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Crop Water Productivity of Rainfed *Toria* (*Brassica rapa* L.) as Influenced by Residual Effect of Organic Manures and Direct Fertilizer Management

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Abstract An experiment was conducted during winter season of 2010-11 and 2011-12 to study the residual effect of organic sources like vermi compost, mustard cake and farm yard manure used in rice cultivation and direct application of inorganic fertilizer management in the form of suphala on the crop water productivity of rainfed *toria* crop (Agrani B-54) in low land rice ecosystem. Among the organic manures, farm yard manure used in rice had the maximum residual effect on *toria* crop growth, yield attributes and seed yield by 608.8 kg ha^{-1} followed by mustard cake (588.2 kg ha^{-1}). The direct application of inorganic fertilizers like suphala during seeding of *toria* recorded maximum seed yield of 625.1 kg ha^{-1}. The least seed yield (483.6 kg ha^{-1}) was noted in control i.e. without fertilizer application. Actual evapo-transpiration (AET) of *toria* crop was low (114.9-130.0 mm) under no manuring and no fertilizer situation but mustard cake manuring in rice followed by high dose of suphala @ 30:30:30 N P_2O_5 K_2O kg ha^{-1} recorded the maximum AET of 154.4 mm. The highest water use efficiency value of 4.91 kg ha-mm^{-1} was also recorded with farm yard manuring in rice plus suphala application in *toria.* Organic manuring in rice cultivation followed by the application of complex fertilizer like suphala at the time of sowing of *toria* may be advocated for rice -*toria* relay cropping in rainfed low land ecosystem.

Keywords Rainfed lowland, Rice-*toria,* Nutrient management, Water productivity.

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Introduction

India ranks fourth largest oilseed producing country in the world. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6% in the total oilseeds production and ranks second after groundnut sharing 27.8% in the India's oilseed economy [1]. The traditional rice growing areas in rainfed shallow lowlands are generally mono cropped with little scope to raise a second crop after rice during November and December by utilizing quick depletion of residual soil moisture. *Paira* cropping provides great scope to raise a second crop under such situation. *Paira* cropping system is widely practiced in several states like Madhya Pradesh, Orissa,

Chhattisgarh, Bihar, West Bengal and Assam in the paddy fields by broadcasting other crops like *lathyrus,* linseed, lentil, black gram, green gram, rapeseed and field pea in standing rice crop 2-3 weeks after flowering [1, 2]. It is a traditional practice of rainfed cultivation to efficiently utilize residual moisture after rice [3]. *Paira* cropping of lentil, *lathyrus* and rapeseed in rice fallows of UP, Bihar, West Bengal and Odisha is practiced because these crops are grown with residual moisture without fertilizer. For sustainable productivity, an integrated nutrient supply and management system with minimum deleterious effects on soil health and to harness the natural nutrient capability and mining of soil reserve is needed [4]. In West Bengal condition, *utera* cropping under rainfed condition can cater to this need on growing *utera* crops in the winter *(rabi)* season, after the wet season rice, utilizing the residual soil moisture by adjusting the sowing time of *utera* crops [1, 3]. The current trend is to explore the possibility of supplementing chemical fertilizers with organic ones, which are eco-friendly and cost effective. Maintaining or increasing soil organic matter content is of great benefit in terms of recycling plant nutrients, minimizing the need for inorganic fertilizers and improving soil physical condition [4]. Therefore, the present investigation was undertaken to study the residual effect of organics used in rice and use of inorganic fertilizer on crop water productivity of *toria* crop in low land ecosystem.

Materials and Methods

A field experiment was conducted to study the effect of nutrient management on soil water availability and crop productivity of *paira toria* crop at Gayespur, Bidhan Chandra Krishi Viswavidyalaya during *rabi* season of 2010-11 and 2011-12. The research farm is situated at 23^0N latitude and 89^0 E longitudes with an average altitude of 9.75 m above MSL. The soil of the experimental field was sandy loam in texture (sand 63.58%, silt 20.59% and clay 15.83%) with a neutral soil reaction (pH 6.9). The soils contain 0.68% organic carbon, total available N 0.085%, available phosphorus 25.30 kg ha^{-1} and available potassium 193.58 kg ha^{-1}. The climate of the area is sub-tropical and humid. During the experimental period the total rainfall received was 2.9 mm. The experimental crop was rapeseed (*Brassica rapa* L.). The crop was locally known as *toria* and the variety was Agrani (B-54) with 110 days duration. The experiment was carried out in a split plot design. The layout of the experiment was done accordingly during *kharif* season i.e. in rice. After harvest of *aman* paddy, rapeseed was sown following the plan of layout. The experiment was carried out with 4 main plot treatments with manures viz. M_1 : 100% RDN as urea (control), M_2 : 25% RDN as vermicompost (VC), M_3 : 25% RDN as mustard cake (MC) and M_4 : 25% RDN @ 60:30:30 N P_2O_5 K_2O kg ha^{-1} as farm yard manure (FYM) and 3 subplot treatments with N P_2O_5 K_2O doses viz. F_1 : 0:0:0, F_2 : 15:15:15, F_3 : 30:30:30 kg ha^{-1}.*Toria* seed was sown on the 4^{th} week of October 2010 and 2011 through broadcasting in standing rice crop 10 days before harvesting. Schedule doses of N P_2O_5 K_2O in the form of suphala (N:P_2O_5:K_2O::15:15:15) were used for easy broadcast in the standing rice crop when soils are saturated. Fertilizer was applied 4 days ahead of seed sowing in the field, so that fertilizer becomes soluble and mixed to the soil. Metasystox @ 1 ml $liter^{-1}$ of water was used as protective measure against aphid infestation in *toria* crop. The *toria* crop was harvested at 118 days after broadcasting. Observations on plant growth and yield attributes like number of siliqua per plant, seeds per siliqua, thousand seed weight and seed and stover yield were taken. The soil moisture was taken at 15 cm soil profile interval up to 60 cm of crop root zone and collected at 15 days interval in rain fed plot. Profile contribution, actual evapo-transpiration and water use efficiency were estimated.

