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Impact of crop diversification on scented rice (*Konjoha*) yield and quality performance in an organic rice ecosystem

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Abstract
The experiment was conducted considering scented rice (*Konjoha*) as main crop with eight different treatments *viz.,* sole rice (T_1), rice + swamp taro intercropping (4:2) (T_2), rice + buffalo spinach intercropping (4:2) (T_3), T_2 + pumpkin in bund (T_4), T_2 + marigold in bund (T_5), T_3 + pumpkin in bund (T_6), T_3 + marigold in bund (T_7) and rice - lathyrus (relay) (T_8). Most of the yield attributes were found to be highest in T_1. The highest value of yield attributes of rice *viz.,* no. of effective tillers/m^2 (13.67), no. of panicles/m^2 (309.67), weight of panicle (1.82 g), no. of filled grains/panicle (95.34) and test weight (14.35 g) were found in T_1. However, the growth and yield attributes of component crops were not influenced significantly under different crop diversification modules. The highest grain yield (18.46 q/ha) was recorded in T_1. It was at par with T_8 (18.44 q/ha). On the other hand, the lowest grain yield (8.58 q/ha) was recorded in T_4. The highest straw yield (45.41 q/ha) was recorded in T_1. While, lowest straw yield (19.96 q/ha) was recorded in T_4. The highest rice equivalent yield (64.57 q/ha) was found in T_5. On the other hand, the lowest rice equivalent yield (19.02 q/ha) was recorded in T_3. The highest B:C ratio of 3.10 was also recorded in T_5 and was closely followed by T_4 (2.94). The study revealed that crop diversification module, T_5 was the best option in respect of profitability. Quality parameters were significantly influenced by different crop diversification modules. The longer rice grain (6.77mm) was observed in T_4. It was *at par* with T_5. The shortest length of grain (6.28mm) was found in T_1. The maximum breadth of grain (2.32mm) was found in T_4. On the other hand, minimum breadth of grain (2.23mm) was found with T_1. The highest L/B ratio (2.94) was found in T_2. The highest protein content (7.35%) was recorded in T_4 while the lowest protein content (7.04%) was found in T_1. It was *at par* with T_8 (7.05%). Effect of crop diversification on milling recovery of grain was found significant. The highest milling recovery (61.97%) was recorded in T_4. The lowest milling recovery (58.33%) was recorded in both T_1 and T_8 respectively.

Keywords: Crop diversification, Joha rice, Organic rice ecosystem

Introduction
Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. It imparts wider choice in the hand of farmers for production of a variety of crops in a given area. The shifting in traditional farming to diversified farming is mobilized by increasing demand for diverse nature of food items. With the advent of modern agricultural technology, especially during the period of the green revolution, there was a continuous surge for diversified agriculture in terms of crops. Diversified agriculture helps in improvement of resiliency and may be the best way to solve the problem of nutritional self-sufficiency and poverty alleviation by generating employment. It also helps in buffering crop production from the effects of variation in climatic condition and extreme events (Lin, 2011) [9]. Crop diversification and inclusion of the new crops can be one of the important technologies in increasing the farmer's income to a greater extent and also beneficial for conserving natural resources (Khanam *et al.*, 2018) [8]. Presently, Assam is considered to be a rice mono-cropped state with a cropping intensity of 149% indicating less utilization of rich resources and poor crop diversification (Anon, 2017). The policy makers have considered crop intensification and diversification as the thrust areas for livelihood security of the farming

community of Assam.

