order to improve sustainable rice production, the duck rice farming system is one of the novelties that can be applied by wetland farmers to reduce the weed seed bank, weed growth, pest load and increase the soil fertility and productivity of land use in rice fields. In this study, field experiments were conducted during Summer, *Kharif* and *Rabi* 2023 at Wetlands. Experimental treatments, viz. green manure - rice - duck treatment, were established to compare with the control and a conventional treatment in the absence of duck. Integrating GMI with Daincha followed by Rice-Duck farming and applying 100 % RDF significantly reduces weed density and increases the rice yield (6333 kg/ha), economic returns and profitability compared to other treatments.

Keywords: pest load; rice - duck farming; soil fertility; weed dynamics; weed seed bank

Introduction

In India, rice is grown in 43.90 million ha, the production level is 114.45 mt and the productivity is about 2607 kg/ha. It is grown under diverse soil and climatic conditions. The productivity level of rice is low compared to the productivity levels of many countries in the world. Therefore, there is ample scope to increase the productivity of rice in the country. In Tamil Nadu, rice is grown in 2.21 million ha, the production level is 8.07 million tonnes and the productivity is about 3658 kg/ha (1).

Rice cultivation is a critical component of global food security, feeding more than half of the world's population (2). As demand for rice continues to grow, farmers face increasing pressure to enhance productivity while minimizing environmental impacts. Traditional rice farming methods often rely on synthetic fertilizers, herbicides, and pesticides, which can degrade soil quality, harm non-target species and pose health risks (3, 4). To address these challenges, sustainable agricultural practices are gaining prominence. Rice planting and animal raising in paddy fields, building an integrated agroecosystem with high species diversity for food production and environmental protection (5). Rice-duck farming is emerging as a promising integrated approach (6). Integrated rice-duck farming, a method of agriculture where rice and ducks are cultivated together in a symbiotic relationship, has gained significant popularity within the agricultural community. This plant-raising system is highly regarded for its multifaceted advantages, encompassing economic, environmental and ecological benefits that have been extensively documented in previous research studies (7). Rearing ducks may offer advantages in managing weeds and the density of their seeds in agricultural soils. It can potentially reduce the occurrence of pest outbreaks and enhance rice production and quality through the enhancement of soil fertility (Fig. 1) (8-10). Keeping ducks in the paddy fields for day and night in rice up to heading stage could increase the economic value of rice grains and ducks and reduce the loss of nutrients that could potentially lead to nonpoint source pollution (11). Rice-duck system could reduce the risk of N and P runoff and leaching, and could improve the use efficiency of N and P by the growth of rice under the ducks due to stirring the water in paddy fields (12-14). Research indicates that emissions of heat-trapping gases, which have global warming potential (CH_4 and N_2O), decreased in the rice-duck system. Rice-duck system significantly reduces the methane emission (8.8 to 16.68 %) compared to conventional rice cultivation (15). Green manure helps to increase humus in soil, carbon sequestration and improves soil fertility (16). Sesbania green manuring (GM) helps in symbiotic nitrogen fixation and increases the soil organic matter and available nutrient status. There will be a substitution of chemical nitrogen with Sesbania GM on the soil quality of the rice and it also increases the N recovery efficiency and soil carbon (17, 18). Substitution of 25 % nitrogen with the green manuring of *Sesbania aculeata* in the base crop rice facilitated the higher uptake of NPK and produced higher

