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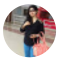
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Yield potential and economic analysis of traditional waterlogged agroforestry systems in North-East (Tripura), India

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ABSTRACT : In present investigation, an attempt was made to estimate yield under different fertilizer doses and economic analysis of waterlogged traditional agroforestry system (locally known as *Doba*) in Tripura, India. The experiment was carried out using randomized block design. Seven treatments consisting of different fertilizer doses, following four replications were applied during 2013-16 to evaluate the effect on yield of *Colocasia*. Among all the treatments, T_5 [$N_{57}P_{57}K_{37}$; application of urea @ 74.56 kg ha^{-1}, SSP @ 186.39 kg ha^{-1} and MOP @ 62.13 kg ha^{-1} after 15 days of transplanting and application of DAP @ 124.26 kg ha^{-1} before one month of harvesting during growth stage] was found better than other treatments. In T_5, higher corm length (74.24 cm), corm diameter (12.10 cm), corm volume (12554.75 cm^3), corm yield (5.07 kg plant^{-1}), yield of stolon (1.36 kg plant^{-1}), average length of petioles (123.25 cm), number of petioles (8) and higher yield of petioles (1.18 kg plant^{-1}) were observed. Impact of different treatments with respect to corm length, corm volume and corm yield plant^{-1} were in the order of $T_5>T_6>T_4>T_7>T_2>T_3>T_1$. The study revealed that this agroforestry model (average B: C ratio = 6.35) can be promoted as one of the important means for livelihood of farming communities in waterlogged areas in Tripura and other parts of North-East India.

Key words: *Colocasia esculenta,* fertilizers, livelihood and waterlogged area.

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1. INTRODUCTION

Agroforestry is a dynamic, ecologically based natural resource management system suitable for increased social, economic and environmental benefits (Leakey, 1996). Intercropping of trees and crops on 3 million ha has been reported (Sen, 1991). Many studies revealed that the nutritional and livelihood security of native and rural communities can be achieved through agroforestry interventions (Das *et al.,* 2017; Sarkar *et al.,* 2017a, b). Agroforestry thus considered as one of the acceptable and profitable land-use practices (Naugraiya and Puri, 2001; Das *et al.,* 2017) which support livelihood improvement through various tangible and intangible benefits (Rajput *et al.,* 2015, 2017). Agroforestry interventions in waterlogged and salinity areas can play an important role as bio-drainage system, by draining out the excess soil water through deep-rooted plants using their bio-energy (Chauhan *et al.,* 2012). Hence, to maximize the productivity of such waterlogged areas and to improve the livelihood and nutrition of those rural communities, agroforestry can be economically viable through scientific intervention (Dagar and Minhas, 2016).

The present study reports a case study of waterlogged agroforestry system (trees/woody perennials + *Colocasia* + fishes + other water loving plants) (locally known as *Doba*) in Tripura state of North-East, India. In this system, the fruit-nuts of areca nut plants are mainly for revenue generation. To the little extent, the fruits of coconut crop are sold for family income. The main household income comes from the cultivation of *Colocasia esculenta* (L.) Schott. of local variety (locally known as *Kachu*, commonly known as *Taro*, under Araceae family). The whole plant of this crop including corm, stolon (locally known as "*Lata* or *Loti*"), leaves and petioles (locally known as "*Kachur doga*/*dagga*") are highly preferred as vegetables. The fish cultivation is also done during rainy season. The other water loving plants also naturally grow in this system (having nutritional and medicinal values), are mainly consumed by the household throughout the year, and rarely sold in market. In the present study, an attempt was therefore, made to explore the whole traditional agroforestry system (trees/woody perennials + *Colocasia* + fishes + other water loving plants) with two main objectives: i) to study the effect of different treatments/fertilizer application on the growth and yield of the crop component and ii) to calculate the economics of the whole agroforestry system.

