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Taro (*Colocasia esculenta* Schott.) based intercropping systems: interspecies interaction effects on growth and yield

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Abstract

Intercropping is a viable option to monoculture with a view to increasing the use efficiency of natural resources. A field experiment was conducted at the Regional Station of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India for three consecutive years (2018-2000) on alfisols under rainfed conditions to study interspecies interaction in taro based intercropping systems. The experiment consisted of seven treatments, T_1-sole taro, T_2-sole maize, T_3-sole pigeon pea, T_4-taro+maize (5:1), T_5- taro+maize (5:2), T_6- taro+pigeon pea (5:1) and T_7-taro+pigeon pea (5:2). The treatments were replicated three times. During the cropping period, the weather was favourble for all the crops in all the years. The results revealed that taro border rows in intercropping resulted in higher growth characters and lower yield components and yield than sole crop rows. Maize and pigeon pea in intercropping resulted in higher growth characters, yield components and yield than sole maize and pigeon pea. Taro was affected by interspecies interference, whereas interspecies interference was minimalfor maize and pigeonpea under intercropping. As intercrop, pigeon pea affected taro corm and cormel yield more than maize as pigeon pea competed with taro for longer period (165 days) than maize (90 days). Under intercropping, the decrease in taro corm and cormel yield was due to decrease in taro population apart from intercrop (maize/pigeon pea) competition. Taro corm yield per ha was affected more than cormel yield per ha under intercropping. The cormel equivalent yield (CEY) of taro sole cropping was higher and comparable to taro+maize (5:1) and taro+pigeon pea (5:1) intercropping systems. However, during unfavourable (lesser rainfall and rainy days) season only the potential of intercropping system will be realized.

Keywords: Cormel equivalent yield, Intercropping, Maize, Pigeon pea, Taro

Introduction

Intercropping is a popular production system in small and marginal holdings in developing countries. It allows more efficient use of on-farm resources, provides year-round ground cover or at least for a longer period than monocultures, in order to protect the soil from desiccation and erosion. Growing more than one crop at a time in the same field, enhances water use efficiency and maintain soil fertility (Rathore, 2016 and Shilpa et al., 2019). Crop insurance is a major principle of intercropping in that if environmental factors change, some of the intercrop does well when others do poorly. Intercropping will not only provide biological insurance against risk of crop failure under aberrant rainfall behaviour in dry land conditions but also ensure more employment opportunities and pest and disease controlto some extent (Suja and Nedunchezhiyan, 2018;

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Trupti et al., 2018). In uplands, intercropping and crop substitution stabilize crop yield. When crops of different growth habits are put together in an intercropping system, it provides greater opportunity to secure higher crop yield from the same piece of land than the monoculture largely due to synergetic effect of component crops (Singh et al., 2017). Among component crops, competition is minimal when differences in growth duration are wider in areas having long crop growing period. The components of the crop association need to have different environmental requirements or contrasting habits.

Cereals, millets, pulses, and root and tuber crops are the major food cropsgrown in rainfed uplands of eastern India. Farmers in this region usually grow more than one food crop in their available landholdings, sometimes, two crops in the same piece of land, separately. Taro (*Colocasia esculenta* Schott.) is grown for its modified stem tubers, which is a rich source of carbohydrate (73-80% on dry weight basis) (Njintang et al., 2007). An annual rainfall of 900-1200 mm spread-over 5-6 months is required for taro cultivation (Nedunchezhiyan and Sahoo, 2019). Taro, a water loving tuber crop is grown in eastern India because of high rainfall and longer crop growing period. However, mid-season and terminal droughts can reduce the yield of taro to a considerable extent. As a sole crop, taro requires huge quantity of seed material (1.2 t ha^{-1}) causing very high initial investment. In small-holder farming system, it may be difficult to invest and during drought, farm economy is severely affected. Hence, intercropping with cereals and pulses under replacement series will reduce seed cost of taro. Intercropping of cereals and pulses in taro canalso act as contingent crops and increase the land use efficiency apart from augmenting farm yield in upland rainfed conditions.

