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Effect of Crop Establishment Methods and Organic Weed Management on Nutrient Uptake, Soil Fertility, and Yield of Aromatic Rice (*Oryza sativa* L)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out during *Kharif*, 2019 in an organic block of Instructional-cum-Research farm of Assam Agricultural University, Jorhat, Assam, India to evaluate the effects of systems of rice establishment and organic weed management practices on the yield, nutrient uptake, and soil fertility of aromatic rice variety *Kola joha*. The experiment was laid out in a split-plot design with systems of establishment in the main plot and organic weed management practices in the subplot. The transplanting method of establishment resulted in a significantly higher grain yield

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of 18.17 quintal/hectare (q ha^{-1}) and nutrient uptake over the direct seeded method. Among the organic weed management practices, the highest grain yield (21.95 q ha^{-1}) and nutrient uptake were recorded with hand weeding at 20 and 40 DAT/DAS which was followed by intercropping of *dhaincha* and incorporation at 40 DAT/ DAS (16.90 q ha^{-1}). The highest available N content (260.86 Kg ha^{-1}) in post-harvest soil was recorded with intercropping of *dhaincha* and incorporation at 40 DAT whereas the highest available P_2O_5 and K_2O contents of soil were recorded with hand weeding at 20 and 40 DAT/DAS.

Keywords: Oryza sativa L; soil fertility; nutrient uptake; organic weed management.

1. INTRODUCTION

"Agriculture in Assam is rice centric and it occupies an area of 2.45 million hectares with a production of 5.23 million tones" [1]. The state of Assam has been endowed with a wide range of variations of rice cultivars including aromatic rice cultivars that have good demand in the local and export market. Therefore, organic production of aromatic rice could be a profitable livelihood option for the farming community of the state of Assam. "The aromatic rice of Assam is a unique class under *sali* (*Kharif*) rice traditionally known as *Joha*. The *Joha* rice cultivars are known for their unique aroma, superfine kernel, good cooking qualities, and excellent palatability" [2]. Organic rice cultivation has been practiced traditionally by the farmers of the state of Assam for a long back. However, the productivity of these organic rice production systems is quite low due to improper nutrient, weed, and pest management practices. Yield losses due to weeds in lowland rice fields range from 20-60% and 30-80 % in transplanted and direct seeded rice, respectively [3]. Despite the serious threat weeds offer to organic rice production, relatively fewer research works has been conducted so far exclusively on weed management in the organic production system. Therefore, the present research was carried out to study the influence of organic weed management practices on yield, nutrient uptake, and post-harvest soil nutrient status of aromatic rice under direct seeded and transplanted methods of establishment.

2. MATERIALS AND METHODS

A field experiment was carried out during *the Kharif* season of 2019 in the organic block of Instructional-cum-Research farm of Assam Agricultural University, Jorhat, Assam, India. The climate of the area is subtropical with an average annual rainfall of 204.20 cm. The mean maximum and minimum temperature during the crop growing period ranged from 25.8°C to 34.8°C and 14.6°C to 26°C, respectively. Weekly average relative humidity during the crop growing season ranged from 86 to 99 % during morning hours and 63 to 90 % during afternoon hours. The soils of the experimental site were sandy loam in texture with pH 5.9, organic carbon (0.58%), available N (242.5 Kg ha^{-1}), available P_2O_5 (18.60 Kg ha^{-1}), and available K_2O (140.6 Kg ha^{-1}). The experiment was laid out in a split-plot design with three replications. The size of each plot was 15 m^2 (5m x 3m). "The treatments consisted of two systems of establishment *viz*., transplanting (SE_1) and direct seeded (wet seeding) method (SE_2) in the main plot and five organic weed management practices *viz*., weedy check (WM_0), hand weeding at 20 and 40 DAT/DAS (WM_1), weeding with rotary weeder at 20 and 40 DAT/DAS (WM_2), weeding with cono weeder at 20 and 40 DAT/DAS (WM_3) and intercropping of *dhaincha (Sesbania aculeata)* and incorporation at 40 DAT/DAS (WM_4) in the sub-plots. The seedlings of the traditional aromatic rice variety *Kola Joha* were raised organically in a nursery bed for the transplanting method of establishment. Pre-germinated rice seeds were manually line sown in the main field as per the treatments of the directed seeded method of establishment on the same day of nursery sowing of rice seeds for the transplanted crop. The recommended dose of nitrogen for traditional rice variety @ 20 Kg ha^{-1} was applied through combinations of three organic sources using 1/3 rd each of farm yard manure, vermicompost, and mustard oil cake. The requirement of P and K of the crop was not supplied separately. The 25 days old rice seedlings were transplanted using 2 seedlings per hill. The spacing adopted for both transplanted and direct seeded was 20 cm x 15 cm. As per the 5^{th} weed management treatment (WM_4) dhaincha seeds were sown on the day of sowing and transplanting in between the rows of rice maintaining one row of *dhaincha* between two rows of rice" [4]. Plant samples collected at 60 DAT/DAS and at harvest were oven-dried, ground, and analyzed for nitrogen by the Kjeldahl method [5], phosphorus by the Venadomolybdate

