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Efficacy of rice duck farming on boosting the productivity of rice [*Oryza sativa* (L.) sub species *Japonica*] in NEPZ, India

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Abstract
A field experiment was conducted during *kharif* season of 2016 at three different places *i.e.*, in the blocks A, B and C of SHIATS Model Organic Farm (SMOF), which comes jointly under Department of Agronomy (NAI) and MSCNE, Faculty of Agriculture, SHUATS and two villages named Pahal kapula and Kadiyan, Allahabad (U.P.). The experiment was conducted to study Efficacy of rice duck farming on boosting the grain yield of rice [*Oryza sativa* (L.) sub species *japonica*] in NEPZ, INDIA. Effect of two different integration (R_1: Rice-Duck system R_2: Rice (Control plot), effect of two production system (S_1: Organic Production System S_2: Conventional Production System) and effect of two different planting method (M_1: Machine transplanted M_2: Hand transplanted) was laid out in RBD with 8 treatment and 3 replications. The results revealed that there was significant and highest dry weight (14.95 g hill^{-1}) and harvest index (40.45%) was observed in T_3 (RDS + CPS + Machine transplanted) and same treatment recorded higher grain yield (4.00 t ha^{-1}) through non-significant which was found to be 95% higher compared with the lowest grain yield (2.05 t ha^{-1}) recorded in treatment T_5 (Control + OPS + Machine transplanted).

Keywords: rice-duck farming, organic rice, machine transplanted, grain yield, japonica rice, farmers practice

Introduction
Rice is a monocotyledonous angiosperm. Rice is the most important staple food in Asia. More than 90% of the world's rice is grown and consumed in Asia, where 60% of the world's population lives. Rice accounts for between 35-60% of the caloric intake of three billion Asians.

Rice has a prevalence to be under monoculture system with the preponderance of its cultivation depending too much on synthetic inputs. However, its productivity remains low against an overall increase in demand due to overdependence on rice monoculture leading to decline in soil fertility resulting from continuous cultivation, nutrient extraction through crop harvest and inadequate nutrient replacement.

Establishing a species-diversified cropping system has been suggested to solve these problems. In recent years, several novel species-diversified farming systems such as rice-fish, rice-duck have been documented to be highly effective in controlling crop diseases, insect pests and weeds in paddy field with less pesticide and herbicide application. Among these systems, rice-duck farming system is a complex planting model of rice wetland system with a long history, which utilizes the instinctive scavenging nature of ducks, such as moving and seeking for food industriously to control the rice disease, pests and weeds, in addition, it may probably increase the farm products and income of farmers. Rice-duck cultivation system became so popular in Asia and the Pacific, which may improve the environment and it may also reduce the effects of conventional agriculture of rice on the environment and environmental costs in production of rice. Reinforcement of rice growth and improvement of soil properties can be expected under rice duck farming. Rice yields increase by up to 20 per cent, resulting in 50 percent higher eradication of the use of synthetic fertilizers and pesticides, reduces manual labour by at least 60% net returns.

Materials and Methods
The experiment was carried out during *Kharif* season 2016. The experiment was carried out at three different places *i.e.*, in the blocks A, B and C of SHIATS Model Organic Farm (SMOF), which comes jointly under Department of Agronomy (NAI) and MSCNE, Faculty of Agriculture, SHUATS and two villages named Pahal kapula and Kadiyan, Allahabad (U.P.).

The experiment site lies between 25- 27° N latitude, 8.5°E Longitude and 98 meters altitude. The climate is characterized by the alternate hot rainy season from late June to early September with mean temperature of 38°C. The soil was sandy loam in texture having a pH (7.11), EC (0.24dSm^{-1}), organic carbon (0.45%), available K (212.00 kg ha^{-1}), P (12.00 kg ha^{-1}) at SMOF and at farmers' organic plot the values of pH (7.15), EC (0.24dSm^{-1}), organic carbon (0.48%), available P (10.00 kg ha^{-1}), K (231.00 kg ha^{-1}) and in farmers' conventional plot soil was sandy loam in texture having a pH (7.80), EC (0.26dSm^{-1}), organic carbon (0.40%), P (17.50 kg ha^{-1}), K (221.00 kg ha^{-1}). The experiment was laid down in Randomized Block Design (RBD) with 8 treatment combinations with 3 factors having 2 levels each *i.e.,* two different integration (R_1: Rice-Duck system R_2: Rice (Control plot), two production system (S_1: Organic Production System S_2: Conventional Production System) and 2 different planting method (M_1: Machine transplanted M_2: Hand transplanted). *Akitha Komachi* variety was used as planting material in this study.

