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Traditional pandal agriculture of cucurbit vegetables utilises a relay intercropping approach with perennial Castor (*Ricinus communis* L.) to conserve resources

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A field experiment was conducted at the Tapioca and Castor Research Station, Yethapur, Tamil Nadu during the *Kharif* seasons of 2020-21, 2021-22 and 2022-23 to determine whether perennial castor (*Ricinus communis* L.) traditional pandal cultivation is suitable for cucurbit vegetable relay intercropping systems. The results indicated that perennial castor + cucumber relay intercropping system produced the highest castor equivalent yield (1701 kg/ha), followed by the perennial castor + ridge gourd (1596 kg/ha). Perennial castor + cucumber relay intercropping system had the highest system productivity (4.66 kg/ha/day), system profitability (338.8 Rs/ha/day), and relative economic efficiency (198.5%) of all the cucurbits. Perennial castor and bitter gourd relay intercropping had the best moisture-use efficiency (6.58 kg/ha/mm), while perennial castor and bottle gourd relay intercropping came in second (6.35 kg/ha/mm). Relay intercropping of perennial castor and cucumber system registered higher net returns (Rs. 1,23,662 ha), followed by perennial castor and ridge gourd (Rs. 1,20,515 ha). The average seed output of perennial sole castor was 1312 kg/ha, which was higher than the other cropping systems, despite the fact that the monetary returns were only Rs 41,801 ha. The relay intercropping of perennial castor + ridge gourd (3.29) and perennial castor + bitter gourd (3.29), followed by perennial castor + cucumber (3.27), had the highest benefit-cost ratio.

Keywords: Cucurbits, Perennial castor, Productivity, Relay intercropping, Resource

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Castor (*Ricinus communis* L.) is a major oilseed crop with industrial use worldwide. Crop failure has increased in solo farming systems due to decreased soil fertility and an unbalanced unimodal rainfall regime. Intercropping may lower crop failure risk[1]. Castor is grown as a single crop as well as in a mixed or intercrop system. It is ideal for intercropping systems due to its wider inter and intra row spacing[2]. Perennial castor has traditionally been used as a border crop or as live fence in both rainfed and irrigated locations. Cucurbit intercropping in castor is uncommon, and no research in India have examined relay intercropping of perennial castor with cucurbit vegetable crops. Cucurbitaceous vegetables have a creeping tendency as well as a climbing and trailing habit. Cucurbit vegetables are traditionally grown on the soil's surface as a creeping vegetable with surface irrigation. When compared to growing these creeper vegetables on aerial trailing systems such as staking, trellis, bower or pandal system, this practise attracts more plant diseases such as phytophthera blight, collar rot, bacterial wilt, gummosis, downy mildew, anthracnose, and so on[3]. Vertical trailing or staking was proven to be superior in increasing yield, achieving good fruit quality, and controlling foliar and fruit diseases in cucumber over ground production[4]. Pandal produced cucurbits produce uniformly sized fruits with homogeneous skin colour, attracting a higher market price. Typically, pandals are formed of expensive stone pillars. Most low-income farmers cannot afford to practise this farming due to the high cost component. Leguminous crops such as black gram, green gram, and groundnut are the principal intercrops in any cropping system in castor farming areas and are known to play an important role in food security, revenue generation, and environmental sustainability. While cucurbits vegetables are not grown as a response intercropping

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system in perennial castor, the productivity and potential economic returns of each relay intercropping system have not been objectively researched. Furthermore, an efficient relay intercropping system for conserving natural resources and sustaining output is required. As a result, the current study was done with the goal of maximising productivity in perennial castor-based pandal farming by evaluating different cucurbits as relay intercrops between wide spaced castor rows for resource saving and maximising productivity.