method and potassium by flame photometer method. The uptake of N, P, and K was estimated by multiplying N, P, K content of the crop with the dry weight of the crop at 60 DAT/DAS and harvest.

Nutrient uptake = Grain/straw yield hectare^{-1} (Kg ha^{-1}) × Nutrient content in grain/straw (%) / 100….. (i)

Total nutrient uptake = Nutrient uptake of grain (Kg ha^{-1}) + Nutrient uptake of straw (Kg ha^{-1})…….. (ii)

3. RESULTS AND DISCUSSION

3.1 Grain Yield and Straw Yield

Transplanting (SE_1) of rice recorded significantly higher grain yield (18.17 q ha^{-1}) and straw yield (30.12 q ha^{-1}) as compared to the direct wet seeding (SE_2) method of the establishment (11.10 q ha^{-1}, 20.17 q ha^{-1}). This might be due to lesser crop weed competition in a transplanted method which resulted in better plant growth and efficient utilization of growth resources. Among the weed management treatments, hand weeding at 20 and 40 DAT/DAS produced the highest grain yield (21.9 q ha^{-1}) and straw yield (35.03 q ha^{-1}) which was followed by intercropping of *dhaincha* and incorporation at 40 DAT/DAS with a grain yield of 16.7 q ha^{-1} and straw yield of 29.26 q ha^{-1} (Table 1). Manual weeding has more advantages because of the complete removal of weeds and helps in increasing grain and straw yield. Increased grain and straw yield with hand weeding at 20 and 40 DAS was earlier reported by Barla et al. [6]. Intercropping of *dhaincha* added not only valuable plant nutrients through atmospheric fixation of nitrogen, but also reduced the occurrence of weeds by occupying the interspaces resulting in the next best yield performance among the organic weed management treatments.

3.2 Nutrient Content and Uptake of Rice at Harvest

Systems of rice establishment significantly influenced the nutrient content and uptake of rice grain and straw except for phosphorous content (Table 2). Higher N, P, and K uptake by rice grain and straw were recorded in the transplanting method as compared to the wet seeding method. Among the organic weed management practices, intercropping of *dhaincha* and incorporation at 40 DAT/DAS (WM_4) recorded significantly the highest nitrogen content of grain (1.1 %) and straw (0.76 %). The phosphorus and potassium contents were recorded highest with hand weeding at 20 and 40 DAT/DAS (WM_1).

Table 1. Yield (q ha^{-1}) and straw yield (q ha^{-1}) as influenced by systems of establishment and organic weed management practices in aromatic rice

Treatment	Grain yield	Straw yield	Harvest Index (%)
Establishment method			
SE_1: Transplanting	18.17	30.12	37.23
SE_2: Direct seeded	11.10	20.57	34.00
SEm±	0.18	1.09	0.29
CD (***P***=0.05)	1.09	6.60	1.80
Weed management			
WM_0: Weedy check	8.38	16.08	34.83
WM_1: Hand weeding at 20 and 40 DAT/DAS	21.95	35.03	36.80
WM_2: Weeding by rotary weeder at 20 and 40 DAT/DAS	14.37	24.89	35.43
WM_3: Weeding by cono weeder at 20 and 40 DAT/DAS	11.58	21.48	35.32
WM_4: Intercropping of *dhaincha* and incorporation at 40 DAT/DAS	16.90	29.26	35.66
SEm±	1.02	0.61	1.14
CD ***(P***=0.05)	3.06	1.85	-
Interaction (SE × WM)			
SEm±	1.45	1.40	-
CD (*P*=0.05)	3.99	6.78	-

DAS: Days after sowing, DAT: Days after transplanting

Table 2. N, P, and K content and uptake of rice at harvest as influenced by systems of establishment and organic weed management in aromatic rice