Rice is cultivated in 158.9 million hectares worldwide with a production of 759.6 million tonnes in 2017 (Chauhan *et al.*, 2017) [5] where India contributes 110.15 million tonnes of rice from 43.19 million hectares of area with a productivity of 2550 kg/ha and has a large potential to become a major exporter of organic rice in the international market. Rice is also the principal food crop of Assam. In spite of its higher importance and market potentiality, it is grown under mono cropping system only, occupying about 2.49 lakh hectares which produces 5.13 lakh tonnes of rice grain. (Anon, 2018). Aromatic rice has a high demand in domestic market and the aromatic rice of Assam is a unique class under *Sali* rice and is traditionally known as "*Joha*" and organic scented rice enjoys special demand and is highly valued in Assam. The area under *Joha* rice is however very low because of its poor productivity. The poor yield level and productivity of this class of rice make it less preferable among the farmers. So, there is a need to overcome these challenges and maximize the productivity and profitability of *Joha* rice in Assam through crop diversification with other commercial crops may open new avenue for higher productivity and profitability from rice ecosystem. Traditionally, Assam is organic by default with heritage of rich bio-diversity. Organic farming is now on high focus for sustainability in Indian agriculture. The Northeastern region of India has already been declared as the organic hub of India. Modern intensive agriculture has led to increase in agricultural production mainly due to development of high yielding crop varieties, adoption of improved crop production technologies, use of synthetic agrochemicals like fertilizers, insecticides, fungicides, herbicides, growth regulators etc. But the extensive uses of these agro-chemicals are causing environmental hazards (Bhandari, 2014) [3]. To overcome these negative effects of modern agriculture, the concept of organic agriculture was developed for a sustainable way of production.

Crop grown on field bund works as a cover crop and provides some extra monetary income to the farmer. Planting of flowers and vegetable strips in rice bunds result in increase in predators and parasitoid numbers of the principal rice pests (Gurr *et al.*, 2016) [7]. Presently, scientific information and agro-techniques of diversified modules in organic rice ecosystem of Assam are limited. The crop intensification and diversification under organic ecosystem are the need of the hour for enhancing farm productivity and livelihood security of the farmers. So, emphasis may be given on enrichment of field level agro bio-diversity by intercropping rice with some other commercial crops, bund crops and relay crops by inclusion of a few crops *viz.*, buffalo spinach, swamp taro, pumpkin, marigold and lathyrus with rice. Intercropping buffalo spinach may be considered as a viable option to maximize productivity and minimize weed pressure through weed suppression. Similarly, Marigold is also a hardy annual flowering plant which can be grown effectively for quick income generation and as border trap crop. Growing pumpkin as mix crop with rice is a general practice in few districts of Assam. It is also grown in the barren bunds with a very little adjustment of the bund height and width which adds an extra income to the farmers. Also, the bright flowers of pumpkin attract some pollinators and a few natural enemies. Lathyrus, being a drought tolerant dual purpose (food and fodder) crop can be grown as relay crop with rice by utilizing residual soil moisture.

Materials and Methods

A field experiment entitled "Crop diversification in organic rice ecosystem" was conducted at the organic block, Instructional-cum-Research farm of Assam Agricultural University, Jorhat during *Kharif* and *Rabi* seasons, 2020-221 to evaluate the effect of crop diversification in organic rice ecosystem. The experimental farm is situated at 26043/N latitude and 94012/E longitude and at an elevation of 86.6 meters above mean sea level (AMSL). The experiment was laid out in a Randomized Block Design (RBD) with three replications. The main crop was scented rice (*Konjoha*) with different diversified modules. The experiment consisted of eight different treatments *viz.*, sole rice (T_1), rice + swamp taro intercropping (4:2) (T_2), rice + buffalo spinach intercropping (4:2) (T_3), T_2 + pumpkin in bund (T_4), T_2 + marigold in bund (T_5), T_3 + pumpkin in bund (T_6), T_3 + marigold in bund (T_7) and rice - lathyrus (relay) (T_8). The land having homogenous fertility and uniform textural makeup at certified organic block of ICR farm, AAU, Jorhat. The soil of the experimental site was clay loam in texture with pH 5.28, organic carbon (0.82%), CEC {6.48 c mole (p+)/ Kg}, medium in available nitrogen (272.45 kg/ha), available P_20_5 (28.11 kg/ha) and low in available K_2O (132.38 kg/ha). The total rainfall recorded during the crop season was 2014.1 mm. The mean maximum and minimum temperature during the whole crop growing period ranged from 20.7 to 34.8^{0}C and 8.4 to 26.9 ^{0}C, respectively.

