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Evaluation of taro (*Colocasia esculenta*)-based cropping system for crop diversification under rainfed upland ecosystem of eastern India

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Abstract

A field experiment was conducted at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, during 2018-2020 on alfisols under rainfed conditions to identify most productive, resource use-efficient and remunerative taro-based cropping system. The experiment consisted of seven treatments, T_1- sole taro, T_2- sole maize, T_3- sole pigeonpea, T_4- taro+maize (5:1), T_5- taro+maize (5:2), T_6- taro+pigeonpea (5:1) and T_7- taro+pigeonpea (5:2). The results revealed that the cormel equivalent yield (CEY) was greater in T_1 and it was statistically on a par with T_4 and T_6. The LER of T_4, T_5, T_6 and T_7 were found >1. This indicated that all the above intercropping systems were biologically efficient. However, advantage of intercropping system was disappeared in T_5, T_6 and T_7, when evaluated via ATER concept. The treatment T_1 resulted in higher gross and net returns as well as B:C ratio however, it was statistically on a par with T_4 and T_6. Taro can be recommended for cultivation as a sole crop under upland ecosystem of eastern India. The treatment taro+maize (5:1) (T_4) can also be recommended for cultivation under rainfed conditions of eastern India for efficient use of resources, and optimum yield and returns. The intercropping system taro+pigeonpea (5:1) (T_6) can also be considered when more emphasis was given on soil health.

Key words: Area time equivalent ratio, Cormel equivalent yield, Gross and net returns, Land equivalent ratio

Taro [*Colocasia esculenta* (L.) Schott.], is capable of withstanding drought and flood. An annual rainfall of 900-1200 mm spread-over 5-6 months is required for its cultivation (Nedunchezhiyan and Sahoo 2019). High rainfall regions of eastern India are highly suitable for taro cultivation under rainfed conditions. As a sole crop, taro requires huge quantity of seed material (1.2 t/ha), causing very high initial investment. However, intercropping with cereals and pulses under replacement series will reduce seed cost of taro. Diversification with pulses not only provides food self-sufficiency but also contribute to nutritional adequacy (Rathore 2016).

Intercropping may be an alternate practice to overcome low productivity in case of low input and low output small scale farming (Dadabhau 2014). Maize+blackgram (*Vigna mungo* L.) intercropping is a viable agronomic means of risk minimizing farmers profit and subsistence oriented (Shilpa *et al*. 2019). The system productivity was higher in cropping systems through the inclusion of vegetables (Bhargavi *et al*. 2019a).

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The overall productivity increases (Singh *et al*. 2017). Inclusion of pulses and tuberous vegetables in cereal based cropping system improve the economic condition of small and marginal farmers owing to higher price and/or higher volume of their main and by products (Sharma *et al*. 2007; Nedunchezhiyan *et al*. 2022). Therefore, present investigation was carried out to find out resource-use efficiency of taro-based cropping system for yield and income under high rainfall upland ecosystem of eastern India.

Materials and Methods

A field experiment was conducted at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, during 2018-2020 on alfisols under rainfed conditions. The climate of location is hot and humid summer, and cool and dry winter. The experimental site soil (top 0.30 m) was having pH 5.7, organic carbon 0.37%, available N 205 kg/ha, available P 20.1 kg/ha and available K 252 kg/ha. The experiment was laid out in a randomized block design with three replications. The experiment consisted of seven treatments, T_1- sole taro, T_2- sole maize, T_3- sole pigeonpea, T_4- taro+maize (5:1), T_5-

taro+maize (5:2), T_6- taro+pigeonpea (5:1) and T_7- taro+pigeonpea (5:2).

All the crops in intercropping were planted at 45 cm × 30 cm spacing. Sole taro at 45 cm × 30 cm spacing, whereas sole maize and pigeonpea at 60 cm × 30 cm spacing. The variety Muktakeshi (taro), H 4226 (maize) and CORG 9701 (pigeonpea) were used. The recommended dose of fertilizers N-P-K 80-60-80, 80-40-40 and 20-40-20 kg/ha were applied for taro, maize and pigeonpea, respectively. In an intercropping, fertilizer dose of respective crops as per net sown area basis was applied.