Materials and Methods

A three-year field experiment was carried out at the Tapioca and Castor Research Station, Yethapur (11.6627° N, 78.4751° E, 200 m altitude), Tamil Nadu, during the *Kharif* seasons of 2020-21, 2021-22, and 2022-23. The experimental region has a tropical climate with distinct wet and dry seasons and bimodal rainfall with more than 980 mm. The experiment was conducted in a randomised block design with seven treatments and three replications, namely, perennial castor as a sole crop, perennial castor- bitter gourd (*Momordica charantia*), perennial castor - ridge gourd (*Luffa acutangula*), perennial castor - snake gourd (*Trichsanthus cucumerina*), perennial castor - bottle gourd (*Legenaria siceraria*), perennial castor - coccinia (*Trichsanthus diocia*), perennial castor - cucumber (*Cucumis sativus*). The experiment began in the *Kharif* season with a perennial castor variety (YTP 1) and a suggested spacing of 3 x 3 m for castor and 2.5 x 2.5 m for cucurbits. Soil of the experimental site was clay loamy with a pH 7.3, low in organic carbon (0.29%) and medium in available nitrogen (228 kg/ ha), medium in available phosphorus (11 kg/ha) and medium in available potassium (305 kg/ha).

Unique agronomic practises such as nipping were performed at the 10th node (42 DAS), followed by pruning operations that left 7 nodes at each primary and secondary branch, shortly after harvesting of secondary, third, and fourth order spikes, to accelerate productive branching per plant and maintain the traditional pandal system. Sowing of castor was on 23.08.2020, whereas respective sowing dates for cucurbits were 10.02.2020, 12.02.2021 and 16.02.2022. Castor was harvested on 25.01.2020, the cucurbits crops were harvested on 03.07.2020, 10.07.2021, 12.07.2022. Cucurbits were sowed in the intra row space of 2.5 x 2.5 m in the ground under the perennial castor trellis construction after harvesting of perennial castor variety YTP 1 branches used as a traditional trellis (Fig. 1). During the first several days, the delicate cucurbit plants are somewhat protected by the trellis crop. By the time the cucurbits mature, the trellis crop will have totally provided adequate sunshine to the cucurbits plants. As a result, the relay systems function well with ground crops that require full sunlight. Threads are used to guide the cucurbit plants to the trellis.

Irrigation channels 50 cm wide were formed between two rows of castor (3m x 3m), and cucurbit seeds were sown on the solder of bunds 0.5 m apart from the main trunk of perennial castor (YTP 1), resulting in cucurbits sown at 2.5 x 2.5 m spacing, paving the way for simple intercultural operations for both castor and cucurbits. Throughout the trial, typical cultural practises were followed. Castor equivalent yield (CEY) was calculated in terms of castor yield of all intercropping treatments based on prevailing market prices (Rs./kg). It was calculated using formula suggested[5].

Castor equivalent yield (CEY) =

$$\frac{\text{Yield of intercrop} \times \text{Price of intercrop}}{\text{Price of castor}} \text{ X } 100$$

The land equivalent ratio (LER) was also computed as LA+LB = AI/AS+BI/BS, where LA and LB are the respective LERs of two crops A and B, LA is obtained by dividing the yield of crop A in intercropping (AI) by the yield of the same crop in sole cropping (AS). LB is calculated in the same way[6]. The Moisture Use Efficiency (MUE) was calculated by dividing the grain yield (kg/ha) to cumulative water used (mm) from sowing to harvest[7]. Relative Economic Efficiency (REE) is a comparative measure of economic gains over the existing system.

REE (%) =

$$\frac{\text{Net income from improved system} - \text{Net income in existing system}}{\text{Net income in existing system}} \text{ X } 100$$

System profitability refers to the profit obtained from crops, measured as net returns on a per hectare basis. This is calculated as the net return per hectare per day, denoted in rupees per hectare per day (Rs/ha/day)[8]. System productivity is yields of different crops are converted into single crop equivalent yield expressed as kg/ha/day. Analysis of variance (ANOVA) was used to detect the significance of treatment effects on different parameters studied. Least significant difference (LSD) was used to separate the mean whenever the treatment means were significantly different. The statistical analysis was done as per the method suggested[9]. The net income per ha was calculated by deducting the total cost of cultivation from gross return per ha. The benefit cost ratio was obtained by dividing the gross returns by cost of cultivation.