Under mechanical transplanting, 14 days old seedling were transplanted with the help of self propelled transplanter, while under conventional transplanting 21 days old seedlings were transplanted with manual labour in puddled soil. Basal application of FYM and Bokashi manure was supplied to crop. Ducklings were released into field when they were 7 to 10 days old. They were released into field @ 350 ha^{-1} after nine days of transplanting. They are released in the field from 6 am to 5 pm. They are withdrawn from the field after 30 DAT because panicle initiation was initiated as they may damage the panicles. Brush weeding was done in duck plots, where as in plots without ducks manual weeding was done with the help of labour.

At the end of the growth period, these items were measured: grain yield, straw yield and yield components such as tillers hill^{-1}, effective tillers hill^{-1}, test weight, one thousand grain weight and harvest index (HI). The economic parameters (net returns, B:C ratio) were worked on the basis of prevailing market prices of inputs and outputs. The data were analyzed by using the 'Analysis of Variance Technique' for Randomized Block Design (RBD). The treatment means were compared at 5% level of significance.

Results and Discussion

The data pertaining to different observations are being presented in Table 1 and 2.

Table 1: Effect of integration, production system and planting method on various parameters of rice

	Treatments	**No. of tillers hill^{-1}**	**CGR(g m^{-2} day^{-1}) 30-45 DAT**	**No. of effective tillers hill^{-1}**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Harvest Index (%)**
	Integration						
R_1	1. Rice-Duck System	11.08	13.48	10.55	3.21	5.37	37.32
R_2	2. Rice (Control)	10.8	13.36	10.62	3.06	5.21	36.91
	F test	NS	S	NS	S	S	NS
	SEm (±)	0.39	0.03	0.36	0.03	0.02	0.3
	CD (P= 0.05)	-	0.09	-	0.1	0.06	-
	Production System						
S_1	1. Organic Production System	9.82	13.55	9.38	2.98	5.13	36.79
S_2	2. Conventional Production System	12.07	13.29	11.78	3.31	5.44	37.44
	F test	S	S	S	S	S	NS
	SEm (±)	0.39	0.03	0.36	0.03	0.02	0.3
	CD (P= 0.05)	1.18	0.09	1.1	0.1	0.06	-
	Planting Method						
M_1	1. Machine Transplanted	10.33	11.53	9.93	2.99	4.66	38.56
M_2	2. Manual Transplanted	11.55	15.31	11.23	3.29	5.91	35.68
	F test	S	S	S	S	S	S
	SEm (±)	0.39	0.03	0.36	0.03	0.02	0.3
	CD (P= 0.05)	1.18	0.09	1.1	0.1	0.06	0.9

Table 2: Interaction effect of integration, production system and planting method on various parameters of rice

	Treatments	**No. of tillers hill^{-1}**	**CGR (g m^{-2} day^{-1}) 30-45 DAT**	**No. of effective tillers hill^{-1}**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Harvest Index (%)**
T_1	RDS + OPS + Machine transplanted	9.53	10.64	8.60	2.11	3.61	36.85
T_2	RDS + OPS + Manual transplanted	10.87	16.22	10.4	3.99	6.83	36.88
T_3	RDS + CPS + Machine transplanted	11.67	12.43	11.27	4.00	5.88	40.45
T_4	RDS + CPS + Manual transplanted	12.27	14.60	11.93	2.78	5.13	35.12
T_5	Control + OPS + Machine transplanted	8.40	10.53	8.27	2.05	3.45	37.22
T_6	Control + OPS + Manual transplanted	10.47	16.78	10.27	3.74	6.6	36.18
T_7	Control + CPS + Machine transplanted	11.73	12.52	11.6	3.77	5.73	39.70
T_8	Control + CPS + Manual transplanted	12.60	13.61	12.33	2.66	5.05	34.53
	F test	NS	S	NS	NS	S	NS
	SEm (±)	0.78	0.06	0.72	0.07	0.03	0.60
	CD (P= 0.05)	-	0.18	-	-	0.11	-
	CV (%)	12.34	0.749	11.85	3.63	1.12	2.79

