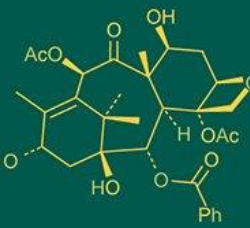
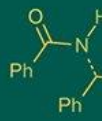


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Identification of profitable rice-vegetable cropping systems for Konkan region of Maharashtra

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Abstract

Crop diversification is an approach that involves cultivating multiple crops on a farm, rather than relying solely on a single crop. In addition to increasing income opportunities, reduces the risk of crop failures due to biotic and abiotic stresses, promotes biodiversity and reduces reliance on chemical inputs, thereby strengthening both sustainability and resilience. Hence, a field experiment was conducted to diversify and select suitable vegetable in cropping sequence for Konkan region of Maharashtra. The experiment was conducted at Agricultural Research Station, Repoli, Maharashtra, during 2020,2021 and 2022 in Randomized Block Design with three replications ten rice based vegetable cropping systems, viz., Rice-Cucumber, Rice-Chilli, Rice-Brinjal, Rice-Cabbage, Rice-Dolichos bean, Rice-Okra, Rice-Bottle gourd, Rice-Red pumpkin, Rice-Bitter gourd, Rice-Little gourd and Rice-Rice were evaluated. Among the various rice based cropping sequences, cultivation of Rice-Brinjal cropping sequence recorded the highest relative equivalent yield (REY) (45.44 q ha⁻¹) during *kharif* season. Whereas, the significantly highest equivalent yield of *rabi* (222.36 q ha⁻¹) was recorded in Rice-Cucumber cropping sequence which was found to be statistically significant over almost all the treatments except Rice-Okra cropping sequence (211.83q ha⁻¹). Similarly the highest system yield (260.46 q ha⁻¹), net return (Rs.103314 ha⁻¹) and benefit: cost ratio (1.24) was also registered in Rice-Cucumber cropping sequence followed by the Rice-Okra cropping sequence (249.63 q ha⁻¹), net return (Rs.82191 ha⁻¹) and benefit: cost ratio (1.19).

Keywords: Crop diversification, rice-based cropping system, cucumber, relative equivalent yield, system productivity, economic returns

Introduction

Rice is one of the most important staple crops in the world and it occupy a premium position among all food commodities, with a cultivation area of approximately 168.36 million hectares (Mha) and an annual production of almost 800 million tons (FAOSTAT,2025). The era of the Green Revolution started during the early 1970s with wheat and rice and since then the rice-rice cropping system has played a significant role in the food security of the region. However, recent years have witnessed a significant slowdown in the yield growth rate of this system and the sustainability of this important cropping system is at risk due to second-generation technology problems and mounting pressure on natural resources. Traditional cultivars and conventional agronomic practices are no longer able to even maintain the gains in productivity achieved during the past few decades. Demand for food is increasing with the increasing population and purchasing power of consumers. Rice-based cropping system is a major cropping system practiced in India, which include the rotation of crops involving cereals, pulses, oilseeds, cotton, sugarcane, green manures, vegetable, etc. Various rice-based cropping systems have been reported from different parts of India ranging from rice-rice-rice to rice followed by different cereals, pulses, oilseeds, vegetables and fiber crops. Rice based cropping systems The rice-rice cropping system is labor-, water-, and energy-intensive and it becomes less profitable as these resources become increasingly scarce and the problem is aggravated with deterioration of soil health, the emergence of new weeds, and emerging challenges of climate change. Therefore, a paradigm shift is required for enhancing the system's productivity and sustainability. Resource-conserving technologies involving zero-or minimum-tillage, dry direct seeding in rice, improved water-and nutrient-use efficiency, innovations in residue management to avoid straw burning, and crop diversification should assist in achieving sustainable productivity and allow farmers to