2. MATERIALS AND METHODS

Study location

This experiment was conducted at one waterlogged area of Kailashahar in the state of Tripura under warm perhumid climate of India (i.e. in North-Eastern region). The total area of the study site was 1.69 ha. The study site is located between 24° 19´ 40.85˝ N latitude and 92° 00´ 08.77˝ E longitude having altitude of 29.26 m above mean sea level, with average annual rainfall (from 2013 - 2016) of 2326.67 mm (IMD, 2017). Plantations of suitable woody perennials (approximately 20 years old) like areca nut, coconut, mango, jackfruit, bamboos, etc. were raised on broad bunds as a component for bund stabilization, earning additional income and enriching the ecosystem. This waterlogged agroforestry system comprises of woody perennials dominated by areca nut, mango, coconut and *Colocasia* of local variety (banda type), generally found to grow in swampy areas along with some fish species like climbing perch/koi (*Anabas testudineus*), magur/walking catfish (*Clarias batrachus*), punti/swamp barb (*Puntius chola*) and darkina/gangetic scissortail rasbora (*Rasbora rasbora*). Some other water loving plant species like helencha (*Enhydra fluctuans*), kalmi saag (*Ipomoea aquatica*), and malancha (*Achyranthes philoxeroides*) are also seen growing in these systems.

Methodology

The experiment was carried out using randomized block design. The size of each plot was 4 m × 5 m and the spacing was 0.45 m × 0.60 m between plant to plant and row to row. Seven treatments consisting of different fertilizer doses (Table 1), following four replications were applied during 2013-16, to evaluate the effect on yield of *Colocasia*.

Nitrogen (N), phosphorus (P) and potassium (K) were applied in the form of urea, Single Super Phosphate (SSP), Muriate of Potash (MOP) and Diammonium Phosphate (DAP). The total yield was bifurcated into different plant parts or parameters *viz.,* corm length (cm), corm diameter (cm), corm volume (cm^3), corm yield (kg $plant^{-1}$), yield of stolon (kg $plant^{-1}$), length of petioles (cm), number of petioles $plant^{-1}$ and yield of petioles (kg $plant^{-1}$).

Cost-benefit ratio and economic valuation

The effect of different fertilizer doses on cost-benefit ratio of *C. esculenta* was calculated considering the local market rates of 2013-16. The cost-benefit ratio estimated from added profit in yield over control and cost of added inputs were analyzed for comparing the treatment and to sort out best fertilizer dose having high impacts.

The economic yield from admixture of woody perennials of 20 years old planted on bunds at the border of doba with the purpose to stabilize the bunds as well as to earn additional income. The revenue from the trees (woody perennials) is uncertain because of high demand and consumption in their household itself rather than selling. Hence, the income from the tree component of bunds mainly depends on farmer's need or interest to either sell or consume by them only. Therefore, the approximation of the economic gain per year (during 2013-16) from the trees was estimated considering all the products/economic parts (*viz.,* edible flowers, fruits/nuts and bamboo culm) sold at the prevalent market rate. Statistical analysis of data was done using SYSTAT-12 software (Wilkinson and Coward, 2007), which was used for computation of descriptive statistics and to compute the effect of different fertilizer doses on yield of *C. esculenta*.

Table 1. Fertilizer doses as treatment for *Colocasia esculenta* to compare the yield.

Treatments	Descriptions
T_1: $N_0P_0K_0$	Control
T_2: $N_0P_{30}K_{37}$	Application of SSP[1] (186.39 kg ha^{-1}) and MOP[2] (62.13 kg ha^{-1}) after 15 days of transplanting
T_3: $N_{35}P_{30}K_0$	Application of urea (74.56 kg ha^{-1}) and SSP (186.39 kg ha^{-1}) after 15 days of transplanting
T_4: $N_{35}P_{30}K_{37}$	Application of urea (74.56 kg ha^{-1}), SSP (186.39 kg ha^{-1}) and MOP (62.13 kg ha^{-1})
T_5: $N_{57}P_{57}K_{37}$	Application of urea (74.56 kg ha^{-1}), SSP (186.39 kg ha^{-1}) and MOP (62.13 kg ha^{-1}) after 15 days of transplanting and application of DAP[3] (124.26 kg ha^{-1}) before one month of harvesting during growth stage
T_6: $N_{114}P_{114}K_{74}$	Application of urea (149.20 kg ha^{-1}), SSP (372.78 kg ha^{-1}) and MOP (124.26 kg ha^{-1}) after 15 days of transplanting and application of DAP (248.52 kg ha^{-1}) before one month of harvesting during growth stage
T_7: $N_{171}P_{171}K_{111}$	Urea (223.68 kg ha^{-1}) + SSP (559.17 kg ha^{-1}) + MOP (186.39 kg ha^{-1}) after 15 days of transplanting and DAP (372.78 kg ha^{-1}) before one month of harvesting during growth stage

