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RESEARCH ARTICLE

DEVELOPMENT OF SUBSTRATE BASED AQUACULTURE FOR RESOURCE POOR FARMERS IN ASSAM

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ABSTRACT

Productivity of a fish pond can be enhanced without increasing nutrient inputs through heterotrophic food production. Individual farmers' pond is limited to the rearing of fry to fingerlings over a period of three months. Most of the individual farmers who practiced fish seed rearing in their seasonal ponds are unable to carry out grow out practices in their ponds because of unavailability of water throughout the year. Besides, the higher consumptive need of resource poor farmers have been a major hurdle in sustaining the operations for successive years. Farmers use advance fish fry of size 20-40mm to stock in fish ponds from local hatchery. Survival of fish seed were ranged from 50-60%. Fish culture was undertaken for 3 months duration. Farmers were trained to use locally available substrate like Palmyra leaf. Survival of fish seed were ranged from 90-95%. Advanced fingerlings of 100-175 gm on an average size harvested and sold to stocking units in the locality to enhance fish production from low productive ponds. Ecologically sustainable: external/ chemical inputs reduced to the great extent. The substrate aquaculture may be considered as organic aquaculture practices. Tiny organisms that live on the surface of objects under waters is an excellent food for browsers. The gross income from sale of 1000 No. of advance fingerlings of 250 kg @ Rs.60 per kg works out to Rs.15000 on a conservative scale. The Internal Rate of Return (IRR) of this technology is more than 50 % with Benefit Cost Ratio of Ratio (BCR) 2 : 1. As such, this technology is technically feasible and economically viable. Hence, a community based project for developing substrate based aquaculture is an income generation activities. A pilot scale trial in an extended number of household ponds, distributed over different agro-ecological zones of the country, has been proposed before dissemination of this technology for wider use as a means of poverty alleviation in Assam and elsewhere in the region.

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INTRODUCTION

The state of Assam is also full of wetlands, derelict water bodies and ponds and tanks with rich fish biodiversity. Fish is an integral part in the diet of the people of Assam. Pond production systems in all the states of India are becoming increasingly reliant on external resources (feed, fertilizers) to supplement or stimulate autochthonous food production for pond fish. In most pond production systems, only about 15–30% of nutrient inputs is converted into harvestable products, the remainder being lost to the sediments, effluent water and the atmosphere (Acosta-Nassar *et al*., 1994; Gross *et al*., 2000). Improving the conversion of nutrients into harvestable products, through adoption of periphyton-based production into existing pond systems, is one solution worth exploring. Substrate based aquaculture is an environment friendly culture technology. The concept of substrate based aquaculture is derived from *Acadja* in West Africa, *Kathas* of Bangladesh, *Samarah* of Cambodia, *Athkotus* of Sri Lanka, *Katal* and *Jeng* of Assam, *Jack* of Tripura and *Phoomdis* of Manipur.

Katal and Jeng of Assam: The principle of substrate based aquaculture is periphyton. Periphyton which is the total assemblages of sessile or attached organisms on any substrate, tiny organisms that live on the surface of objects under waters which is called as *biofilm bacteria.* Biofilm bacteria is an excellent food for browsers. Periphyton is defined here as the entire complex of all sessile biota attached to the substratum, plus associated detritus and micro-organisms. Bacteria provide a significant source of carbon through extra-cellular polymer (Pearl 1979; Hobbie and Lee 1980), besides providing essential amino acids and vitamins (D'Agostino and Pravasoli 1970). However, the particle-bound sessile bacterial aggregates (biofilm) are preferred to their planktonic free cells by zooplankton and fish because of easy and economic exploitation (Ferguson and Ruble 1976). Bacteria are known to colonize on substrate and to develop into micro-colonies with extra-cellular polymeric substance anaerobic cells to form biofilm (Costerton 1984). Usually, bacterial biofilm cell density is 100 to 1000 times greater than the planktonic population per unit weight. A fourfold increase in the density and biomass of *Daphnia magna* through increased biofilm on a glass surface has been demonstrated by Langis *et al*. (1988). Agricultural wastes and aquatic weeds are easily available and biodegradable and seem to be more ideal for colonization of bacteria than inert glass and plastic surfaces.

The idea is originally derived from traditional fishing methods, such as the 'acadjas' of Côte d'Ivoire (Welcomme, 1972), the 'samarahs' of Cambodia (Shankar *et al*., 1998) and the 'katha' fisheries of Bangladesh (Wahab and Kibria, 1994), where tree branches are placed in shallow open waters to attract fish and enhance productivity. Preliminary data reported by Hem and Avit (1994) suggested that fish yields in an 'acadja-enclos' could be up to 8 tons ha/ year, eight times higher than in control areas without artificial substrate. Increased food availability and better protection from predators may explain the high yields. The results from experiments in aquaculture ponds, where stocking and predation are more controlled, vary from no effect (Shrestha and Knud Hansen,1994; Faruk-ul-Islam, 1996; Azim *et al*., 2001a) to a 40–80% increase in fish yield in ponds with artificial substrates compared to control ponds (Ramesh *et al*., 1999; Wahab *et al*., 1999; Keshavanath *et al*., 2001). Since carp polyculture system mostly depends on organic manure, due to insufficient and inadequate application of the same, fish production remains at sub optimal level in farmer's field condition. Thus it is suggested to undertake substrate based aquaculture practices with the use of palm leaves could be effectively utilised for rearing of advance fish fry to advance fingerlings from such low productive fish ponds. Development of such a viable and low cost technology and its application to current farming practices will definitely help increase fish yield in farmer's field and help secure food security.