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reduce inputs, maximize yields, increase profitability, conserve the natural resource base, and reduce risk due to both environmental and economic factors. A number of technological innovation and diversification options have been suggested to overcome the system's sustainability problems but some of them have not been fully embraced by the farmers as these are expensive, knowledge-intensive or do not fit into the system and have resulted in some other unforeseen problems. Different concerns and possible strategies needed to sustain the rice-wheat cropping system. In the changing global scenario nutritional security in the country is an important issue of agriculture. Vegetables play a very important role in daily human diet, since they are very important source of vitamins minerals and edible salts. They also supply carbohydrates for energy and proteinous compounds for muscle development. India is second largest producer of vegetable in world after China. Vegetable production is the major driver of sustainable agriculture. Although, India has produced more than its requirement but at household level, still there is nutritional deficiency (Noopur *et al.* 2023) [8]. Out of 341.63 million tons of horticulture produce, vegetable production is 200.45 million tons (APEDA, 2023) [1]. Hence, vegetable play a major role in improving food, income and nutritional security at household (Panwar *et al.* 2019) [9] as well as at national level. The demand of vegetable would be increase from 12.12 million tonnes in the year 2011 to 17.46 million tonnes in the year 2031 (Kumari and Panda, 2020) [6]. Continuous mono-cropping of rice for longer periods on the same piece of land causes soil fatigue resulting in poor crop productivity which has widened the demand and supply gap in the region. Self-sufficiency and nutritional security in the state are not possible without embedding vegetables in rice-fallow areas, even though vegetable production requires much higher inputs as compared to field crops (Congreves and Van Eerd, 2015) [2]. Crop diversification is an approach that involves cultivating multiple crops on a farm, rather than relying solely on a single crop. In addition to increasing income opportunities, crop diversification enhances soil health, reduces the risk of crop failures due to biotic and abiotic stresses, promotes biodiversity, and reduces reliance on chemical inputs, thereby strengthening both sustainability and resilience. For instance, diversifying the rice-wheat cropping systems in the Indian subcontinent to include legumes and vegetables has increased dietary diversity and improved soil health, leading to greater productivity and sustainability within the agroecosystem (Kataki, 2002) [5]. By keeping these facts there is need to diversify the traditionally grown less remunerative cropping system for more remunerative cropping systems. Since there is practically no information available on these aspects of vegetable based cropping systems, hence, a field experiment was conducted to diversify and identify suitable vegetable based cropping system/sequence for higher productivity and profitability under Konkan region of Maharashtra.

Materials and Methods

A field study was carried out at the Agricultural Research Station, Repoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra (18°18'65"N latitude and 73°32'08"E longitude with an altitude of 37.19 m above