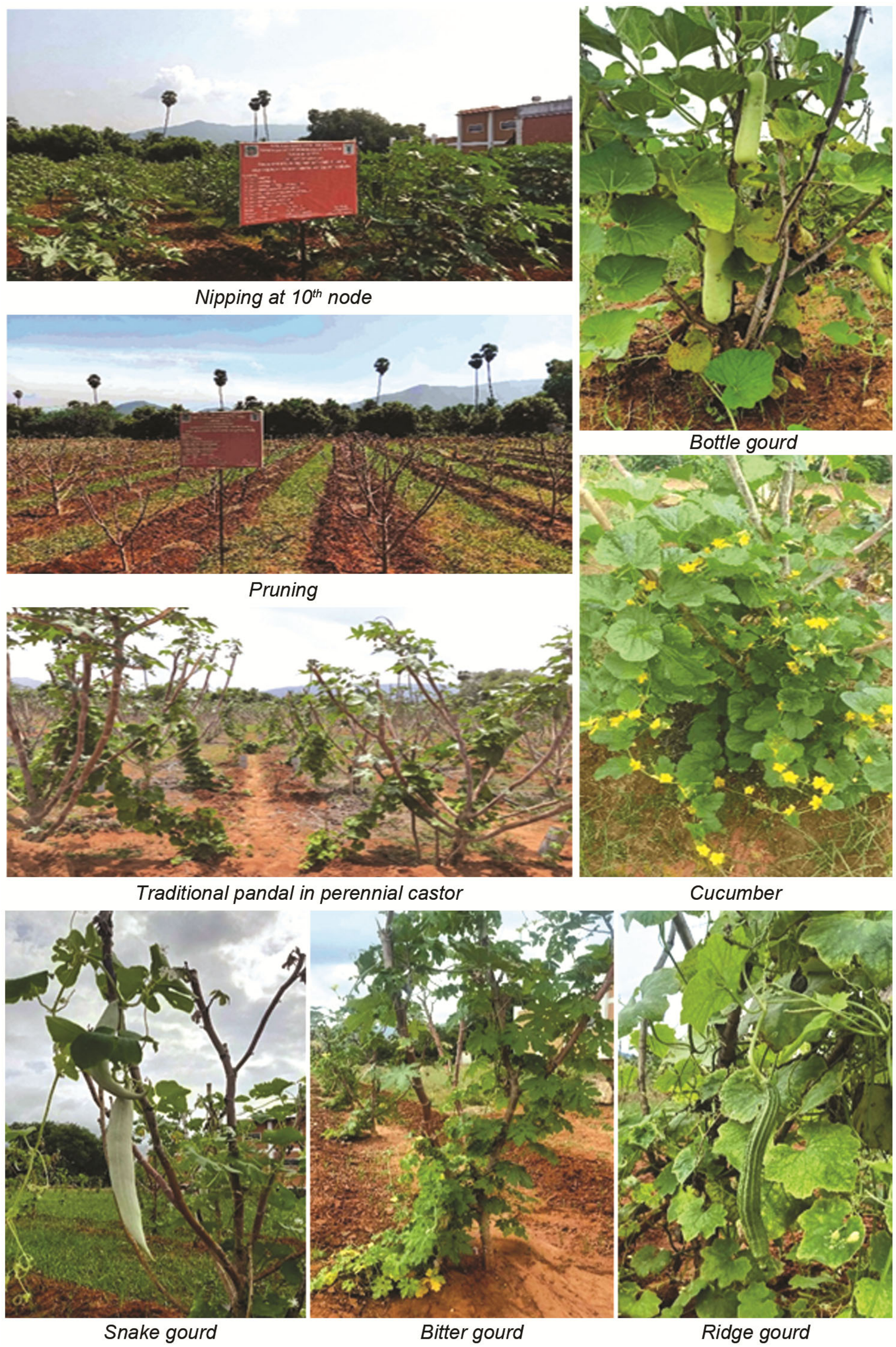

Fig. 1 — Traditional pandal cultivation of cucurbits in perennial castor crop

Results and Discussion

Growth and yield parameters of perennial castor

Results indicated no significant effect of different relay intercropping system on growth and yield attributes of perennial castor (Table 1). Plant height of perennial castor was recorded maximum in perennial sole castor (152.3 cm) followed by perennial castor-snake gourd (148.5 cm) system. Similarly, number of productive branches were highest in perennial sole castor (14.9) followed by perennial castor-snake gourd (14.2) system. Relay intercropping of perennial castor with cucurbits did not affect yield of perennial castor significantly (Table 1). Seed yield was highest in perennial sole castor (1312 kg/ha) compared with other relay intercropping system. It was observed that yield of perennial castor was not affected by different intercropping systems. This may be due to no demand on resources or avoid competition in cropping system, which cucurbits sown only after harvesting of the castor. Similar results were reported by[10] in castor with leguminous intercropping systems.