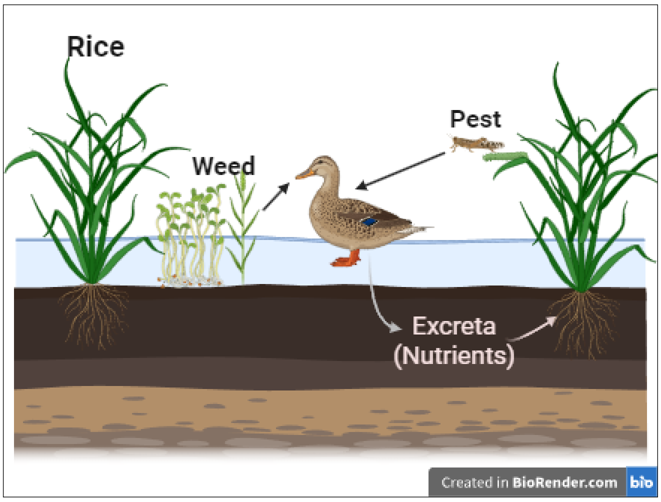

Fig. 1. Schematic diagram of Rice - duck farming

system economic, residue and biological yields than a chemical fertilizer alone, as well as improving the soil quality (19). This experiment aimed to evaluate the effectiveness of integrated rice -duck farming in improving rice yield and quality, reducing pest outbreaks and enhancing soil fertility. This experiment was also aimed at evaluating the effectiveness of integrated rice-duck farming on various aspects of agricultural sustainability. Specifically, soil weed seed bank dynamics, weed suppression, pest load reduction, soil fertility enhancement and overall productivity improvements in rice cultivation.

Materials and Methods

Experimental site and design

Field experiments were conducted during Summer, Kharif and Rabi 2023 at Wetlands, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The farm is located in the North-western tract of Tamil Nadu at 11˚N latitude and 77˚E longitude, at an altitude of 426.7 m above mean sea level and belongs to the Western Agro-climatic zone of Tamil Nadu. The initial soil sample was drawn randomly from 0-15 cm depth of the field before sowing and analysed.

The experiment was laid out in a Randomized Block Design with three replications. The treatment consists of 6 treatments, viz. T_1 – Control, T_2- Rice - Duck farming alone, T_3 - Rice - Duck farming + 100 % RDF (NPK), T_4 - GMI with Daincha *fb* Rice - Duck farming, T_5 - GMI with Daincha *fb* Rice - Duck farming + 75 % of RDF and T_6 - GMI with Daincha *fb* Rice - Duck farming + 100 % of RDF.

Agronomic management

In this experiment, eighteen plots, each measuring 500 m² (25 m × 20 m), were chosen from a shallow lowland rice field. Each plot was separated from the others with raised dykes and surrounded with plastic netting to prevent the escape of ducks from the treated plots as well as to prevent the entry of other predators from outside the rice fields. A short-duration rice variety, ADT 53, was used for the experiment (105-110 days). Twenty-one-day-old seedlings were transplanted. Ducklings were released @ 40 ducks/ acre for 3 hours at a 4-day interval from 20 DAT to heading stage. The rice was fertilised as per the treatment schedule (Table 1). Full doses of phosphorus and potassium and nitrogen fertiliser were applied in four equal splits, viz., basal, tillering, panicle initiation and heading stages. The irrigation was applied with a 5 cm depth up to physiological maturity. Need-based plant protection measures were taken as per the TNAU crop production guide 2020.

Observations

To study the characteristics of the prevalent weeds in the rice fields, fresh weed samples were collected. For each plot, weed samples were obtained by randomly placing a 1 m² iron frame in five locations at 60 DAT. Types of weeds in each square were investigated. After uprooting the weeds, they were washed and oven-dried at 60 °C for 48 h. The dry matter weight of the weeds was then recorded. Weed control efficiency (WCE %) was calculated using the following equation 1 formula:

$$WCE\ (\%) = (DMC - DMT)\ /DMC \times 100 \qquad \text{(Eqn. 1)}$$

where DMC = Dry matter of weeds in the control field and DMT = Dry matter of weeds in experimental fields.

The study involved measuring various parameters related to plant growth and yield. Plant height was recorded and the number of panicles per square meter (panicles m^{-2}) was counted. The total number of grains per panicle was also determined. The weight of 1000 grains was measured to assess grain quality. The harvested grains were sun-dried to a moisture content of 14 %, then weighed. Finally, the grain yield per hectare (ha^{-1}) was calculated based on the dried grain weight.