MATERIALS AND METHODS

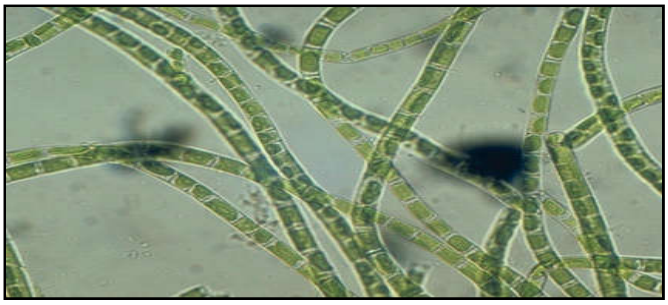
There are 5035 Nos. of individual fish ponds covering about 634.42 ha out of which only 10 ha of fish ponds have been selected to carry out field trial in Vill: Dhanbari, PO: Bagdoba, Rangjuli Tribal Development Block, Dist: Goalpara, Assam. 12 earthen ponds (10 × 7.5 m, mean water depth 1.2 m and water spread area : 0.2 ha) in the Goalpara district of Assam have been studied, in depth, for assessing their financial viability. Fisheries official of Government of Assam and NGO were associated in the field trial during November, 2008. Secondary data available on fresh water aquaculture sector has been collected from District Fisheries Development Office, Goalpara. Primary information has been collected from fish farmers, fish farmers groups, traders, godown owners, and commission agents through personal interviews, based on a structured questionnaire. Information collected included, status of availability of inputs required for fresh water aquaculture, composition and changing trends in aquaculture technology, composition of fish catch, seasonal variations in fish catch, design and cost of various artificial fish food, operational costs, income, credit availability, marketing channels, post-harvest management etc., Financial viability has been assessed by the discounted cash flow technique using financial parameters like NPW, BC Ratio, IRR and Return on Investment (%).

Pond facilities and design: The primary occupation of the people in this field project area is largely agriculture and labour work. All farmers in this area considered as small and marginal fish farmers. They are cultivating rice, vegetables, Potato and Pineapple. >30% of the people are scheduled tribes. They are the major tribal groups viz, Rabha and Boro. The other sources of livelihood for the tribal are Fishery, Piggery, Goatary and Poultry. Mostly 0.1ha to 0.2 ha larger water bodies are located in the field trial area. Such water bodies could be effectively utilised for rearing of advance fish fry to advance fingerlings with the substrate aquaculture technique is found to be very suitable in the visited field area. Because of the following hurdles, farmers in this area are undertaking unscientific fish culture although water bodies are very conducive for scientific fish culture technology. The Farmers are found to be stocking the fish with heavy density and repeated harvesting methodology as per the market demand but without application of manures/fertilizers or artificial feeding as also in absence of aeration provision. As a result, they are getting fish production hardly 500 kg per ha per year. Moreover, the necessary inputs required for fish rearing/culture operations are not readily available in the local area such as Single Super Phosphate and Vitamins except urea. Whereas, Lime is being supplied from Guwahati. Not only that, but, Raw Cow Dung is not readily available, since all RCD is not sufficiently available for application in fish pond in villages as very little amount are left after application of the same in their homestead gardens and agricultural fields and Mustard Oil Cake is being supplied from Barpeta, Mangalduri, Darrang which are 250 to 300 km away from the field trial area. However, seed is available from the eco-hatchery located in the Dhupdhara village of the project area is supplying the required quantity of seed to the needy fish farmers of entire project area.

Substrate selection and pond preparation: Farmers are traditionally using tree branches and bamboo poles coupled with floating aquatic weed as FAD (Fish Aggregating Device) which serves to promote the growth of fish by increasing natural food availability through production of periphyton on these substrates. This practise is being locallly called as *Kathal Fisheries*. Locally available Palmyra Leaves were selected as substrates because of its wide availability and low price. Of the several types of locally available bamboos, *Bambusa* sp. was also chosen as it is less useful for house building purposes. However, Palymera leaves were found to be most suitable for substrate aquaculture. All the ponds are nothing but the existing water bodies, reclamation of the same by dewatering and excavation was not possible and also not necessary. Weed eradication as also removal of predators is being done by engaging labourers. It is the only requirement towards capital expenditure. Whereas, input cost will be consisting of basic raw material and its requirements. The basic raw material requirement for the unit is Substrate. The proposed 220 Palmyra Leaves having diameter of 60 cm per sq.mtr for 1000 sq.mtr will be the most suitable to be used as Substrates.