Table 3: Effect of integration, production system and planting method on soil health after harvesting on of rice

	Treatment	Organic Carbon (%)	pH	EC (dS m^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	RDS + OPS + Machine transplanted	0.55	6.81	0.28	18.43	237.23
T_2	RDS + OPS + Manual transplanted	0.51	6.75	0.28	15.54	264.20
T_3	RDS + CPS + Machine transplanted	0.43	7.25	0.29	19.92	232.02
T_4	RDS + CPS + Manual transplanted	0.41	7.31	0.31	19.17	229.32
T_5	Control + OPS + Machine transplanted	0.53	6.94	0.28	16.23	231.00
T_6	Control + OPS + Manual transplanted	0.47	6.92	0.27	14.69	252.13
T_7	Control + CPS + Machine transplanted	0.38	7.51	0.28	18.19	234.13
T_8	Control + CPS + Manual transplanted	0.37	7.45	0.27	17.98	232.12
	F test	S	NS	NS	S	S
	SEm ±	0.005	0.029	0.005	0.230	0.600
	CD (P= 0.05)	0.017	-	-	0.134	1.849
	CV (%)	2.161	0.724	3.572	0.438	0.442
	Initial value (a) T_1 & T_5	0.45	7.11	0.24	12.00	212.00
	(b) T_2 & T_6	0.48	7.15	0.24	10.00	231.00
	(c) T_3, T_4, T_7 & T_8	0.40	7.80	0.26	17.50	221.00

Number of tillers hill^{-1}

Among the factor levels Non-Significant and higher number of tillers hill^{-1} (11.08) were recorded in treatment R_1 (Rice-Duck system) in integration. Significant and higher number of tillers hill^{-1} (12.07) was recorded in S_2 (Conventional production system) in production systems. Whereas, among planting methods significant and higher tillers hill^{-1} (11.55) were recorded in M_2 (Manual transplanted).

In combined effect of factors non-significant but highest number of tillers hill^{-1} (12.60) was recorded in treatment T_8 (Control + CPS + Manual transplanted). The paddling movement of the ducklings/ducks may have had a stimulating effect, thereby the production of massive tillers in rice plants (Furuno, 2001). Organic sources offer more balanced nutrition to the plants, especially micro nutrients, which positively affect number of tiller in plants (Miller, 2007) and in the current study it may be attributed to the more availability of nitrogen that played a vital role in cell division. A similar trend was also reported by Mahmud *et al.*, 2016 [5]. Besides this, tillering also depends largely upon soil physical conditions that were improved by the addition of organic matter (Usman *et al.*, 2003) [15].

Crop Growth Rate (g m^{-2} day^{-1})

Among the factor levels significant and higher (13.48 g m^{-2} day^{-1}) at 30-45 DAT interval in treatment R_1 (Rice-Duck system). Higher and significant CGR (13.55 g m^{-2} day^{-1}) was found in treatment S_1 (Organic production system) in production systems and in planting methods significant and higher CGR (15.31 g m^{-2} day^{-1}) was observed in M_1 (Machine transplanted).

In combined effect of factors highest significant and highest CGR (16.78 g m^{-2} day^{-1}) at 30-45 DAT interval was observed in treatment T_6 (Control + OPS + Manual transplanted).

Higher radiation use efficiency in the leaf photosynthesis might have led to higher photo assimilate production and thus increased the CGR and net assimilation rate (NAR) (Naing *et al.*, 2010) [9]. Similar result were observed in Debberma and Abraham 2014.