Economic analysis

The total expenditure for the experiment, from sowing to harvest, including field preparation, was calculated based on the market price of inputs at TNAU and expressed in ₹ha^{-1}. The

Table 1. Treatment details and fertilizer schedule

Treatment	Details
T_1 - Control	Rice is grown as per the TNAU-recommended packages. (Absence of ducks and green manure)
T_2 - Rice - duck farming alone	Rice grown without herbicide and fertilizer application Presence of ducks and absence of green manure incorporation
T_3 - Rice - duck farming + 100 % RDF (NPK)	Rice grown without herbicide and 100 % NPK (150:50:50 kg NPK/ha) Presence of ducks and absence of green manure incorporation
T_4 - GMI with daincha *fb* Rice - Duck farming	Rice grown without herbicide and fertilizer application Presence of ducks and green manure incorporation
T_5 - GMI with daincha *fb* Rice - Duck farming + 75 % of RDF	Rice grown without herbicides and 75 % NPK Presence of ducks and green manure incorporation
T_6 - GMI with daincha *fb* Rice - Duck farming + 100 % of RDF	Rice grown without herbicides and 100 % NPK Presence of ducks and green manure incorporation

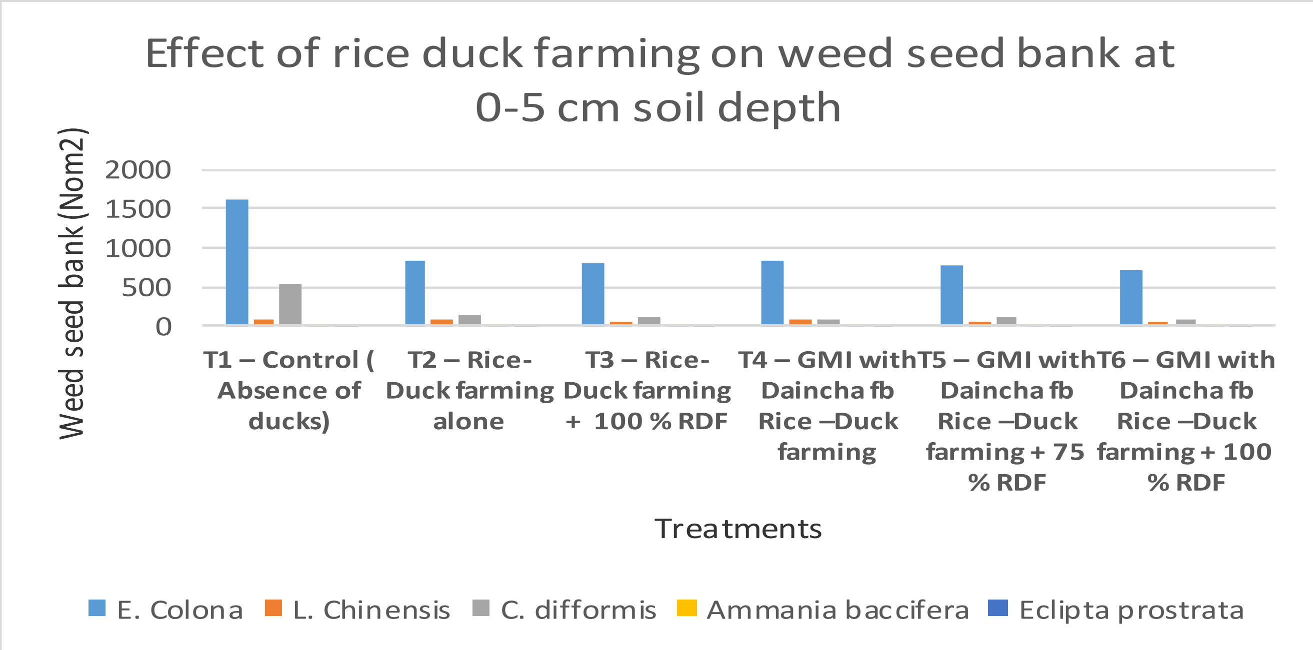

Fig 2. Species wise weed seed count (No.m^{-2}) at 0-5 cm soil depth

gross return was determined by calculating the total income from both grain yield and straw yield of each treatment, using the minimum support price set by the Government of India and also expressed in ₹ ha^{-1}. The net return for each treatment was then obtained by subtracting the cost of cultivation from the gross return, with the result expressed in ₹ ha^{-1}. Additionally, the benefit-cost ratio was calculated by dividing the gross return by the cost of cultivation.

Benefit cost ratio = Gross return (₹ ha^{-1}) / Cost of cultivation (₹ ha^{-1}) (Eqn. 2)

Soil analysis

From each treatment plot, composite soil samples were drawn at 0 -15 cm depth and shade dried for 3 days, sieved through a 2 mm sieve and used for post-harvest nutrient analysis. The values of available N, available P and available K in soil were computed and expressed in kg ha^{-1} (Table 2) (20-22).

Table 2. Physico-chemical properties of soil

I. Physical properties	Value