Research on growth, yield attributes and yield of component crops in spatially diverse systems such as intercropping can provide an insight on crop competition and cropping pattern design. Investigation carried out in various field experiments revealed that yields of maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L.) were found to increase, whereas soybean (*Glycine max* L.) showed decrease in border rows of strip-intercropping system (Lesoing and Francis, 1999b). In silty clay loam soil, Lesoing and Francis (1999) found that maize yield increased 23% in 8-row alternating strips. In Bhubaneswar (India), Nedunchezhiyan et al., (2011) found that strip intercropping had 10.2 to 44.3% higher sweet potato (*Ipomoea batatas* L.) yieldin adjacent border rows than sole crop rows. Sweet potato yields were higher (5.4 to 27.7%) in strip intercropping than in monoculture when calculated across the entire strips in equal area basis (Nedunchezhiyan et al., 2011). The information on yield and yield components of taro and other intercrops when grown in intercropping is not available. If yield components and the spatial cropping patterns that influencecrop yield contributions can be identified, systems can be designed to increase potential productivity. Hence, the present investigation has been carried out to find out the interspecies interaction effects on growth, yield components and yield of taro, maize and pigeon pea (*Cajanus cajan* L.) under intercropping.

Materials and Methods

A field experiment was conducted at the Regional Station of ICAR-Central Tuber Crops Research Institute (20° 14' 50" N and 85° 47' 06" E), Bhubaneswar, Odisha, India for three consecutive years (2018-2000) on alfisols under rainfed conditions. During the crop growing season, the average maximum and minimum temperature were 32.2 and 23.2°C, respectively. The average relative humidity was 74.6%. The total rainfall during crop growing period was 1568.2 mm with 74 rainy days. The climate of the location is characterized by a hot and humid summer, and a cool and dry winter. The soil of the experimental site (top 0.30 m) was having pH 5.7, organic carbon 0.37%, available N 205 kg ha^{-1}, available P 20.1 kg ha^{-1} and available K 252 kg ha^{-1}. 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 pigeon pea, T_4-taro+maize (5:1), T_5-taro+maize (5:2), T_6- taro+pigeon pea (5:1) and T_7-taro+pigeon pea (5:2). All the crops in intercropping were planted at 45 × 30 cm spacing. Sole taro at 45 x 30 cm spacing, whereas sole maize and pigeon pea at 60 × 30 cm spacing. The variety Muktakeshi (taro), H-4226 (maize) and CORG 9701 (pigeon pea) were used in this study. The recommended dose of fertilizers N-P-K 80-60-80, 80-40-40 and 20-40-20 kg ha^{-1} were applied for taro, maize and pigeon pea, respectively. In the intercropping system, the 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 the treatments, half dose of N and full doses of P and K were applied at the time of sowing/planting, while remaining N was applied 1 month after sowing/planting. The experiment was sown/planted during 2nd week of June in all the years. Maize was harvested at 90 days after sowing (DAS), taro was harvested 165 days after planting (DAP) and pigeon pea was harvested 200 DAS.

Observations on growth characters of taro at 90 DAP and, maize and pigeon pea at 90 DAS and maturity were recorded. Observations on yield components and yield of taro, maize and pigeonpea were recorded at harvest. Comparisons were made between border and one middle (inside) row of taro, maize and pigeon pea under intercropping systems. Comparisons between borders and inside rows in a fixed pattern are statistically valid. The cormel equivalent yield (CEY) data was computed taking into the consideration of selling price of taro corm and cormels, maize and pigeon pea seeds along with their yield.