Treatments	N Content (%)		P Content (%)		K Content (%)		N Uptake (Kg ha^{-1})			P Uptake (Kg ha^{-1})			K Uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Establishment method															
SE_1: Transplanting	1.02	0.66	0.26	0.17	0.73	0.99	19.14	20.82	39.96	4.86	5.40	10.26	14.35	30.51	44.86
SE_2: Direct seeded	0.96	0.63	0.25	0.16	0.71	0.97	10.46	13.54	24.01	2.76	3.41	6.18	7.98	20.41	28.40
SEm±	0.004	0.004	0.006	0.0073	0.0041	0.003	0.13	0.57	0.60	0.06	0.24	0.18	0.21	0.97	0.93
CD (P=0.05)	0.027	0.02	NS	NS	0.025	0.01	0.79	3.50	3.69	0.37	1.48	1.15	1.30	5.90	5.71
Weed management															
WM_0: Weedy check	0.78	0.51	0.21	0.14	0.42	0.82	6.10	8.34	14.45	1.65	2.37	4.02	3.27	13.28	16.55
WM_1: Hand weeding at 20 and 40 DAT/DAS	1.08	0.73	0.28	0.19	0.91	1.07	23.6	25.70	49.31	6.05	6.94	13.00	19.86	37.68	57.54
WM_2: Weeding by rotary weeder at 20 and 40 DAT/DAS	1.02	0.65	0.26	0.163	0.73	0.99	14.49	16.34	30.83	3.78	4.06	7.84	10.34	24.82	35.16
WM_3: Weeding by cono weeder at 20 and 40 DAT/DAS	0.98	0.60	0.25	0.16	0.69	0.96	11.24	13.02	24.27	2.86	3.44	6.31	7.95	20.85	28.80
WM_4: Intercropping of *dhaincha* and incorporation at 40 DAT/DAS	1.1	0.76	0.27	0.17	0.85	1.04	18.55	22.50	41.06	4.73	5.22	9.95	14.42	30.67	45.09

Treatments	N Content (%)		P Content (%)		K Content (%)		N Uptake (Kg ha^{-1})			P Uptake (Kg ha^{-1})			K Uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
SEm±	0.009	0.006	0.007	0.0075	0.0049	0.008	1.10	0.38	1.29	0.24	0.31	0.44	0.89	0.56	1.26
CD (*P*=0.05)	0.029	0.01	0.02	0.022	0.014	0.02	3.31	1.15	3.89	0.73	0.95	1.32	2.67	1.69	3.78
Interaction (SE × WM)	NS	NS	NS	NS	NS	NS	S	S	S	S	NS	S	S	S	S

Table 3. Effect systems of establishment and organic weed management practices on available N, P_2O_5, and K_2O of soil after harvest of aromatic rice

Treatments	N (Kg ha^{-1})	P_2O_5 (Kg ha^{-1})	K_2O (Kg ha^{-1})
Establishment method			
SE_1: Transplanting	243	13	138
SE_2: Direct seeded(wet seeding)	233	12	135
SEm±	0.37	0.12	0.48
CD (P=0.05)	2.28	0.78	2.96
Weed management			
WM_0: Weedy check	202.38	8.30	129.65
WM_1: Hand weeding at 20 and 40 DAT/DAS	255.53	16.21	141.91
WM_2: Weeding by rotary weeder at 20 and 40 DAT/DAS	239.08	12.26	136.06
WM_3: Weeding by cono weeder at 20 and 40 DAT/DAS	232.06	10.23	133.28
WM_4: Intercropping of *dhaincha* and incorporation at 40 DAT/DAS	260.86	14.81	139.76
SEm±	1.64	0.21	0.60
CD (P=0.05)	4.93	0.64	1.81
Interaction (SE × WM)	-	-	-

Table 4. N, P, and K uptake (Kg ha^{-1}) by weeds at 60 DAT/DAS and at harvest as influenced by systems of establishment and organic weed management practices in aromatic rice