System productivity on cucurbits yield

Pooled analysis revealed that, among the all the cucurbits studied, higher cucurbit yield was obtained under perennial castor + bitter gourd (5151 kg/ha) as compared to other relayed cucurbits. This higher cucurbit yield of bitter gourd was mainly attributed to its high yielding potential over other cucurbits also bitter gourd climber trailed on the castor plant branches, continues to growing and trailed on the plant without ground support. So vines are less susceptible to pest and diseases as they do not come in direct contact with the soil. Intercropping of cucumber and tomato was found to be beneficial over monoculture[11]. They also reported intercropping as a beneficial system of crop production and often gives more yield than sole cropping, because crops grown in association with each other may use resource more efficiently than sole crops.

The maximum system productivity (4.66 kg/ha/day) was obtained in perennial castor-cucumber relay intercropping system followed by perennial castor-ridge gourd system (4.37 kg/ha/day). The lowest system productivity (3.06 kg/ha/day) was found in perennial castor-snake gourd system (Table 1) owing to lower fruit yield in spite of higher market price in cucumber. Similar findings with higher net returns and system productivity in castor based intercropping system were reported[12]. Therefore, cucumber and ridge gourd was found to be a compatible relay intercrop with perennial castor. It indicates that the system exploited the resources in a better way and created less competition to castor.

Castor equivalent yield and land equivalent ratio

The yield of all the component crops was converted into CEY based on existing market price to determine comparative efficiency of different treatment combinations. The castor equivalent yield was significantly higher in castor-ridge gourd relay intercropping system (1596 kg/ha) than sole crop of castor. Relay intercropping of castor with ridge gourd was found to be a profitable system. The higher castor

Table 1 — Growth, yield attributes and castor equivalent yield of traditional pandal system of perennial castor - cucurbits based relay intercropping system (Pooled mean of three years)

Relay intercropping system	Castor plant height (cm)	No. of productive branches/plant in castor	Spike length of castor (cm)	No. of capsules/Spike of castor	Shelling % of castor	Test weight of castor (g)	Oil content of castor (%)	Castor yield (kg/ha)	Cucurbits yield (kg/ ha)	CEY (kg/ha)
Castor sole (YTP-1)	152.3	14.9	71.6	111.1	66.1	43.3	45.2	1312	-	-
Castor-Bitter gourd	142.6	12.5	76.9	113.6	66.3	43.2	45.0	1243	5151	1546
Castor-Ridge gourd	143.2	12.8	79.0	111.8	65.4	43.2	46.6	1293	3191	1596
Castor-Snake gourd	148.5	14.2	73.2	113.5	65.8	43.4	46.1	1269	4192	1118
Castor-Bottle gourd	145.8	13.6	69.2	117.2	64.2	43.2	45.9	1251	4920	1230
Castor-Coccinia	139.3	12.4	70.9	114.1	66.5	43.1	45.6	1252	2207	736
Castor-Cucumber	139.8	13.2	72.7	112.5	66.6	43.0	45.9	1272	3401	1701
S. Em.±	4.66	1.44	2.94	4.89	2.44	1.34	1.24	108.85	127.0	98.0
CD (p=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	356.1	208.9

Table 2 — Economics, system productivity, profitability relative economic efficiency and moisture use efficiency in traditional pandal system of perennial castor - cucurbits based relay intercropping system (Pooled mean of three years)

Relay intercropping system	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BC Ratio	System productivity (kg/ha/day)	System profitability (Rs/ha/day)	REE (%)	MUE (kg/ha/mm)
Castor sole (YTP-1)	31970	73770	41801	2.32	0	114.5	0	1.27
Castor-Bitter gourd	51095	167298	116203	3.29	4.23	318.4	178	6.58
Castor-Ridge gourd	52796	173310	120515	3.29	4.37	330.2	188	4.62
Castor-Snake gourd	49743	143174	93431	2.88	3.06	256.0	124	5.62
Castor-Bottle gourd	53417	148830	95414	2.79	3.37	261.4	128	6.35
Castor-Coccinia	49639	119230	69591	2.41	2.02	190.7	66	3.56
Castor-Cucumber	54673	178335	123662	3.27	4.66	338.8	196	4.81
S. Em.±	-	-	-	-	0.81	2.38	1.91	0.87
CD (p=0.05%)	-	-	-	-	2.34	6.10	3.67	2.51