Nitrogen (N), phosphorus (P) and potassium (K) were applied through urea, single super phosphate and muriate of potash, respectively. In all treatments, half dose of N and full doses of P and K were applied at the time of planting, while remaining N was applied 1 month after planting. The experiment was planted during second week of June in all the years. Maize was harvested 90 days after sowing, taro 165 days after planting and pigeonpea 200 days after sowing.

The average maximum and minimum temperature were 32.2 and 23.2°C, respectively. The total rainfall during crop growing period was 1568.2 mm with 74 rainy days. The cormel equivalent yield (CEY) data was computed taking into the consideration of selling price of taro corm and cormels, maize and pigeonpea seeds along with their yield.

$$\text{CEY (t/ha)} = \text{cormel yield (t/ha)} + \frac{\text{Corm/ maize/ pigeonpea yield (t/ha) x sale price of corm/ maize/ pigeonpea (₹/t)}}{\text{Sale price of cormel (₹/t)}}$$

The land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated as follows:

The land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated as follows:

$$LER = \frac{Ya}{Yaa} + \frac{Yb}{Ybb}$$

where, Ya = intercrop yield of crop ‘a’

Yb = intercrop yield of crop ‘b’

Yaa = pure stand yield of crop ‘a’

Ybb = pure stand yield of crop ‘b’

$$ATER = \frac{LA \times DA + LB \times LB}{T}$$

where, LA and LB are partial LERs of component crops A and B. DA and DB are duration of crops A and B, and T is the total duration of intercropping system.

The data were statistically analyzed and significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level.

Results and Discussion

Yield

The CEY computed revealed that T_1 recorded greater CEY (Table 1). This was due to higher genetic potential of higher tonnage yield as well as favourable rainfall during crop growing period. During all years average total rainfall received during crop growing period was 1568.2 mm with 74 rainy days, which was sufficient for raising sole taro crop. The CEY of T_4 and T_6 was statistically on par with T_1. But the CEY of T_5 and T_7 was significantly lower than T_1. This indicated that if one row of taro was replaced with maize or pigeonpea in an intercropping, they could compensate replaced taro population yield. Thokchom *et al.* (2016) reported that among taro intercropped treatments maximum taro yield was recorded in combination with single row of cowpea. The reduction in taro yield is compensated by intercrop (cowpea) yield in intercropping. If two rows of taro were replaced with maize or pigeonpea in an intercropping, they could not compensate replaced taro population yield (Table 1). Chhetri and Sinha (2020) also reported that maize+cowpea intercropping system 2:2 row ratio (replacement series) recorded higher maize equivalent yield than 2:4 row ratio. The CEY of T_2 and T_3 were significantly lowest. This was due to lower tonnage seed yield of maize and pigeonpea compared to taro. Inclusion of taro as an intercrop in maize and pigeonpea, the CEY of the intercropping treatments more than doubled.

The CEY of T_4 and T_5 was 248 and 212% higher respectively than T_2. The CEY of T_6 and T_7 was 138 and 105% higher respectively than T_3. The higher CEY in these treatments was due to higher tonnage taro yield as well as higher yield of maize and pigeonpea under intercropping than sole cropping on net area sown basis. Bhargavi *et al.* (2019b) also reported that the inclusion of high value crops, i.e. vegetables increased the system productivity.

Taro yield decreased under intercropping (Fig.1). The decrease in yield was due to decrease in taro population under intercropping. Taro corm yield was more affected than cormel yield under intercropping. The decrease of taro corm yield ranged from 17.1 to 41.9% under intercropping, whereas decrease of taro cormel yield ranged from 16.1 to 38.0% (Fig. 1). The taro yield was also influenced by intercrops under intercropping. Pigeonpea reduced taro yield more than maize under intercropping (Fig. 1).