$$\text{CEY (kg ha}^{-1}\text{)} = \text{Cormel yield (kg ha}^{-1}\text{)} + \frac{\text{Corm/maize/pigeon pea yield (kg/ha)} \times \text{Sal price of corm/maize/pigeon pea (.... kg/ha)}}{\text{Sale pric of cormel (..... per kg)}}$$

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

Growth characters of taro

The perusal of data presented in Table 1 revealed that under intercropping, taro growth characters like plant height and number of leaves per hill were higher compared to sole taro at 90 DAP (Table 1). Under intercropping, taro plant height and number of leaves per hill were more in border rows than middle rows (Table 1). This was due to shade effect caused by the tall intercrop (maize/pigeon pea) grown in taro. The shade effect of intercrop (maize/pigeon pea) was found on taro growth in all the intercropping systems. Two rows of intercrop (maize/pigeon pea) had more effect than one-row on taro plant height and number of leaves per hill (Table 2). Among the intercropping systems, taro plant height and number of leaves per hill were higher in taro+pigeon pea (5:2) than the other intercropping systems (Table 2). This was because pigeon pea offered more shadow due to its branching and a greater number of leaves than maize. Taro shoot dry matter per plant was higher in intercropping than sole cropping at 90 DAP (Table 1). Under intercropping, taro shoot dry matter per plant was more in border rows than middle rows (Table 1). This was due to higher growth characters of taro under intercropping. Two rows of intercrop (maize/pigeon pea) had more effect than one-row on taro shoot dry matter per plant (Table 2). Among intercropping systems, taro shoot dry matter per plant was higher in taro+pigeon

Table 1. Growth characters of taro in various row positions in cropping systems at 90 DAP (Pooled data of 3 years)*

Row position	Plant height (cm)	No. of leaves hill^{-1}	Shoot dry matter plant^{-1} (g)	Corm+cormels dry matter plant^{-1}(g)
Taro cropping	74.2±1.0	7.4±0.21	14.9±0.2	58.4±3.6
Tarointercropping				
Border row	94.4±14.0	8.0±0.30	16.1±0.6	44.9±4.1
Middle row	83.5±9.2	7.7±0.29	15.6±0.5	50.8±2.2
Mean row	89.0±11.2	7.9±0.28	15.8±0.5	47.9±3.1

*Mean± Standard deviation

Table 2. Growth characters of taro in intercropping and sole cropping systems at 90 DAP (Pooled data of 3 years)*

Cropping system	Plant height (cm)			No. of leaves per hill			Shoot dry matter plant^{-1} (g)			Corm+cormels dry matter plant^{-1}		
	Border row	Middle row	Mean	Border row	Middle row	Mean	Border row	Middle row	Mean	Border row	Middle row	Mean
Taro	74.9±0.7	73.5±1.2	74.2±0.8	7.5±0.10	7.3±0.31	7.4±0.20	15.0±0.2	14.7±0.3	14.9±0.2	57.0±3.3	59.7±4.5	58.4±3.9
Taro+ maize (5:1)	79.8±0.4	75.6±0.5	77.7±0.3	7.7±0.06	7.4±0.20	7.6±0.12	15.3±0.1	15.1±0.1	15.2±0.1	50.4±1.9	53.8±1.5	52.1±1.7
Taro+ maize (5:2)	79.8±0.4	75.6±0.5	77.7±0.3	7.7±0.06	7.4±0.20	7.6±0.12	15.3±0.1	15.1±0.1	15.2±0.1	50.4±1.9	53.8±1.5	52.1±1.7
Taro+ pigeon pea (5:1)	82.4±1.1	77.1±1.5	79.8±1.3	7.9±0.10	7.6±0.12	7.8±0.10	15.8±0.2	15.3±0.1	15.6±0.1	44.7±1.4	50.4±1.1	47.5±0.6
Taro+ pigeon pea (5:2)	106.2±1.6	83.4±1.1	94.8±1.2	8.2±0.06	7.8±0.15	8.0±0.06	16.4±0.2	15.8±0.2	16.1±0.2	44.9±0.3	50.7±0.4	47.8±0.3
Taro+ pigeon pea 5:2)	109.3±1.2	97.8±1.5	103.6±0.6	8.4±0.15	8.0±0.23	8.2±0.15	16.7±0.3	16.2±0.4	16.5±0.4	39.7±1.0	48.4±1.3	44.1±0.3