Results and Discussion

Crop growth and yield attributes

Nutrient management in lowland rice ecosystem significantly influenced plant population at harvest of *toria utera* crop. Plant population in FYM applied plot was 115.4 plants per sqm (Table 1) and the least plant population was recorded in the plot where there was no organic manure. Organic applied in rice had a significant influence on plant population, which might be attributed to better hydro-physical environment [2]. Residual effect of organic manuring showed increased branches per plant of *toria* to the extent of

Table 1. Crop growth and yield of rainfed *toria* crop as influenced by residual effect of manuring in rice and direct fertilizer application in *utera* crop (two years pooled). NM-No manure, VC-Vermi-compost, MC-Mustard cake, FYM-Farm yard manure.

Treatments	Plant population m^{-2}	Plant height (cm)	Branches $plant^{-1}$	Dry mater (g m^{-2})	Siliqua $plant^{-1}$	Seeds $siliqua^{-1}$	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Manures (M: Sources)									
M_1 - NM	105.0	61.3	2.52	223.1	95.4	12.2	511.8	1214.2	29.6
M_2 - VC	104.9	63.6	2.72	224.1	94.2	12.7	544.6	1211.6	30.6
M_3 - MC	119.8	67.1	2.73	253.2	102.2	13.8	588.2	1348.8	30.1
M_4 - FYM	115.4	65.5	3.01	244.2	101.9	12.1	608.8	1256.8	32.5
CD (p = 0.05)	9.61	2.266	0.16	20.14	5.33	0.78	20.91	99.84	1.548
Fertilizers (F: NPK kg ha^{-1})									
F_1 - 0:0:0	86.3	62.9	2.41	188.8	91.4	12.3	483.6	1218.2	28.4
F_2 - 15:15:15	115.8	63.2	2.66	243.4	98.9	12.4	581.3	1251.8	31.5
F_3 - 30:30:30	131.6	66.8	3.16	276.9	104.9	13.7	625.1	1330.6	33.0
CD (p =0.05)	18.47	2.30	0.15	44.97	6.19	1.13	29.106	60.14	1.62

19.4% over no manure situation. Fertilizer doses @ 30:30:30 N:P_2O_5 : K_2O kg ha^{-1} increased the plant population to the tune of 52.49% over the control situation. Branches per plant in *toria* increased from 2.41 to 3.16 per plant with the increase in fertilizer doses to the extent of 31.1% over no control. The highest siliqua number per plant (104.9) was found in case of NPK @ 30:30:30 kg ha^{-1} fertilizer dose and the least number of siliqua (91.4) were noted in control as expected. Organic manuring in rice had least residual effect on siliqua number per plant in *toria* crop but the highest number of siliqua (110.7) was noted with NPK @ 30:30:30 kg ha^{-1}. The number of seeds per siliqua was increased with increasing dose of inorganic fertilizer. Result showed that the higher number of seeds per siliqua i.e. 13.7 was observed in case of 30:30:30 kg ha^{-1} dose of NPK fertilizer. The increase of seeds per siliqua due to the increase dose of fertilization was up to 11.38% over control. The maximum seeds per siliqua (13.8) were recorded with mustard cake followed by vermi-compost (12.7).