[1]SSP: single super phosphate; [2]MOP: muriate of potash; [3]DAP: diammonium phosphate

3. RESULTS AND DISCUSSION

Effect of different fertilizer doses on yield of *Colocasia esculenta*

The effect of various fertilizer/treatment combinations exhibited significant differences with the growth of various plants (Table 2). Among all the treatments, T_5 ($N_{57}P_{57}K_{37}$; application of Urea @ 74.56 kg ha^{-1}, SSP @ 186.39 kg ha^{-1} and MOP @ 62.13 kg ha^{-1} after 15 days of transplanting and application of DAP @ 124.26 kg ha^{-1} before one month of harvesting during growth stage) found better than other treatments. In this treatment, higher corm length, corm diameter, corm volume, corm yield, stolon yield, petiole length, number of petioles and yield of petioles were observed. While comparing within the seven different treatments, T_5 recorded as the optimum level having highest impact on the yield. Impacts of different treatments with respect to corm length, corm volume and corm yield plant^{-1} were in the order of $T_5>T_6>T_4>T_7>T_2>T_3>T_1$. The treatment's impact on corm diameter was in the order of $T_5>T_6>T_7>T_4>T_2>T_3>T_1$, and for stolon yield plant^{-1}, it was recorded in the order of $T_5>T_6>T_7>T_4>T_3>T_2>T_1$. Average length of petiole was in the order of $T_5>T_6>T_7>T_4>T_3>T_2>T_1$, number of petioles and yield of petioles plant^{-1} were observed in the order of $T_5>T_6>T_4>T_7>T_3>T_2>T_1$. This could be attributed to the better maintenance of nutrients in the soil solution for availability to *Colocasia.* The increase in yield might be due to build-up in available nutrients through fertilizer application of in-organic source (Sepehya *et al.*, 2012). High water stress may result in uneven tuber growth of bulking rate (Smith, 1987). Kader and Rolle (2004) also had drawn an inference that the temperature influences the uptake and metabolism of mineral nutrients by plants by increasing the transpiration rates.

Economic analysis and cost-benefit ratio

The estimated cost-benefit ratio from added profit of yield over control and cost of added inputs was recorded highest in T_5, followed by T_6, T_4, T_7, T_3 and T_2 (Table 3). The approximation of the economic gain per year during 2013-16 from the admixture of woody perennials of 20 years old, planted on bunds and boundaries was estimated at the prevalent market price (Table 4). The high revenue was recorded to be generated mainly from the plantation of areca nut with estimated net income as Rs. 88646.45 ha^{-1}, followed by mango plantation (Rs. 9088.76 ha^{-1}) and coconut plantation (Rs. 8698.22 ha^{-1}) (Table 4). But the income from other trees (woody perennials) is uncertain because of high demand and consumption in their household itself rather than selling. Hence, the income is mainly from areca nut, coconut and mango as woody perennials and from the cultivation of *C. esculenta* (net return as Rs. 1042059.23 ha^{-1}); hence, can provide better livelihood and nutrition to the farmers. The total cost of cultivation of the system including the value of leased land was estimated to be Rs. 173964.15 ha^{-1} and the gross return estimated from various yields was estimated as Rs. 1335553.96 ha^{-1} (Table 4).