Sand (%)	41.87
Silt (%)	12.20
Clay (%)	45.93
Texture	Clay loam
II. Chemical properties	
Soil reaction (pH) (1:2.5 soil-water suspension)	8.18
Electrical conductivity (dS m^{-1}) (1:2.5 soil-water suspension)	0.28
Organic carbon (g kg^{-1})	0.28
Available N (kg ha^{-1})	248
Available P_2O_5 (kg ha^{-1})	20
Available K_2O (kg ha^{-1})	510

Results and Discussion

Weeds seed bank

The effectiveness of six different treatments (T_1–T_6) on the control of various weed species was evaluated, with specific focus on *Echinochloa colona*, *Leptochloa chinensis*, *Cyperus difformis*, *Ammania baccifera* and *Eclipta prostrata*. The results indicated significant variation in weed control across different treatments for all species tested. This conformed with the previous reports on weed control efficiency and productivity in rice-fish-duck integrated farming system (23). Another study showed that increasing the density of ducks in rice fields can enhance the mobility and the opportunities that more weeds will be eaten by ducks (24). Similarly, the activity of ducks also creates the same result as a herbicide plot because duck walking activities in the rice field not only disturb the water but also create a muddy field when trampling on it, which in turn inhibits light from reaching the weed seed (Fig. 2) (25).

Effect of rice-duck farming on weed dry weight and weed control efficiency (WCE)

The result in total dry weight of weed in each treatment showed that there was a significant difference between the control with the rice-ducks plots (Fig. 3). Among the treatments, Green Manure Incorporation (GMI) with *Daincha* + Rice-Duck farming combined with 100 % RDF (Recommended Dose of Fertilizers) (T_6) recorded a higher WCE (57.7 %) over the control (T1). This was followed by Rice-Duck farming with 100 % RDF (T_3), which might be due to better control of weeds. The dry weight of weeds was also low (6.53 gm^2) in Green Manure Incorporation (GMI) with *Daincha* + Rice-Duck farming combined with 100 % RDF (Recommended Dose of Fertilizers) at 60 DAT, which was followed by Rice-Duck farming with 100 % RDF (T_3). Similar findings were also reported in the rice-duck integrated farming system (26).