Seed yield

Seed yield of *toria* grown as utera crop in low land rice field was significantly influenced by residual effect of organic sources of nitrogen applied in rice and fertilizer management in *utera* crop. The maximum seed yield of *toria* crop was recorded 625.1 kg ha^{-1} with N: P_2O_5 : K_2O @ 30:30:30 kg ha^{-1}. The least seed yield (483.6 kg ha^{-1}) was noted in control. The yield increase was to the tune of 20.20 to 29.26% with the increased level of inorganic fertilizer doses up to N:P_2O_5: K_2O @ 30:30:30 kg ha^{-1} applied in *toria utera* crop. The similar result is obtained in rapeseed [5, 6]. Among the organic manures, FYM had recorded maximum seed yield of 608.8 kg ha^{-1} followed by mustard cake (588.2 kg ha^{-1}). Residual effects of organic manuring in rice in terms of yield changesof *utera* crop like *toria* were the tune of 6.41–18.95% over inorganic source of N. The highest stover yield (1330.6 kg ha^{-1}) was noted with the maximum dose of fertilizer (N P_2O_5 K_2O kg ha^{-1} @ 30:30:30 kg ha^{-1}). The increase in stover yield was to the tune of 9% over control. Application of different organic sources increases the stover yield by 11.08%. Maximum stover yield (1348.8 kg ha^{-1}) was observed with the mustard cake application. The residual effect of organic manures and direct inorganic fertilizer management significantly influenced the harvest index of *toria* crop. The maximum harvest index was achieved under FYM (32.5%) and with N: P_2O_5: K_2O @ 30:30:30 kg ha^{-1} (33.0%) fertilizer management. Many researchers have reported positive response of fertilizers on growth and yield attributes of *toria* [7–9].

Water availability and productivity

In rainfed *toria* crop, *in-situ* soil moisture and winter rainfall are very crucial for crop growth and yield in

Table 2. Water availability and water productivity of rainfed *toria* crop as influenced by residual effect of manuring in rice and direct fertilizer application in *utera* crop. PC– Profile contribution, P–Precipitation, AET–Actual evapo-transpiration, WUE–Water use efficiency.

Treatments	PC (mm)	Soil moisture extraction pattern (%) 0-15 cm	15-30 cm	30-45 cm	45-60 cm	P (mm)	AET (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
M_1F_1	114.0	40.18	28.80	17.82	13.21	2.9	116.9	466.6	3.99
M_2F_1	112.0	34.79	29.47	23.99	11.75	2.9	114.9	453.3	3.94
M_3F_1	127.1	33.06	30.36	24.88	11.68	2.9	130.0	514.6	3.96
M_4F_1	114.4	42.92	24.51	21.06	11.45	2.9	117.3	500.0	4.26
M_1F_2	121.3	41.83	23.99	18.72	15.47	2.9	123.9	518.6	4.18
M_2F_2	125.8	35.37	28.54	19.47	13.19	2.9	128.9	600.0	4.65
M_3F_2	142.2	36.14	22.36	23.94	17.56	2.9	144.9	573.3	3.95
M_4F_2	132.2	36.68	32.37	17.70	13.23	2.9	135.1	633.3	4.68
M_1F_3	125.7	41.96	27.45	20.12	10.47	2.9	128.6	550.0	4.27
M_2F_3	120.4	44.44	24.70	19.35	11.51	2.9	123.3	580.6	4.71
M_3F_3	151.5	36.17	27.50	19.20	17.16	2.9	154.4	676.3	4.38
M_4F_3	138.1	41.38	36.52	15.70	6.40	2.9	141.0	693.3	4.91

lowland rice ecosystem. Soil water availability in terms of profile contribution (PC) from soil reserve was maximum with the higher dose of fertilizer and residual effect of organic sources ranging from 112.0 to 151.5 mm (Table 2). PC came mostly from top soils (0–30 cm) contributing >60%. Contribution gradually decreased with the depth. Application of N: P_2O_5 : K_2O fertilizer @ 30:30:30 kg ha^{-1} doses increased the profile water uptake with organic sources like FYM, mustard cake and vermi-compost. Application of organic manures in rice increased the PC by 35% over no manure situation. The highest PC was noted 151.5 mm with N:P_2O_5 : K_2O @ 30:30:30 kg ha^{-1} under mustard cake residual situation. Winter rainfall contribution was least amount to about 2.9 mm only. The actual evapo-transpiration (AET) was very much influenced by PC in rice *utera* system. The highest AET (154.4 mm) was recorded with N:P_2O_5 : K_2O @ 30:30:30 kg ha^{-1} + mustard cake and the least AET value was 114.9 mm in the no fertilizer with vermi-compost. Water productivity expressing yield gain per unit water use by the crop in terms of water use efficiency (WUE) increased with manure and fertilizer application in rice *utera* cropping system. The highest WUE value of 4.91 kg ha^{-1} mm^{-1} was recorded with the treatment N: P_2O_5 : K_2O @ 30:30:30 kg ha^{-1} + FYM and the least value of WUE 3.94 kg ha^{-1} mm^{-1} was noted in crops on zero fertilizer plot.

Thus considering the plant growth, yield attributes yield and water uptake, organic manuring like farm yard manure @ 5 t ha^{-1} in rice followed by suphala complex fertilizer application @ 30:30: 30 N: P_2O_5 : K_2O kg ha^{-1} in saturated soil 10-12 days before harvesting of rice may be advocated for rice-*toria* relay cropping in rainfed low land ecosystem of similar situation.

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