This was due to duration of interference of intercrop with main crop. Maize as an intercrop reduced taro corm yield 17.1-32.9% and cormel yield 16.1-29.0%, whereas pigeonpea as an intercrop reduced taro corm yield 26.6-41.9% and cormel yield 20.7-38% (Fig. 1). Increasing intercrop population resulted in decrease of taro yield, however it was not in linear. When one row of taro was replaced with maize (T_4), reduction in taro corm and cormel yield was 17.1 and 16.1%, respectively (Fig. 1). When two rows of taro were replaced with maize (T_5), the reduction in taro corm and cormel yield was 32.9 and 29.0%, respectively (Fig. 1). Similarly, one row of taro was replaced with pigeonpea (T_6), the reduction in taro corm and cormel yield was 26.6 and 20.7%, respectively. When two rows of taro were replaced with pigeonpea (T_7), the reduction in taro corm and cormel yield was 41.9 and 38.0%, respectively (Fig. 1).

Maize and pigeonpea as an intercrop recorded higher yield in intercropping than sole crops on net area sown basis (Fig. 1). Sowing of one row of maize/pigeonpea in treatments T_4/T_6 occupies 16.7% area, whereas sowing of two rows of maize/pigeonpea in T_5/T_7 occupies 28.6% area. One row of maize in T_4 recorded 27.6% of sole maize yield (T_2), whereas two rows of maize in T_5 recorded 43.6% of sole maize yield (T_2). Similarly, one row of pigeonpea in T_6 recorded 29.8% of sole pigeonpea yield (T_3), whereas two rows of pigeonpea in T_7 recorded 42.5% of sole pigeonpea yield (T_3).

The yield advantage of maize and pigeonpea in intercropping systems with taro probably occurred from the difference in timing of utilization of resources by different crops. Maize and pigeonpea are tall growing with deep root system, whereas taro is short height with shallow root system. Intercropping ensures efficient utilization of natural resources like light, nutrients, water and space but also conserve it by reducing soil erosion and lodging, suppresses weed growth thereby helps in yield increment (Shilpa *et al*. 2019). Under intercropping, taro recorded lower yield than sole crop on net area sown basis with pigeonpea, but no influence was found with maize (Fig. 1).

Sowing of five rows of taro in T_4 and T_6 occupies 83.3% area, whereas in T_5 and T_7 occupies 71.4% area. Taro yield in T_4 and T_5 (intercropping with maize) was found 83.7 and 70.1% of sole crop yield, respectively whereas, in T_6 and T_7 (intercropping with pigeonpea) was found 77.9 and 61.1% of sole crop yield, respectively. Thus, in T_4, taro yield recorded 83.7% of sole crop yield from 83.7% net sown area and in T_5, taro yield recorded 70.1% of sole crop yield from 71.4% net sown area. This showed that growing maize as an intercrop sown either one or two rows have not affected taro yield.

There is no competition for above ground (light and space) and below ground (water and nutrients) resources in taro+maize intercropping systems (T_4 and T_5). Whereas, in T_6 taro yield recorded 77.9% of sole crop yield from 83.7% net sown area and in T_7, taro yield

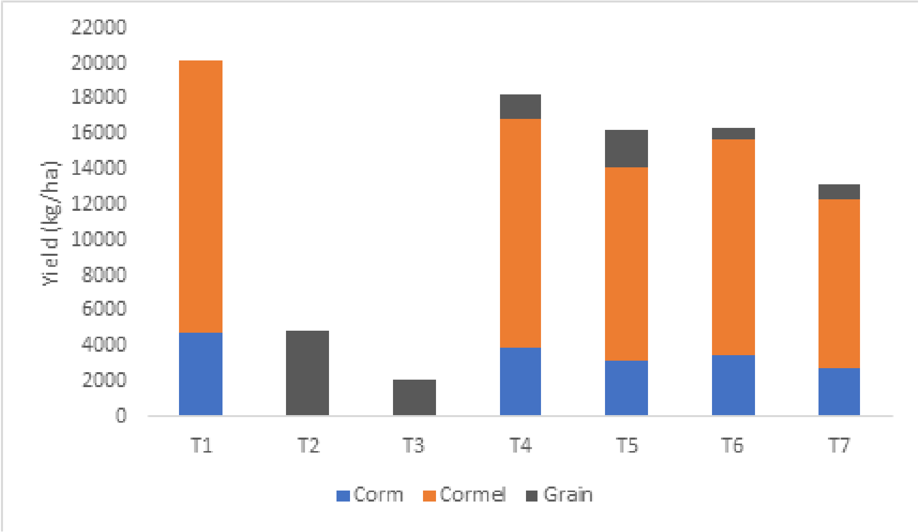

Fig. 1. Yield of taro, maize and pigeonpea in sole as well as in intercropping system