Number of productive tillers

Significantly higher number of productive tillers per hill was recorded in the treatment with Green Manure Incorporation (GMI) with *Daincha* + Rice-Duck farming combined with 100 % RDF (Recommended Dose of Fertilizers) (T_6), which produced

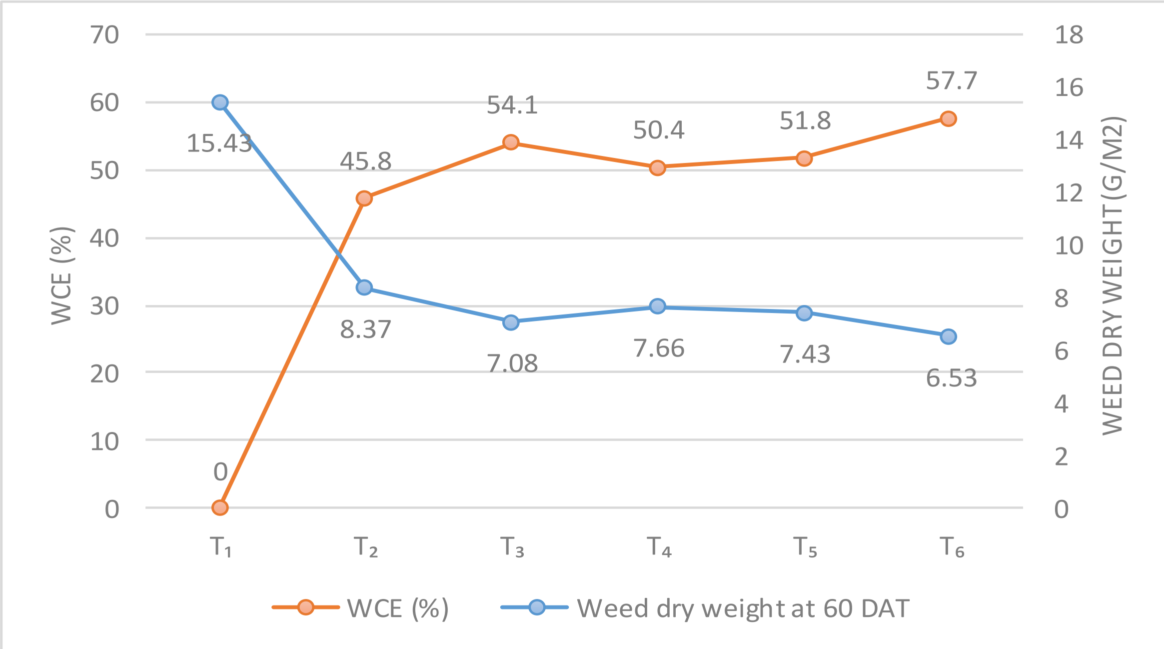

Fig 3. Effect of rice-duck farming on weed dry weight (g m^{-2}) and weed control efficiency (%) (Pooled data of Summer, 2023, *Kharif* 2023 and *Rabi* 2023)

an average of 14.6 tillers per hill. This was closely followed by Rice-Duck farming with 100 % RDF (T_3) yielding 14.4 tillers per hill. These results indicated that the addition of duck, *Daincha* as green manure and RDF significantly enhances tiller productivity. Additionally, the duck dropping might be stimulating rice plant growth through higher nutrient availability and suppressing the weed growth. Ducks' presence on rice land can protect a high level of soil fertility. Duck's excreta can increase nutrients of soil and by providing macronutrients and micronutrients such as Phosphorus (P), potassium (K), iron (Fe), manganese (Mn), boron (B) and calcium (Ca), which results in possessing the required elements rice in grain filling (13)

Yield

The grain yield indicates that significantly higher yield was produced in GMI with Daincha fb Rice–Duck farming + 100 % RDF) (T_6) (6333 kg ha^{-1}) (Table 3) and this was on par with Rice-Duck farming with 100 % RDF) (T_3) due to higher grain filling, scooping and stirring activities disturbs the old rice roots which will helpful in regeneration of new rice plant and better nutrient absorption. Similar results were also reported under rice-duck farming system (10).