The overall cost-benefit ratio of this system was estimated as 6.35, which signifies the livelihood potential and much needed intervention from scientific communities for its extension to other parts of the country with similar land-use characteristics. Many studies reported that planting of *Casuarina* species, *Eucalyptus* species and *Acacia* under waterlogged areas can provide extra income and products like fuelwood, fodder, timber and other forestry products to the farmers (Roy Chowdhury *et al.,* 2011). Dagar and Minhas (2016) reported that in coastal sandy areas particularly along beaches of Odisha, *Casuarina equisetifolia* is successfully grown. Seasonally

Table 2. Effect of different fertilizer doses on yield of *Colocasia esculenta.*

Treatments	Corm length (cm)	Corm diameter (cm)	Corm volume (cm^3)	Corm yield (kg) plant^{-1}	Stolon yield (kg) plant^{-1}	Length of petioles (cm)	Number of petioles	Petiole yield (kg) plant^{-1}
T_1: $N_0P_0K_0$	25.13^d	6.08^d	3391.25^d	1.06^d	0.43^d	50.75^d	5.25^c	0.29^e
T_2: $N_0P_{30}K_{37}$	47.25^c	7.53^c	7933.25^b	3.75^b	0.71^c	63.50^{cd}	6.00^{bc}	0.56^d
T_3: $N_{35}P_{30}K_0$	45.25^c	7.03^c	6297.00^c	2.44^c	0.78^c	71.75^c	6.25^{bc}	0.75^c
T_4: $N_{35}P_{30}K_{37}$	61.25^b	9.50^b	8855.25^b	4.13^b	1.13^b	88.00^b	6.50^b	0.94^b
T_5: $N_{57}P_{57}K_{37}$	74.25^a	12.10^a	12554.75^a	5.07^a	1.36^a	123.25^a	8.00^a	1.18^a
T_6: $N_{114}P_{114}K_{74}$	73.11^a	11.32^a	10986.23^a	4.99^a	1.27^a	114.74^a	7.66^a	1.12^a
T_7: $N_{171}P_{171}K_{111}$	59.78^b	9.57^b	8767.34^b	3.87^b	1.16^b	79.10^b	6.32^b	0.87^b

Within a column means followed by the same letter are not significantly different at the 0.05 level of probability by Duncan's multiple range test

Table 3. Effect of different fertilizer doses on cost-benefit ratio of *Colocasia esculenta* estimated from added profit of yield over control.

Treatments	Yield ($t\ ha^{-1}$)		Added yield over control ($t\ ha^{-1}$)		Value of added yield	Cost of added inputs ($Rs.\ ha^{-1}$)	Added profit over control ($Rs.\ ha^{-1}$)	Cost - benefit ratio ($Rs.\ ha^{-1}$)
	Corm + Petioles	Stolon	Corm + Petioles	Stolon				
T_1: $N_0P_0K_0$	48.31	15.39	-	-	-	-	-	-
T_2: $N_0P_{30}K_{37}$	107.36	25.41	59.05	10.02	458073.35	159368.82	298704.53	1.87
T_3: $N_{35}P_{30}K_0$	167.84	27.91	119.53	12.53	662059.13	159235.75	502823.39	3.16
T_4: $N_{35}P_{30}K_{37}$	174.64	40.44	126.33	25.05	787313.56	159660.00	627653.57	3.93
T_5: $N_{57}P_{57}K_{37}$	223.67	48.67	175.36	33.28	1048558.52	161456.99	887101.53	5.49
T_6: $N_{114}P_{114}K_{74}$	218.66	45.45	170.35	30.06	978666.32	165182.56	813483.76	4.92
T_7: $N_{171}P_{171}K_{111}$	169.63	41.51	121.32	26.12	716790.29	169075.13	547715.16	3.24

Variable cost: Urea: Rs. 6.60 kg^{-1}; SSP: Rs. 8.00 kg^{-1}; MOP: Rs. 11.54 kg^{-1}; DAP: Rs. 24.44 kg^{-1}

Fixed cost: Rental values of land per year whole plot: Rs. 59171.60 ha^{-1}; Land preparation: Rs. 4437.87 ha^{-1}; Layout and ridge making: Rs. 5325.44 ha^{-1}; Cost of plantlets/planting materials: Rs. 3 $plantlet^{-1}$; Transplanting cost: Rs. 3550.30 ha^{-1}; Fertilizer application: Rs. 887.57 ha^{-1}; Labour: Rs. 300 $labour^{-1}$; Manual cleaning and pruning of unwanted/dead petioles: Rs. 2662.72 ha^{-1}; Plant protection chemicals: Rs. 0.00 ha^{-1} $season^{-1}$; Harvesting cost of stolon: Rs. 5325.44 ha^{-1}; Harvesting cost of corm+petioles: Rs. 9763.31 ha^{-1}; Cleaning and grading: Rs. 1597.63 ha^{-1}.