Number of effective tillers hill^{-1}

Among the factor levels non-significant and higher number of effective tillers hill^{-1} (10.62) was observed in R_2 (Rice control) in integration. Significantly higher number of effective tillers hill^{-1} (11.78) was observed in S_2 (Conventional production system) among production systems and in planting methods significantly higher number of effective tillers hill^{-1} (11.23) was observed in M_2 (Manual transplanted). While in combined effect of factors non significant Highest number of effective tillers was observed in treatment T_8 (Control + CPS + Manual transplanted) with a value of 12.33 hill^{-1} which was 49% higher when compared to lowest value (8.27 hill^{-1}), though, the second highest value was registered in treatment T_4. However, nearest value under OPS was only 18.55% lower than the said value.

The mismatch of nutrient release from organic sources and crop demand, as influenced by seasonal conditions in the initial years (Surekha *et al.*, 2013) [13] particularly in trail plots in the farmers' field. Once the soil fertility is built up sufficiently, organic system may also produce equal yields as conventional system.

Grain yield (t ha^{-1})

Among the factor levels significantly higher grain yield (3.21 t ha^{-1}) was observed in treatment R_1 (Rice-Duck system) in integration. Treatment S_1 (Organic production system) registered significant and maximum value of grain yield (3.31 t ha^{-1}) among production system. While in planting methods the higher and significant grain yield (3.29 t ha^{-1}) was observed in treatment M_2 (Manual transplanted).

In combined effect non-significant and highest grain yield of 4.00 t ha^{-1} was observed in T_3 (RDS + CPS + Machine transplanted) which was found to be 95% higher compared with the lowest grain yield (2.05 t ha^{-1}) recorded in treatment T_5 (Control + OPS + Machine transplanted) However, second highest value of 3.99 t ha^{-1} was registered in treatment T_2 (RDS + OPS + Manual transplanted). This is clear evidence that organic production system is as efficient as CPS.

Duck causes increase in grain yield in comparison with a treatment by duck's absence. This may be accrued to the fact that duck could control weeds properly on rice land, which could increase rice competitiveness ability, by its activity and pecking, and also by adding excreta to rice land leading to increase of soil fertility. Moreover paddling by duck causes more oxygenation, and also by providing nutrients in rizhosphere root space causes growth stimulation and increasing yield components such as grain number per panicle, filled grain per panicle, and one thousand grain weight (Mofidian *et al.*, 2015) [7].

The increase in grain yield components may be due to the fact that more available water enhanced nutrient availability, which improved nitrogen and other macro and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to sink

(Siavoshi *et al.*, 2011) [11]. Higher grain yield recorded in mechanical transplanted rice might be due to proper transplanting depth, higher hill density, uniform transplanting efficiency, and lesser percentage of damaged hill and minimum percentage of hill missing (Munnaf *et al*., 2014) [8].

Straw yield (t ha^{-1})

Significantly higher straw yield (5.37 t ha^{-1}) was observed in treatment R_1 (Rice-Duck system) was observed among integration. In production systems treatment S_1 (Organic production system) registered Significant and maximum value of straw yield (5.44 t ha^{-1}). While in planting methods the higher and significant straw yield (5.91 t ha^{-1} respectively) was observed in treatment M_2 (Manual transplanted).

The combined effect was significant between production system, integration and planting method. The superior value of straw yield (6.83 t ha^{-1}) was found with the treatment combination T_2 (RDS + OPS + Manual transplanted) which was 97.97% higher than the lowest straw yield (3.45 t ha^{-1}) as observed in T_5 (Control + OPS + Machine transplanted)

Organic manure in combination with inorganic fertilizers might have increased the vegetative growth of plants and thereby increased straw yield of rice (Mahmud *et al*., 2016) [5]. This might be due to higher concentration of macro and micronutrients in the composted poultry manure and higher and steady nutrient release (Sangeetha *et al*., 2013) [10].

It may also be due to the shading of leaves of one plant to another because shaded plants show more vegetative growth (Uddin *et al*., 2011) [14].

Harvest index (%)

Integration recorded higher value (37.32%) of harvest index in R_1 (Rice-Duck system), while among production system, treatment S_2 (Conventional production system) registered maximum harvest index (37.44%) and in planting methods significant and higher value (38.56%) was observed in M_1 (Machine transplanted).

The combined effect was non-significant between production system, integration and planting method. The highest HI (40.45%) was observed in treatment combination T_3 (RDS + CPS + Machine transplanted).