recorded 61.1% of sole crop yield from 71.4% net sown area. This showed that pigeonpea as an intercrop sown either one or two rows have affected taro yield. Pigeonpea was competing with taro for above ground (light and space) and below ground (water and nutrients) resources through-out the crop growing period.

Inclusion of maize and pigeonpea in taro, though the total yield was reduced compared to sole taro but it has advantage during aberrant weather conditions. These intercropping systems prevent total crop failure because maize and pigeonpea tap water and nutrients from deep layer due to their deep root-system (Behera *et al.* 2007; Dodiya *et al.*, 2018). Inclusion of pigeonpea as an intercrop with tuber crop supplies additional nutrient to crop plant by converting and fixing atmospheric nitrogen in available form through symbiosis with rhizobial strains (Geno and Geno 2001). Diversification with cereals, legumes and tuber crops not only provides food self-sufficiency but also contribute to nutritional adequacy (Singh *et al.* 2017; Suja and Nedunchezhiyan 2018).

Biological efficiency

The LER of T_4, T_5, T_6 and T_7 were found >1 (Fig. 2). This indicated that all the above intercropping systems were biologically efficient. Among all the intercropping systems, T_5 was found with highest LER and it was followed by T_4 (Fig. 2). Better LER in 2:2 row ratio of maize+cowpea intercropping system than other combination was reported by Chhetri and Sinha (2020). In this experiment, the duration of intercrops was widely varied. Hence, area time equivalent ratio (ATER) was used for assessing the intercropping efficiency.

The ATER of treatment T_4 was nearly one (0.99) and all other treatments were 0.94 and less. The resource use and resource complementarily between two species of high and low tonnage yielding crops was greater in T_4. The highest ATER in T4 indicated that growth requirement of both the component crops differs in time resulting in higher per day yield of the system due to temporal complementary effect. Thus, the advantage of intercropping system was disappeared in T_5, T_6 and T_7, when evaluated via ATER concept (Fig. 2). Similar findings in maize+black gram (Kheroar and Patra, 2014) and maize+cowpea (Chhetri and Sinha, 2020) were also reported.

Post-harvest soil nutrient status

The post-harvest soil nutrient status after three years of experimentation revealed that pH was increased in all the treatments over initial level (Table 2). Higher pH level was noticed in the treatment T_3 followed by T_7 and T_6. The organic carbon content in the post-harvest soil was found higher than initial level in all the treatments (Table 2). The treatment T_3 resulted in higher organic carbon level compared to other treatments. The next best treatments were T_6 and T_7. This may be due to large quantity of leaf shedding and organic exudates from the roots were added to the soil by pigeonpea compared to other crop species both sole as well as intercropping systems. Improved organic carbon aggregation in soil was noticed with the recycling of residues and mulches (Shukla *et al.*, 2020).