mean sea level) during 2020, 2021 and 2022. The soil of experimental site was medium black clay loam in texture with initial pH, soil organic carbon, available N, P and K as 6.08, 9.2 g kg⁻¹, 164.01 kg ha⁻¹, 15.88 kg ha⁻¹ and 182.24 kg ha⁻¹, respectively. The experiment was laid out in randomized block design with three replications in the same location throughout the study period. Treatments comprised of ten rice based vegetable cropping systems, namely, Rice (*O. sativa*)-Cucumber (*Cucumis sativus*), Rice-Chilli (*Capsicum annum*), Rice-Brinjal (*Solanum melongena*), Rice-Cabbage (*Brassica oleracea*), Rice-Dolichos bean, Rice-Okra (*Abelmoschus esculentus*), Rice-Bottle gourd (*Lagenaria siceraria*), Rice-Red pumpkin (*Cucurbita maxima*), Rice-Bitter gourd (*Momordica charatia*), Rice-Little gourd (*Coccinia grandis*) and Rice-Rice were evaluated. The rice crop was taken in *Kharif* season and vegetable were grown in *rabi* season. *Rabi* crops were raised under irrigated condition with recommended package of practices (Table 1). The grain yield of rice was recorded from the net plot and computed to kg ha⁻¹. The crop was fertilized with 100: 50:50 kg ha⁻¹ of N, P₂O₅ and K₂O, respectively. Half dose of N and full dose of P₂O₅ and K₂O was applied at sowing and remaining dose of N was applied in two split doses. The other recommended cultural practices and plant protection measures were followed for the healthy crop. Weeding was done manually 20 and 40 DAT. The growth and yield observations from each plot were recorded at harvest. During *Rabi* season all vegetable crops was sown/transplanted according to their spacing and fertilized with their recommended dose of fertilizer (Table 1). Half dose of nitrogen and full dose of phosphorus and potassium was applied at sowing and remaining dose of nitrogen was applied in two split doses. The growth and yield observations from each plot were recorded at each picking. The data collected on growth and yield of crop were statistically analyzed as per the standard analysis of variance (ANOVA) procedure for randomized block design and the Critical Difference (CD) test at 5% probability was calculated to detect the difference between treatment means. The rice equivalent yield (REY) was calculated to compare the system performance by converting the non-rice crop's yield into an equivalent paddy yield based on price. The yields from *rabi* crops were converted into rice equivalent yield by multiplying the yield by the prevailing market price of each produce, then dividing by the price of rice for different years. The rice equivalent yields from the *kharif* and *rabi* seasons were then summed to obtain the system rice equivalent yield. Productivity efficiency was calculated by taking total production on a rice equivalent basis in a sequence divided by 365 and expressed as kg ha⁻¹ day⁻¹ (Singh *et al.*, 1993) [12]. The cost of cultivation was calculated by including costs incurred on all the input for each cropping sequence which includes the capital and labour cost. Gross returns were obtained by the product of price of rice and the REY obtained under different cropping sequence. BC ratio was calculated by the ratio of gross returns to the total cost of cultivation. Gross and net returns were computed using prevailing rates of produce and agro inputs. Minimum support price of rice of respective years was considered for calculation of REY.

Table 1: Agronomic activities and inputs used in different cropping sequences during three consecutive years

Cropping sequence	Varieties		Spacing		Recommended fertilizer dose (Kg ha ⁻¹)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Rice-Cucumber	Karjat-3	Sheetal	20x15cm	1.5 x 1.0 m	100:50:50	135:60:30
Rice-Chilli	Karjat-3	Konkan Kirti	20x15cm	60x45cm	100:50:50	150:50:50
Rice-Brinjal	Karjat-3	Prabha	20x15cm	60x60 cm	100:50:50	150:50:50
Rice-Cabbage	Karjat-3	Golden acre	20x15cm	45x45 cm	100:50:50	120:60:60
Rice-Dilichous bean	Karjat-3	Konkan bhushan	20x15cm	45x30 cm	100:50:50	60:60:60
Rice-Okra	Karjat-3	Konkan bhendi	20x15cm	45x30 cm	100:50:50	100:50:25
Rice-Bottle gourd	Karjat-3	Samrat	20x15cm	1.5 x 1.0 m	100:50:50	100:50:50
Rice-Red pumpkin	Karjat-3	CM-14	20x15cm	3.0 x 0.5 m	100:50:50	100:50:50
Rice-Bitter gourd	Karjat-3	Konkan tara	20x15cm	1.5 x 0.5 m	100:50:50	120:60:30
Rice-Little gourd	Karjat-3	Alibaug local	20x15cm	1.5 x 0.5 m	100:50:50	120:60:30
Rice-Rice	Karjat-3	Karjat-3	20x15cm	20x15cm	100:50:50	100:50:50

Results and Discussion

Table 2: Effect of different rice-based cropping systems on yield (q ha⁻¹) of different crops (mean pooled of 3 years)