Economics

The study evaluated different treatments in rice-duck farming systems and their impacts on gross return, net return and benefit-cost (B:C) ratio. The highest gross return was observed in T_6 (GMI with Daincha, followed by Rice-Duck farming + 100 % RDF), achieving ₹135332 per hectare. This was closely followed by T_3 (Rice-Duck farming + 100 % RDF) with ₹130014 per hectare. The lowest gross return was noted in T_2 (Rice-Duck farming alone), which generated ₹ 77635 per hectare. T_6 also recorded the highest net return of ₹ 75417 per hectare, followed by T_3 with ₹70759 per hectare. The control treatment (T_1) had a net return of ₹48363 per hectare, while T_2 had the lowest net return of ₹34635 per hectare. The B:C ratio, an indicator of profitability, was highest in T_6 (2.26), indicating the best return on investment. T_3 followed with a B: C ratio of 2.19. T_1 had the lowest B: C ratio of 1.63, showing lower profitability compared to other treatments. T_2, despite having the lowest gross and net returns, showed a moderate B: C ratio of 1.81 due to relatively lower input costs. These results showed that integrating GMI with Daincha, followed by Rice-Duck farming and applying 100 % RDF, significantly enhances economic returns and profitability compared to other treatments.

Table 3. Effect of rice-duck farming on weed characters, growth and yield of rice (Pooled data of Summer, 2023, *Kharif* 2023 and *Rabi* 2023)

Treatments	No. of productive tillers/hill	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross income (₹/ha)	Net Income (₹/ha)	B:C ratio
T_1 – Control (Absence of ducks)	14.2	5878	7810	125370	48363	1.63
T_2 – Rice-duck farming alone	11.5	3639	4855	77635	34635	1.81
T_3 – Rice-duck farming + 100 % RDF	14.4	6092	8174	130014	70759	2.19
T_4 – GMI* with Daincha fb Rice –Duck farming	11.7	3895	5141	83041	39381	1.90
T_5 – GMI with daincha fb Rice –Duck farming + 75 % RDF	13.2	5142	6598	109438	53587	1.96
T_6 – GMI with daincha fb Rice –Duck farming + 100 % RDF	14.6	6333	8672	135332	75417	2.26
SEd	0.5	224	275	-	-	-
CD at 5 %	1.0	452	553	-	-	-

*GMI - Green manure incorporation

Conclusion

In India, duck farming has been practiced by the farmers for their own interest. It is a very lucrative business. Ducks are reared for egg and meat production. Ducks occupy an important position next to chicken farming in India. They form about 10 % of the total poultry population and contribute about 6- 7 % of total eggs produced in the country. The duck, till recently, was practically reared only by the small and marginal farmers, mostly in the Southern and Eastern coastal areas, North-eastern India and Jammu and Kashmir.

Rice-duck system is better than the traditional system. The yield and yield parameters of rice are influenced by the rice -duck system. It will create a favourable environment for the growth of rice due to trampling and incorporation of weeds. Further, the faecal matter from ducks will be added nutrient for the crop. Cultivation of rice with ducks can increase nutrient absorption, soil nutritional improvement and proper aeration of the soil. The usage of pesticides, herbicides and chemical fertilizers can be reduced and weeding cost can be saved. Hence, GMI with Daincha fb Rice-Duck farming + 100 % RDF may be a viable option for reducing weed density and increasing yield (6333 kg/ha).

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Authors' contributions

PG conceptualized the study, contributed to methodology, carried out the investigation, participated in original draft preparation, reviewed and edited the manuscript and supervised the work. VM contributed to methodology, participated in the investigation, and assisted in the original draft writing. KT was involved in methodology development. KN contributed to original draft preparation, manuscript review and editing, and handled visualization. PP provided supervision and critical guidance. All authors have read and approved the final version of the manuscript.

Data Availability Statement

The data used and presented in this paper are available upon request from the corresponding author.

Compliance with ethical standards

Conflicts of Interest: The authors declare no conflicts of interest.

Ethical issues: None

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