Treatments	60 DAT/DAS			Harvest		
	N	P	K	N	P	K
Establishment method						
SE_1: Transplanting	9.28	6.04	6.30	6.50	1.83	6.09
SE_2: Direct seeded (Wet seeding)	13.96	8.54	9.49	13.64	3.79	12.07
SEm±	0.15	0.06	0.15	0.09	0.08	0.10
CD (P=0.05)	0.94	0.41	0.96	0.55	0.51	0.64
Weed management						
WM_0: Weedy check	25.22	15.11	17.75	19.92	5.54	17.90
WM_1: Hand weeding at 20 and 40 DAT/DAS	4.74	3.01	2.99	4.26	1.23	4.40
WM_2: Weeding by rotary weeder at 20 and 40 DAT/DAS	9.17	5.78	5.94	8.30	2.15	6.92
WM_3: Weeding by cono weeder at 20 and 40 DAT/DAS	13.27	8.67	8.79	12.35	3.38	10.43
WM_4: Intercropping of *dhaincha* and incorporation at 40 DAT/DAS	5.69	3.88	4.0	5.89	1.76	5.76
SEm±	0.27	0.14	0.54	0.23	0.07	0.18
CD (P=0.05)	0.81	0.42	1.62	0.69	0.22	0.55
Interaction (SE × WM)	S	S	S	S	S	S

Efficient weed control with hand weeding resulted in the lowest level of competition for the nutrients between crop and weeds and thus the highest content and uptake of nutrients was recorded by the hand-weeded rice crop. Hand weeding at 20 and 40 DAT/DAS (WM_1) resulted in the highest N, P, and K uptake due to higher grain yield and straw yield recorded under this treatment. This finding is in conformity with the findings of Radhakrishnan et al. [7], Ravisankar et al. [8], Fageria [9].

3.3 Available N, P_2O_5 and K_2O Content of Soil

Crop establishment methods significantly influenced the available N, P_2O_5, and K_2O contents of post-harvest soil (Table 3). The transplanting method resulted in higher soil nutrient content compared to the direct seeded method. Among the weed management practices, available N content (260.86 Kg ha^{-1}) of soil was highest with intercropping of *dhaincha* and incorporation at 40 DAT (WM_4) followed by hand weeding at 20 and 40 DAT/DAS (WM_1) (255.53 Kg ha^{-1}). The available P_2O_5 and K_2O content of soil were recorded highest in WM_1 (16.21 Kg ha^{-1}, 141.91 Kg ha^{-1}) followed by WM_4 treatment (14.81 Kg ha^{-1}, 139.76 Kg ha^{-1}). The highest available nitrogen recorded with intercropping of *dhaincha* and incorporation at 40 DAT might be due to the addition of plant biomass to the soil which enhanced the availability of nitrogen. Similar findings were reported by Kumar and Sahi, [10].

3.4 N, P, and K Uptake by Weeds at 60 DAT/DAS and at Harvest

Systems of establishment significantly influenced the N, P, and K uptake by weeds (Table 4). The transplanting method resulted in lower nutrient uptake by weeds compared to wet-seeded rice at both stages of observations. As discussed earlier, the transplanted seedlings established well and competed better with weeds for growth resources than wet-seeded seedlings. Similar findings were earlier reported by Chander and Pandey [11]. All the weed management practices recorded significantly lower N, P, and K uptake by weeds compared to the weedy check treatment (WM_0). Treatment comprising hand weeding at 20 and 40 DAT/DAS (WM_1) resulted from the lowest nitrogen (4.74 Kg ha^{-1}) and phosphorus (3.01 Kg ha^{-1}) uptake by weeds at 60 DAT/DAS followed by intercropping of *dhaincha* and incorporation at 40 DAT/DAS (WM_4) (5.69, 3.88 Kg ha^{-1}), respectively. Potassium uptake (2.99 Kg ha^{-1}) was significantly low in hand weeding at 20 and 40 DAT/DAS (WM_1) and found at par with intercropping of dhaincha and incorporation at 40 DAT/DAS

(WM_4) (4.0 Kg ha^{-1}). Hand weeding at 20 and 40 DAT/DAS (WM_1) recorded the lowest nitrogen, phosphorus, and potassium uptake (4.26, 1.23, and 4.40 Kg ha^{-1}), respectively by weeds followed by intercropping of dhaincha and incorporation at 40 DAT (WM_4) of rice (5.89, 1.76 and 5.76 Kg ha^{-1}) at harvest.

4. CONCLUSION

Hand weeding at 20 and 40 DAT/ DAS was found to be the best organic weed management practice for maximization of yield, nutrient uptake, and soil fertility maintenance under both transplanted and direct seeded methods of rice establishment of aromatic rice. Intercropping of *dhaincha* and incorporation at 40 DAT/ DAS was found to be the next best alternative organic weed management practice for aromatic rice.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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