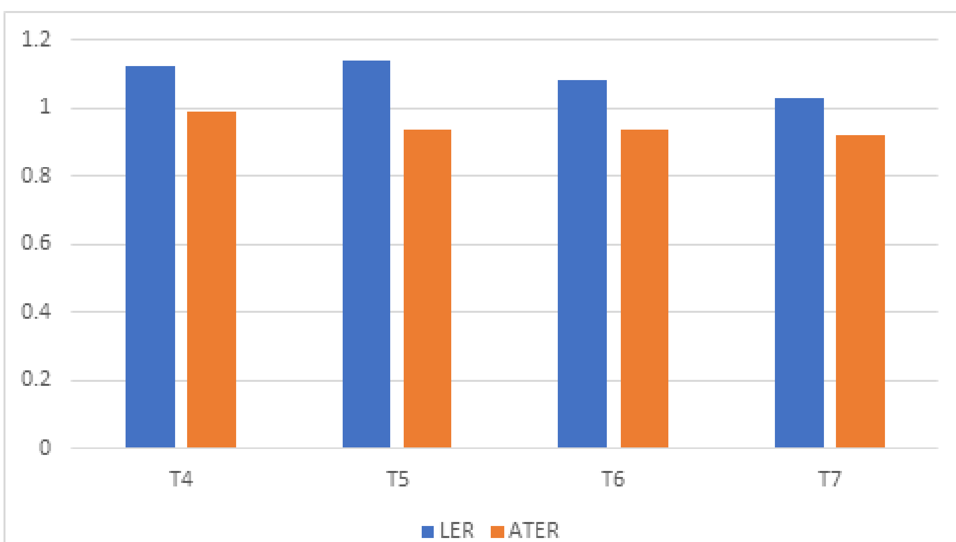

Fig. 2. LER and ATER of intercropping system

The post-harvest soil available N, P and K content were higher than initial levels (Table 2). The treatments T_7 and T_6 resulted in higher amount of post-harvest soil available N, P and K content and it was followed by T_3. This was due to application of recommended dose N, P and K, and contribution of decomposed organic matter from the crop plants. The higher build-up of soil nutrients caused by decomposition of above and below ground residues due to enhanced crop growth activities by application of recommended dose of manures and fertilizers was also reported by Sarangi *et al.* (2020) and Sharma *et al.* (2021).

Economics

The cost of cultivation was higher with taro either as a sole or as an intercrop (Table 1). The treatment T_1 resulted in highest cost of cultivation, followed by T_4 and T_6 (Table 1). This was mainly due to huge quantity of taro seed material required for cultivation as well as its cost. The treatment T_3 and T_2 recorded lower cost of cultivation due to lower seed cost as well as other input costs (fertilizers). The treatment T_1 registered with greater gross and net returns as well as B:C ratio (Table 1). This was mainly due to higher tonnage of taro yield. The gross and net returns as well as B:C ratio of T_4 and T_6 were statistically on a par with T_1 and were the next best treatments. The treatment T_2 and T_3 recorded lower gross and net returns as well as B:C ratio (Table 1). This was due to lower yield of maize and pigeonpea.

Conclusion

Considering yield and return, taro+maize intercropping system (5:1) can be recommended for cultivation as a

Table 1: Cormel equivalent yield and economics of taro, maize and pigeonpea involved intercropping systems

Treatment	Cormel equivalent yield (t/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B: C ratio
T_1	18.59	111400	278900	167500	2.50
T_2	4.86	55200	72900	17700	1.32
T_3	7.00	50600	105100	54500	2.07
T_4	16.90	105000	253500	148500	2.41
T_5	15.19	99900	227800	127900	2.28
T_6	16.64	104100	249700	145600	2.40
T_7	14.37	98800	215600	116800	2.18
SEm±	0.67	2700	10000	9000	0.09
CD (5%)	2.05	8200	30800	27800	0.27

Sale price of corm 10000 ₹/t; cormel 15000 ₹/t; maize 15000 ₹/t; pigeonpea 50000 ₹/t

Table 2: Post-harvest soil nutrient status of taro intercropping system

Treatment	pH	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	5.8	0.39	212	21.2	261
T_2	6.0	0.43	216	22.1	266
T_3	6.3	0.48	230	23.4	276
T_4	5.8	0.40	218	22.2	268
T_5	5.9	0.42	222	23.2	272
T_6	6.1	0.44	232	24.4	280
T_7	6.2	0.46	236	24.9	282
SEm±	0.07	0.01	4.2	0.2	5.3
CD (5%)	0.2	0.03	13	2.6	16

crop diversification option under rainfed conditions of eastern India with lower risk. The intercropping system taro+pigeonpea (5:1) can also be considered when more emphasis was given on soil health.

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