Table 4. Economics of agroforestry system of waterlogged area (doba).

S.No.	Species	Number of plants (ha^{-1})	Economic parts	Total cost of cultivation ($Rs.\ ha^{-1}$)	Gross return ($Rs.\ ha^{-1}$)	Net return ($Rs.\ ha^{-1}$)	Cost-benefit ratio
1.	Woody perennials planted on bunds*						
a.	*Areca catechu*	139	Nut	6952.66	95599.11	88646.45	12.75
b.	*Cocos nucifera*	7	Fruit	1420.12	10118.34	8698.22	6.13
c.	*Borassus flabellifer*	2	Fruit	266.27	2183.43	1917.16	7.20
d.	*Mangifera indica*	5	Fruit	1278.11	10366.86	9088.76	7.11
e.	*Sesbania grandiflora*	1	Flower	70.00	640.00	570.00	8.14
f.	*Artocarpus heterophyllus*	2	Fruit	540.00	3280.00	2740.00	5.07
g.	*Melocanna baccifera*	2	Culm	180.00	1000.00	820.00	4.56
2.	*Colocasia esculenta*	35787	All parts	161456.99	1203516.21	1042059.23	6.45
3.	Fishes (35 kg)			1500.00	8050.00	6550.00	4.37
4.	Other plants (40 kg)	Stem, leaves		300.00	800.00	500.00	1.67
	Total			173964.15	1335553.96	1161589.82	-
	Average						6.35

*Fixed cost of plantation of woody perennials (including the cost of seedlings, digging pits, fertilizer cost, labour cost, etc. as per earlier rate mentioned by the farmers); *A. catechu:* Rs. 30 $plant^{-1}$; *C. nucifera*: Rs. 50 $plant^{-1}$; *B. flabellifer*: Rs. 25 $plant^{-1}$; *M. indica*: Rs. 70 $plant^{-1}$; *S. grandiflora:* Rs. 50 $plant^{-1}$; *A. heterophyllus:* Rs. 70 $plant^{-1}$: *M. baccifera:* Rs. 40 $plant^{-1}$; and the variable cost as harvesting of economic yield of different species as Rs. 10 $plant^{-1}$, Rs. 150 $plant^{-1}$, Rs. 200 $plant^{-1}$, Rs. 200 $plant^{-1}$, Rs. 20 $plant^{-1}$, Rs. 200 $plant^{-1}$ and Rs. 50 $plant^{-1}$, respectively (as per local rate of 2014-15).

flooded alluvial lands of the Gangetic plains in Uttar Pradesh are unsuitable for short statured herbaceous annual but may facilitate very high yields of genera such as *Populus, Syzygium, Tamarind, Acacia* etc. (Chaturvedi, 1985). In many of the waterlogged areas of West Bengal, few species like *Eucalyptus* species, *Terminalia arjuna, Melia azedarach, Acacia auriculiformis*, *Syzygium cumini,* etc. seemed to survive well. Moreover, in Assam, species like *Trewia nudiflora, S. cumini* and *Lagerstroemia flosreginae* could withstand waterlogged condition (Ahmed and Hazarika, 2007).

4. CONCLUSION

Among all the treatments, application of Urea @ 74.56 kg ha^{-1}, SSP @ 186.39 kg ha^{-1} and MOP @ 62.13 kg ha^{-1} after 15 days of transplanting and application of DAP @ 124.26 kg ha^{-1} before one month of harvesting during growth stage can be recommended from the study. The study also reveals that this type of land-use can be promoted as one of the important means for livelihood improvement in warm perhumid climate. Plantation of suitable woody perennials like areca nut, coconut, mango, jackfruit, bamboos, etc. on bunds is highly recommended for bund stabilization, additional income and other benefits like fodder, ecosystem services. The overall cost-benefit ratio of this system was estimated as 6.35, which signifies the livelihood potential and much needed intervention from scientific communities for its extension to other parts of the country with similar land-use characteristics.

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