*Mean± Standard deviation

pea (5:2) than the other intercropping systems (Table 2). This was due to greater plant height and number of leaves per hill of taro. However, taro corm and cormel dry matter per plant was higher in sole cropping than intercropping at 90 DAP (Table 1). Under intercropping, taro corm and cormel dry matter per plant was lesser in border rows than middle rows (Table 1). This showed that under shaded conditions the photosynthates present in the shoot could not be translocated to corm and cormels. Two rows of intercrop (maize/pigeon pea) had more effect than one-row on taro corm and cormel dry matter per plant (Table 2). Among intercropping systems, taro corm and cormel dry matter per plant was lower in taro+pigeon pea (5:2) than other intercropping systems (Table 2). This was due to more shade effect inspite of higher shoot dry matter, plant height and number of leaves per hill of taro.

Growth characters of intercrops

Growth characters of maize and pigeon pea were affected by cropping systems. In maize and pigeon pea, greater plant height and number of functional leaves were recorded under intercropping system compared to sole cropping (Table 3) at 90 DAS and harvest. This was mainly due to lesser intra and inter species competition in intercropping than sole cropping. Maize and pigeonpea utilized the available resources efficiently under intercropping. This was also evidenced among intercropping systems. Maize and pigeon pea (border) rows might have a higher relative potential yield advantage owing to greater height difference compared to adjacent taro rows and more competitive advantage in root zone. Nedunchezhiyan (2011) reported similar findings in sweet potato strip intercropping with pigeonpea, maize, rice and ragi. The 5:1 ratio of intercropping recorded higher growth characters than 5:2 ratio. This was due to lesser competition from same species of intercrops in 5:1 than 5:2.

Yield components and yield of intercrops

Yield components of maize and pigeonpea were affected by cropping systems. In maize and pigeon pea, higher number of cobs per pods per plant, number of seeds per cob per pod and 1000 seed weight were recorded under intercropping system compared to sole cropping at harvest (Table 3). This was mainly due to higher growth characters per plant in intercropping than sole cropping (Table 3). The photosynthates stored in shoot was efficiently translocated to developing sink that led to higher yield components. Under intercropping, pigeon pea and maize rows might have a higher relative potential yield advantage owing to greater height difference compared to adjacent taro rows and more competitive advantage in root zone. Among intercropping systems, 5:1 ratio of intercropping resulted in higher yield components than 5:2 ratio (Table 3). This was due to highergrowth characters in 5:1 than 5:2. Further, the seed yield per plant was higher in the treatment taro+maize (5:1) compared to the other treatments. This was due to intercropping effect apart from maize genetic character. In all the intercropping treatments, seed yield per plant was higher than sole cropping. Increased number of cobs/pods per plant and seeds/cob or pods might be due to greater light interception by rows in intercropping, resulting in greater photosynthesis rates and development of more cobs/pods and seeds per cob/pod.

The data presented in Table 4 revealed that seed yield (kg ha^{-1}) of maize was higher than pigeon pea irrespective of cropping system. This was due to genetic yield potential of maize. Seed yield (kg ha^{-1}) of maize and pigeon pea was affected by cropping systems. Higher seed yield (kg ha^{-1}) of maize and pigeon pea was noticed in sole cropping compared to intercropping. This was due to higher net sown area under sole cropping than intercropping. Among intercropping systems, 5:2 ratio of intercropping produced higher seed yield than 5:1 ratio

Table 3. Growth and yield components of maize and pigeon pea in intercropping and sole cropping systems (Pooled data of 3 years)