REE: Relative economic efficiency, MUE: Moisture use efficiency
Cost of the produce castor Rs. 60/kg; bitter gourd Rs. 18/kg; ridge gourd Rs. 30/kg; snake gourd Rs. 16/kg; bottle gourd Rs. 16/kg; coccinia Rs. 20/kg; and cucumber Rs. 30 kg.

equivalent yield was due to additional intercrop yield with lower reduction in main crop yield[13]. Among different relay intercropping systems, castor-bitter gourd recorded higher land equivalent ratio (1.81) than other intercropping systems, indicating that 81% more area was required in a pure cropping system to equal the yield of relay intercropping. Lowest LER was observed in castor-coccinia relay intercropping system. With this cropping pattern, LER was significantly greater than 1.00 indicating an advantage of intercropping over pure stands, in terms of the use of environmental resources for plant growth[14]. On the other hand, the high value of LER observed, revealed that interspecific interaction or complementarity was greater than the competition so that intercropping resulted in greater land-use efficiency.

Moisture use efficiency

Between the different cucurbits relay intercropping with perennial castor, bitter gourd in castor recorded substantially higher moisture use efficiency (6.58 kg/ha/mm) closely followed by castor-bottle gourd (6.35 kg/ha/mm) system. The lowest moisture use efficiency (1.27 kg/ha/mm) was being recorded in perennial sole castor. The highest moisture use efficiency compared to lower might be due to the better ability of bitter gourd to take up available moisture from the soil as compared to other relay crops[14].

Economics, relative economic efficiency and system profitability

Among the cucurbits based relay intercropping with traditional pandal cultivation of perennial castor, Relay intercropping of perennial castor and cucumber yielded significantly higher net returns (Rs. 1,23,662 ha), followed by castor and ridge gourd system (Rs. 1,20,515 ha) (Table 2). Similarly, intercropping could result in an increase in the productivity of vegetables per unit area and improved gross return[15]. The relay intercropping of castor + ridge gourd (3.29) and castor + bitter gourd (3.29), followed by castor + cucumber (3.27), had the highest benefit-cost ratio. Intercropping was more productive and have positive effect on growth when planted with vegetables[16].

In the case of relative economic efficiency (REE), all the relay intercropping had higher economic gain over the sole castor (Table 2). Among the relay intercropping, Castor + cucumber system recorded the highest economic gain (196%) followed by castor-ridge gourd (188%). Inclusion of more number of crops in exiting system resulted in higher productivity, employment generation, which ultimately turned in higher economic output over routine cropping sequences[17]. The maximum system profitability (338.8 Rs/ha/day) was obtained in castor-cucumber relay intercropping system followed by castor-ridge gourd (330.2 Rs/ha/day) system. This may be attributed to differences in yield, cost of cultivation and prices of economic produce of relay intercropping in sequences. This higher and more stable yield, especially with reduced inputs, is primarily attributed to resource complementarity[18,19]. In this context, intercrop species more efficiently utilize available resources due to their differing spatial, temporal, and phenological characteristics[20].

Conclusions

From the three years field investigation, results confirmed that castor yield was unaffected by traditional pandal system and relay intercropping and with cucurbits vegetable crops. Relay intercropping of cucurbits increased significantly the CEY, system productivity, relative economic efficiency and system profitability compared to perennial sole castor cultivation. The results showed that relay intercropping cucumber, bitter gourd or ridge gourd had high yield advantages and a higher area based productivity than when grown traditional pandal system of perennial sole castor. Traditional pandal system of castor and relay intercropping not only enhances productivity and system sustainability but also enhances farmer's income, employment and reduces risks against climatic aberrations and changes.

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Conflict of Interest

There is no conflict amongst the authors as it is evidence-based learning and collection of information from the farming community, although nothing is confidential.

Author Contributions

VP: Investigation, data collection, writing; SK: Review, and editing; HC: Data collection, KP: Data collection, MS: Review; MA: Editing.

Data Availability

All the collected data are presented in the article.

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