Appreciably higher harvest index shows the efficiency of converting biological yield into economic yield (Kusalkar *et al*., 2003) [4].

Soil health

In the organically manured plots of SMOF, significant and highest organic carbon (0.55%) was found in treatment with duck component, *i.e.*, treatment T_1 (RDS + OPS + Machine transplanted). It was 24.44% higher than the initial value (0.45%). The most close to neutral pH (6.94) was observed in treatment T_5 (Control + OPS + Machine transplanted). Exactly same EC value (0.28 dS m^{-1}) was observed in both treatment T_1 and T_5. Further, treatment T_1 (RDS + OPS + Machine transplanted) registered highest available P_2O_5 (18.43 kg ha^{-1}), which was 53.58% higher than the initial value (12.00 kg ha^{-1}). The available K_2O (237.23 kg ha^{-1}) registered in treatment T_1 (RDS + OPS + Machine transplanted) was 11.90% higher than the initial value of 212.00 kg ha^{-1}. In farmers' field, among the organically treated plots with duck showed highest organic carbon of (0.51%) registered in treatment T_2 (RDS + OPS + Manual transplanted), which was 6.25% higher when compared to initial value of organic carbon (0.45%). The most close to neutral pH (6.92) was observed in treatment T_6 (Control + OPS + Manual transplanted). The acceptable EC value (0.28 dS m^{-1}) was observed in both the treatments. Plots with duck showed greater influence on available P_2O_5 (15.54 kg ha^{-1}) that was registered in treatment T_2 (RDS + OPS + Manual transplanted), which was the maximum increase when compared to remaining treatments, that is 55.4% higher than the initial value (10.00 kg ha^{-1}). Significant and higher available K_2O (264.20 kg ha^{-1}) was registered in treatment T_2 (RDS + OPS + Manual transplanted), which was 14.37% higher than the initial value of 231.00 kg ha^{-1}.

In conventional plots of farmers' field highest organic carbon 0.43% was observed in duck treated plot, *i.e.*, treatment T_3 (RDS + CPS + Machine transplanted), which was increased by 7.5% than the initial value of 0.40%.The pH was near neutral (7.25) in treatment T_3 (RDS + CPS + Machine transplanted), while, the EC, highest value (0.31 dS m^{-1}) was observed in T_4 (RDS + CPS + Manual transplanted). Significant and highest available P_2O_5 (19.92 kg ha^{-1}) registered in treatment T_3 (RDS + CPS + Machine transplanted) that is 13.82% higher than the initial value (17.50 kg ha^{-1}). Available K_2O (234.13 kg ha^{-1}) was registered in T_7 (Control + CPS + Machine transplanted) which was 5.94% higher than the initial value of 221.00 kg ha^{-1}.

Zheng *et al*., (1997) [16] reported that the total NPK and organic matter content of rice-duck fields increased considerably. This indicates that the grazing of the ducks enriched the soil's nutrients probably through their excreta (Akter and Hossian, 2011) [1].

There may have been improvement in soil parameters, particularly the fertility (organic carbon and available N, P and K), and biological properties, with organics compared to inorganic fertilizers (Surekha *et al*., 2013) [13]. A reason for the soil organic carbon increase may be the slow decomposition of applied and native soil organic matter due to prevailing anoxic conditions and formation of 'hard-to' decompose soil organic carbon under rice crop (Singh *et al*., 2004) [12].

Conclusion

Rice-duck cultivation system has a better efficiency in comparison with typical cultivation system. Duck's presence is an effective factor in rice yield and its components. However, duck's presence causes increasing of effective indicators in yield. Duck's excreta can cause enhancement in soil fertility, as a result using fertilizer on rice land is reduced. In typical rice cultivation, farmers try to reach a better yield and also try to combat pests and weeds on rice lands; they need to use chemical fertilizers and pesticides. Yet overusing chemical substances is destructive for the environment and rice quality. Simultaneous cultivation of rice and duck can enhance nutrient absorption, soil nutritional improvement, and proper aeration of the soil. Therefore, by this production system (rice-duck cultivation system), the usage of pesticides, herbicides, and chemical fertilizers are reduced, eventually environmental pollution is decreased, thereby a populace with a healthy life.

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