Results and Discussion

The results of the experiment on "Crop diversification in organic rice ecosystem" are presented in Table 1 and 2 to study the influence of various treatments on yield attributes, yield, rice equivalent yield and economics of Scented rice (*Konjoha*) under organic ecosystem. The phenological events of all crops under different diversification modules were observed to understand their growth and development behavior. All the crops received normal *Kharif* environment to express their normal performance. The component crops took different durations as per their genetic makeup and environmental influence under the present experimental condition. On an average, rice, buffalo spinach, swamp taro, pumpkin, marigold and lathyrus took 130, 86.3, 240, 123, 91.5 and 122 days, respectively for harvest and completion of life span.

Yield attributes of scented rice

Yield attributes like panicle length and test weight (table 2) did not differ significantly due to crop diversification. While, there was positive influence on no. of effective tillers/m^2, no. of panicles/m^2, weight of panicle, no. of filled grains/panicle. The highest value of yield attributes of rice *viz.*, no. of effective tillers/m^2 (13.67), no. of panicles/m^2 (309.67), weight of panicle (1.82 g), no. of filled grains/panicle (95.34), test weight (14.35 g) were found with sole cropping of rice (T_1). In this module rice was grown as pure stand with optimum plant population. The microclimatic, biotic and abiotic conditions were favourable for rice cultivation. The maximum panicle length (21.89 cm) was observed in rice + swamp taro intercropping + pumpkin in bund (T_4). It might be due to the modification of the microclimatic situation caused due to intercropping of rice with other component crops. These results are in agreement with the findings of Rabeya *et al.* (2018) [14].

Scented rice yield, rice equivalent yield and B:C ratio

The intercropping of rice with swamp taro and buffalo spinach at 4:2 intercropping ratio reduced the grain and straw yield under this replacement series (table 1). The highest grain yield (18.46 q/ha) was recorded with sole rice (T_1). It was at par with (T_8) rice - relay lathyrus (18.44 q/ha). While the lowest grain

yield (8.58 q/ha) was recorded in (T_4) rice + swamp taro intercropping + pumpkin in bund. Highest straw yield (45.41 q/ha) was recorded with sole rice (T_1). While the lowest straw yield (19.96 q/ha) was recorded in rice + swamp taro intercropping + pumpkin in bund (T_4). The highest rice equivalent yield (64.57 q/ha) was found in rice + swamp taro intercropping+ marigold in bund (T_5). On the other hand, the lowest rice equivalent yield (19.02 q/ha) was recorded in rice + buffalo spinach intercropping (T_3) and was in agreement with the works of Rana *et al.* (2013) [15], Xinru *et al.* (2016) [18] and Meena *et al.* (2013) [11].

The highest B: C ratio of 3.10 was recorded in rice + swamp taro intercropping + marigold in bund (T_5). It was closely followed by (T_4) rice + swamp taro intercropping + pumpkin in bund (2.94). On the other hand, the lowest B: C ratio of 0.95 was found in rice + buffalo spinach intercropping (T_3). Rabeya *et al.* (2018) [14], Nazrul and Shaheb (2015) [13] and Tiwari *et al.* (2002) [16] also reported similar economic profitability of crop diversification.

Quality analysis of scented rice

Though all the quality parameters are expressed by means of genetic traits, scientific evidences are available to show better grain quality under diversified organic farming. Quality of the rice grain was measured in context of length (L) and breadth (B) of grain, L/B ratio, protein content and milling recovery. Quality parameters were significantly influenced by different crop diversification modules. Almost all the parameters were positively influenced under diversified farming as compared to sole cropping. The highest value of kernel length (6.77mm), breadth (2.32mm), protein content (7.35%) and milling recovery (61.97%) were recorded in rice + swamp taro intercropping + pumpkin in bund (T_4) (table 2). Also, the highest L/B ratio (2.94) of kernel was reported in rice + swamp taro intercropping (T_2). The variation in the quality parameters might be due to the variation in external environment or micro-climate created under the different diversified modules. Such results were earlier reported by Xiangqian *et al.* (2012) [17], Bora *et al.* (2014) [4], Meena *et al.* (2018) [10] and Das *et al.* (2010) [6].