Cropping system	Maize/Pigeon pea							
	At 90 DAS		At harvest					
	Plant height (cm)	No. of functional leaves	Plant height (cm)	No. of functional leaves	No. of cobs plant^{-1} or pods plant^{-1}	No. of seeds cob^{-1} or pod^{-1}	1000 seed weight	Seed yield plant^{-1} (g)
Maize	167.2	8.2	164.8	8.1	1.1	194.3	233.1	47.4
Pigeonpea	125.7	135.3	172.8	26.4	158.4	3.8	85.3	25.3
Taro+maize (5:1)	170.1	8.3	169.3	8.3	1.2	231.4	235.5	51.8
Taro+maize (5:2)	168.3	8.2	166.5	8.2	1.2	212.5	234.2	50.3
Taro+pigeon pea (5:1)	130.2	150.2	179.2	30.4	187.2	4.0	8.6	30.7
Taro+pigeon pea (5:2)	127.4	142.8	178.1	28.2	172.9	3.9	86.4	28.1

(Table 4). This was due to the higher net sown area in 5:2 than 5:1. If calculatedon the basis of net area sown, seed yield (kg ha^{-1}) of maize and pigeonpea was higher in intercropping than sole cropping (Table 3). Among intercropping systems, 5:1 ratio of intercropping produced higher seed yield than 5:2 ratio (Table 3). This was due to lesser competition within the species as well as higher growth attributes. Nedunchezhiyan (2011) also reported similar findings in sweet potato-based cropping systems.

Yield components and yield of taro

The yield components of taro was influenced by cropping systems. Taro sole cropping produced higher corm and cormel yield per plant both in the border and middle rows compared to intercropping systems (Table 4). In taro sole cropping, both corm and cormel yields were higher in border rows than middle and mean rows (Table 4). The reduction in corm and cormel yield per plant in 5:2 was higher than 5:1 intercropping system. As intercrop, pigeon pea affected taro corm and cormel yield per plantmore than maize. This was due to pigeon pea competing with taro for longer period (165 days) than maize (90 days). In intercropping system, corm yield per plant was higher in border rows than middle and mean rows. Whereas, cormel yield per plant was higher in middle and mean rows than border rows. This showed that under shaded conditions, cormel yield was more affected than corm yield with respect to border rows.

Taro corm and cormel yield per ha was found to decrease under intercropping (Table 4). The decrease in taro yield was due to decrease in taro population apart from competition from the intercrop (maize/pigeon pea) under intercropping. Taro corm yield per ha was more affected than cormel yield per ha under intercropping. The decrease of taro corm yield per ha ranged from 17.1 to 41.9% under intercropping, whereas decrease of taro cormel yield per ha ranged from 16.1 to 38.0% (Table 4). The taro corm and cormel yield per ha was also influenced by intercrops under intercropping. Pigeon pea reduced taro corm and cormel yield per ha more than maize under intercropping (Table 4). This was due to duration of interference of intercrop with main crop. Maize as an intercrop reduced taro corm yield by 17.1-32.9% and cormel yield by 16.1-29.0%, whereas pigeon pea as an intercrop reduced taro corm yield by 26.6-41.9% and cormel yield by 20.7-38% (Table 4). Increasing intercrop population resulted in decrease of taro corm and cormel yield, however it was not linear. When one row of taro was replaced with maize (5:1), the reduction in taro corm and cormel yield was 17.1 and 16.1%, respectively (Table 4). When two rows of taro were replaced with maize (5:2), the reduction in taro corm and cormel yield was 32.9 and 29.0%, respectively (Table 4). Similarly, when one row of taro was replaced with pigeon pea (5:1), the reduction in taro corm and cormel yield was 26.6 and 20.7%, respectively. When two rows of taro were replaced with pigeon pea (5:2), the reduction in taro corm and cormel yield per ha was 41.9 and 38.0%, respectively (Table 4).