Treatment	Kharif Rice grain yield (qha ⁻¹)	Kharif straw yield (qha ⁻¹)	Kharif REY (qha ⁻¹)	Rabi REY (qha ⁻¹)	Rabi REY (qha ⁻¹)	System Yield (qha ⁻¹)	System Productivity efficiency (kg ha ⁻¹ day ⁻¹)
T ₁ : Rice-Cucumber	39.81	48.71	44.84	178.59	222.36	260.46	71.36
T ₂ : Rice-Chilli	39.67	48.91	44.73	118.32	184.16	221.10	60.58
T ₃ : Rice-Brinjal	40.24	50.26	45.44	187.07	155.32	192.53	52.75
T ₄ : Rice-Cabbage	39.36	48.51	44.37	164.68	102.68	139.80	38.30
T ₅ : Rice-D. Bean	39.88	50.14	45.08	97.64	121.98	159.40	43.67
T ₆ : Rice-Okra	39.85	49.53	44.98	128.17	211.83	249.63	68.39
T ₇ : Rice-Bottlegourd	39.37	48.99	44.44	181.03	113.54	150.91	41.34
T ₈ : Rice-Pumpkin	38.61	48.46	43.62	193.55	121.78	159.33	43.65
T ₉ : Rice-Bittergourd	39.36	48.67	44.39	133.23	138.68	176.35	48.32
T ₁₀ : Rice-Littleguord	39.58	48.73	44.62	158.94	165.21	203.07	55.63
T ₁₁ : Rice-Rice	35.12	43.67	39.65	44.96	44.96	81.28	22.27
S.E. (m) +	0.72	0.96	0.84	12.20	9.15	9.00	2.47
C.D. (0.05)	2.25	3.00	2.60	37.96	28.47	28.00	7.67

Table 3: Economics of Rice-vegetable cropping systems

Treatments	Mean System REY (q ha ⁻¹) (K + R)	Total gross returns (Rs.ha ⁻¹) (K + R)	Total cost of cultivation (Rs.ha ⁻¹) (K + R)	Net returns (Rs.ha ⁻¹)(K + R)	B:C ratio
T ₁ : Rice-Cucumber	260.46	531345	428031	103314	1.24
T ₂ : Rice-Chilli	221.10	451051	386734	64317	1.17
T ₃ : Rice-Brinjal	192.53	392754	376451	16303	1.04
T ₄ : Rice-Cabbage	139.80	285192	279997	5195	1.02
T ₅ : Rice-D. Bean	159.40	325176	321583	3593	1.01
T ₆ : Rice-Okra	249.63	509252	427061	82191	1.19
T ₇ : Rice-Bottlegourd	150.91	307850	307398	452	1.00
T ₈ : Rice-Pumpkin	159.33	325040	313699	11341	1.04
T ₉ : Rice-Bittergourd	176.35	359754	350244	9510	1.03
T ₁₀ : Rice-Littleguord	203.07	414256	368330	45926	1.12
T ₁₁ : Rice-Rice	81.28	165811	253960	-88149	0.65
S.E. (m) +	9.00	18357			
C.D. (0.05)	28.00	57112			

Selling rates (Rs.q⁻¹)

Crop	Rice (2020)	Rice (2021)	Rice (2022)	Cucumber	Chilli	Brinjal	Cabbage	D. Bean	Okra	Bottle gourd	Pumpkin	Bitter gourd	Little guord
Grain/vegetables	1815	1940	2040	2400	3000	1600	1200	2400	3200	1200	1200	2000	2000
Straw	200	200	200	--	--	--	--	--	--	--	--	--	--

Yield of kharif and rabi crops: The mean pooled data of Average yield and economic performance of rice-vegetable cropping systems during 2020, 2021 and 2022 are presented in Table 2 and 3. From the result, it was observed that the treatment T₃ (Rice-brinjal cropping system) was recorded highest grain yield (40.24 q ha⁻¹) and straw yield (52.76 q ha⁻¹) during *kharif* season. Whereas, the during *rabi* season the treatment (T₈) R-Pumpkin (193.55q ha⁻¹) recorded the highest yield.