Table 1: Effect of crop diversification on yield and its attributes of scented rice at harvest under organic rice ecosystem

Treatments	Panicle weight (g)	Panicles /m^2	Effective tillers/hill	Filled grains/ panicle	1000 grain weight (g)	Grain yield (q/ha)	Straw yield (q/ha	Rice equivalent yield (q/ha)	Benefit: Cost ratio
T_1: Sole rice (*Joha*)	1.82	309.67	13.67	95.34	14.35	18.46	45.41	26.40	1.75
T_2: Rice+Swamp Taro (4:2)	1.66	253.78	12.11	93.67	14.30	8.70	20.71	38.77	2.25
T_3: Rice+Buffalo Spinach (4:2)	1.49	237.00	11.78	83.34	14.28	11.18	26.55	19.02	0.95
T_4: T_2+Pumpkin in bunds	1.46	224.11	11.44	82.67	14.20	8.58	19.96	62.61	2.94
T_5: T_2+Marigold in bund	1.53	246.67	11.89	83.44	14.29	8.67	22.11	64.57	3.10
T_6: T_3+Pumpkin in bund	1.16	233.67	11.11	71.67	13.90	10.99	26.07	42.63	2.11
T_7: T_3+Marigold in bund	1.45	242.33	11.22	77.44	13.94	11.12	28.52	44.04	2.25
T_8: Rice- Lathyrus (Relay)	1.76	305.91	13.33	95.33	14.34	18.44	45.35	33.15	1.92
S.Em (±)	0.09	8.58	0.63	4.34	0.14	0.28	0.51	0.27	-
CD (P=0.05)	0.26	26.03	1.91	18.18	NS	0.17	0.54	0.82	-

Table 2: Effect of crop diversification on quality parameters of scented rice at harvest under organic rice ecosystem

Treatments	Kernal length (mm)	Kernal breadth (mm)	L/B of kernal	Protein content (%)	Milling recovery (%)
T_1:Sole rice (*Joha*)	6.28	2.23	2.82	7.04	58.33
T_2: Rice + swamp taro (4:2)	6.72	2.29	2.94	7.21	60.77
T_3: Rice + buffalo spinach (4:2)	6.37	2.25	2.83	7.11	59.43
T_4:T_2 + pumpkin in bund	6.77	2.32	2.92	7.35	61.97
T_5: T_2 + marigold in bund	6.76	2.31	2.92	7.31	61.88
T_6: T_3 + pumpkin in bund	6.67	2.29	2.92	7.19	60.53
T_7: T_3 + marigold in bund	6.66	2.27	2.93	7.17	60.20
T_8: Rice - lathyrus (relay)	6.31	2.24	2.82	7.05	58.33
S.Em(±)	0.02	0.01	0.02	0.01	0.04
CD(P=0.05)	0.06	0.03	0.05	0.02	0.72

Conclusion

The scented rice cultivars of Assam are famous for its unique aroma, superfine kernel with marvelous palatability and for this reason it gets extra premium price. Presently, awareness on organic *Joha* rice cultivation is gaining momentum in Assam for health concerns and premium prices of organic *Joha* rice. Sole cultivation of organic *Joha* rice may not be profitable for farmers as productivity is poor and premium markets infrastructure are not yet developed to ensure premium price to farmers of Assam. This study revealed that crop diversification module, rice + swamp taro intercropping + marigold in bund was found to be the best diversified module in terms of rice benefit: cost ratio. Crop diversification module, rice + swamp taro intercropping + pumpkin in bund also qualified as next best module in terms of above parameter. In general, the present study revealed that the productivity, profitability and quality in organic rice ecosystem can be increased by efficient crop diversification modules and under lowland rice ecosystem may show new promise to fulfill diversified food need and extra farm income. The present study also highlighted the role of rice bunds for generating extra income. Proper testing of the efficient modules under on-farm situation may validate the feasibility before adoption by the farmers. Thus, from this study it can be concluded that there is scope for increasing farm income by growing high quality *Joha* rice through diversified farming under organic management system and this study may be taken as guideline to conduct further research for enhancing farmer's income.

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