The results of CEY revealed that taro sole cropping resulted in higher CEY and it was statistically comparable to taro+maize (5:1) and taro+pigeonpea (5:1) intercropping systems (Table 4). This was due to favourable rainfall during crop growth period of taro and its higher yield. During the three years period of experimentation, the average total rainfall received during the crop growth period was 1568.2 mm with

Table 4. Yield components and yield of taro, and seed yield of intercrops at harvest as influenced by intercropping systems (pooled data of 3 years)

Cropping system	Corm yield plant^{-1} (g)			Cormel yield plant^{-1} (g)			Corm yield (kg ha^{-1})	Cormel yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Cormel equivalent yield (kg ha^{-1})
	Border row	Middle row	Mean	Border row	Middle row	Mean				
Taro	70.2	69.4	69.8	213.3	212.5	212.8	4744	15420	0	18593
Maize	0	0	0	0	0	0	0	0	4862	4862
Pigeon pea	0	0	0	0	0	0	0	0	2101	7006
Taro+maize (5:1)	69.4	64.2	66.8	212.0	212.4	212.2	3934	12934	1344	16900
Taro+maize (5:2)	64.2	62.4	63.3	206.0	210.8	208.4	3184	10945	2122	15187
Taro+pigeon pea (5:1)	59.4	56.8	58.1	198.2	204.2	201.2	3480	12235	627	16647
Taro+pigeon pea (5:2)	55.3	52.3	53.8	178.3	186.5	182.4	2755	9561	892	14373
SEm±	-	-	-	-	-	-	-	-	-	667
CD (P=0.05)	-	-	-	-	-	-	-	-	-	2053

*Sale price of corm 10 ₹ kg^{-1}; cormel 15 ₹ kg^{-1}; maize 15 ₹ kg^{-1}; pigeonpea 50 ₹ kg^{-1}

74 rainy days, which was sufficient for raising sole taro crop. During years of lesser rainfall and rainy days, the importance of maize and pigeon pea will be realized. The CEY of taro+maize (5:2) and taro+pigeon pea (5:2) intercropping systems was significantly lower than taro sole cropping. This indicated that if one row of taro was replaced with maize or pigeon pea 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 pigeon pea in an intercropping, they could not compensate replaced taro population yield (Table 4). Chhetri and Sinha (2020) also reported that maize+cowpea intercropping system in 2:2 row ratio (replacement series) resulted in higher maize equivalent yield than 2:4 row ratio. The CEY of maize and pigeon pea sole cropping was significantly lowest. This was due to lower seed yield of maize and pigeon pea compared to taro.

Conclusion

It is concluded that growth, yield components and yields of taro, maize and pigeon pea were more affected by intercropping systems. Taro border rows in intercropping showed higher growth characters and lower yield components and yield than sole crop rows. Maize and pigeon pea in intercropping resulted in higher growth characters, yield components and yield than sole maize and pigeonpea. Taro was affected by interspecies interference, whereas interspecies interference was minimal for maize and pigeon pea under intercropping. Hence, they utilized available natural resources more efficiently. As an intercrop, the effect of pigeon peaon taro corm and cormel yield was more than maize because of longer period of competition. The decrease in taro yield was due to decrease in taro population apart from competition from intercrop under intercropping. Taro corm yield per ha was more affected than cormel yield per ha under intercropping. The CEY of taro sole cropping was higher and comparable to taro+maize (5:1) and taro+pigeon pea (5:1) intercropping systems. However, during unfavourable seasons (lesser rainfall and rainy days), especially under the present-day climate change scenario, the potential of intercropping system can be better exploited. To further add to the intercropping advantage, the plant density can be increased in the border rows, use of narrower strips (e.g., alternating two row strips) and growing of intercrops in additive series are recommended. Measurements of light, nutrient, and water use by individual rows across the rows could reveal more detail on how component crops would be affected. These are the areas for future research.

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