Rice Equivalent Yield (REY), System yield and System productivity efficiency

Total productivity of different cropping sequences was determined by Rice Equivalent Yield (REY) calculated from the yield of component crops. From the three years result of rice-vegetable based cropping sequence, it was found that the highest relative equivalent yield (REY) during *kharif* season was (45.44 q ha⁻¹) recorded in Rice-Brinjal cropping sequence. It was statistically significant over Rice-rice

cropping system and at par with all other rice-vegetable based cropping sequence treatments. Whereas, the significantly highest equivalent yield of *rabi* (222.36 q ha⁻¹) was recorded in Rice-Cucumber cropping sequence which was found to be statistically significant over almost all the treatments except Rice-Okra cropping sequence (211.83q ha⁻¹). Similarly the highest system yield (260.46 q ha⁻¹) was also registered in Rice-Cucumber cropping sequence followed by the (249.63 q ha⁻¹) Rice-Okra cropping sequence. Similar results also reported by Kalita *et al.*, (2018) [4] the highest REY was recorded in winter rice-tomato sequence, followed by winter rice-cabbage as compared to the other cropping sequences. Upadhaya *et al.*, 2022 [14] also recorded highest rice equivalent yield (24.95 t ha⁻¹) in the maize cabbage sesame cropping system. Mandal *et al.*, (2015) which stated that inclusion of one vegetable crop in three or four crops-based cropping patterns sharply increase the rice equivalent yield of cropping pattern. Data on system productivity efficiency presented in Table 2, data showed that the effect on system productivity efficiency was significant with the highest value in Rice-Cucumber cropping sequence (70.36 kg ha⁻¹ day⁻¹), followed by Rice-Okra cropping sequence (68.39 kg ha⁻¹ day⁻¹). Upadhaya *et al.*, 2022 [14] also reported that the system productivity was increased by 187% and profitability by 299.52% in the maize Cole crops sesame cropping system over the rice wheat cropping system.

Economics of the different Rice-Vegetable cropping systems

The data regarding economics of the different Rice-vegetable cropping systems are presented in Table 3. Economic analysis was done on the basis of prevailing market price of the commodities. The highest gross return (Rs. 531345ha⁻¹) net return (Rs.103314 ha⁻¹) and benefit: cost ratio (1.24) was recorded in case of Rice-Cucumber cropping sequence. Followed by Rice-okra sequence recorded gross return (gross return (Rs. 509252ha⁻¹) and net profit (Rs. 82191) and benefit: cost ratio (1.19) as compared to remaining system. This might be attributed to higher production and more remunerative price of cucumber and okra. Prasad *et al.* 2020 reported that rice-pea-okra cropping system with gross return of Rs. 356912, net return of Rs. 164762 and B:C ratio of 1.86. Tomar and Tiwari (1990) [13], Ram *et al.* (2012) [11] and Mondal *et al.* (2015) [7] also reported that rice-vegetable crop-based cropping sequence is agronomically feasible and economically profitable with inclusion of vegetables, compared to existing farmers cropping pattern of rice-wheat system.

Conclusion

It can be concluded that under irrigated condition of Raigad district of Maharashtra the existing rice based cropping system can effectively be diversified with inclusion of vegetables like cucumber, okra and Cabbage during *rabi* season which were viable systems in productivity and economical point of view. Among the various rice based cropping sequences, cultivation of Rice-Brinjal cropping sequence recorded the highest relative equivalent yield (REY) (45.44 q ha⁻¹) during *kharif* season. Whereas, the significantly highest equivalent yield of *rabi* (222.36 q ha⁻¹) was recorded in Rice-Cucumber cropping sequence which was found to be statistically significant over almost all the treatments except Rice-Okra cropping sequence (211.83q

ha⁻¹). Similarly the highest system yield (260.46 q ha⁻¹), net return (Rs.103314 ha⁻¹) and benefit: cost ratio (1.24) was also registered in Rice-Cucumber cropping sequence followed by the Rice-Okra cropping sequence (249.63q ha⁻¹) net return (Rs.82191 ha⁻¹) and benefit: cost ratio (1.19).

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