The requirement of other inputs/raw material mainly includes, inter alia, Lime and Advanced Fry**.** 80 kg of Lime @ 800 Kg/ Ha will be used to make the water body conducive for rearing operation. Seed and laborers also are the other basic requirement towards the input cost. Seed cost consists of 1200 Advanced Fry of 3.5 cm size @ 12000 per Ha will be stocked to rear further to attain advance size of 250 gm each with rearing period of 4 months. Labour cost will be minimal. Watch & ward and Marketing will be taken care of by fish farmer himself. Only for harvesting of advanced fingerlings requires TWO labours.

Water supply and fertilization: Starting one week after substrate installation the periphyton biomass growing on the substrates. After the substrates were installed, the ponds were filled with the water from a nearby source if requires. The water depth in each pond was monitored daily (fluctuating from 1.15 to 1.35 m) and maintained by adding water to replace losses at weekly intervals.



RESULTS

A schedule of fortnightly fertilization required for traditional (control) fish seed rearing ponds with semi-decomposed cattle manure, urea and triple super phosphate (TSP) at the rates of 3000, 100 and 100 kg/ha, respectively, was started immediately after pond filling and maintained throughout the period. However, in substrate aquaculture pond, in the field trail area is found to be not possible because of the non availability of the mentioned inputs. Even though, stocking of 1200 Advanced Fry of 3.5 cm size @ 12000 per ha per crop with the 90% survival rate, production of advance fingerlings1000 No.of 250 gm each per crop of 4 months was achieved. Two such crops per year is found to be more feasible.

Techno-Economic feasibility vis-a-vis Financial Analysis: Total outlay of the substrate aquaculture taking into consideration the operating cost of one cycle in the first year works out to Rs. 7450. Out of two recommended crops/cycles in a year, operational cost of only one cycle at Rs. 5450 in the first year has been envisaged in the project. Hence, operational cost for only one crop as also income from only one crop has taken into consideration for estimation of economics. The gross income from sale of 1000 No. of advance fingerlings of 250 kg @ Rs.60 per kg works out to Rs.15000 on a conservative scale. The internal rate of return of the scheme is more than 50 % with (BCR) Benefit Cost of Ratio at 15% 2: 1 and N P W at 15% is 11679. As such, the substrate aquaculture is technically feasible and economically viable. The economic analysis as also details of income and expenditure from the unit is given in the annexure II. The net surplus works out to Rs. 30,000 from second year onwards on a conservative scale. Even if any fish farmer avail the bank loan assistance, since, the scheme is economically viable and bankable as well, and the repayment schedule indicates that the principal amount of bank loan with interest can be repaid in one year.

The summary of the same along with other general lending terms is given below

Techno-Economic feasibility vis-a-vis Financial Analysis

Unit size : 0.1WSA

Crop/cycles : 2

Stocking density : 1200 Advanced Fry of 3.5 cm size @ 12000 per ha per crop

Rearing period : 4 months per crop

Survival rate : 90 %

Production of advance fingerlings: 1000 No. of 250 gm each per crop

Total project outlay taking into consideration the operating cost of one cycle in the first year works out to Rs. 7450. Out of two recommended crops/cycles in a year, operational cost of only one cycle at Rs. 5450 in the first year has been envisaged in the project. Hence, operational cost for only one crop as also income from only one crop has taken into consideration for estimation of economics. Total project outlay taking into consideration the operating cost of one cycle in the first year works out to Rs. 7450. The gross income from sale of 1000 No. of advance fingerlings of 250 kg @ Rs.60 per kg works out to Rs.15000 on a conservative scale. The internal rate of return of the scheme is more than 50 % with (BCR) Benefit Cost Ratio of 2: 1. As such, the scheme is technically feasible and economically viable. The repayment schedule indicates that the interest and the principal amount of bank loan can be repaid in a year.

The Financial analysis of both Substrate and Controlled Aquaculture system is as follows

	Substrate Aquaculture	Controlled Aquaculture	Percentage increase
Capital cost	2000	2000	
Operational cost of one crop	5450	9750	78 %
Total Project Out Lay	7450	11750	
Production of Advance Fingerlings	1000 Nos.	600 No	60 %
Survival rate of Stocked advance fry	90%	50 %	
N P W at 15% DF	11679	15763	
B C R at 15% DF	2 :1	1.57 :1	
I R R	500 %	297%	

A detailed economics of the said bankable model is given below

Unit cost of substrate aquaculture in 0.1ha i.e. 1000 m^2 Water Spread Area(WSA)					
No.	**Item**				
A	**Capital Cost**	**Qty**	**Unit**	**Cost (Rs.) per unit**	**Amount (Rs.)**
1	Cost of reclamation				
a	Cost of excavation for 1000 m3 for 1 m excavation less 20% i.e. for 800 m3	800	Cum	45	Not required
b	Weed eradication by 3 labours	3	day	75	675
c	Removal of predators by netting by 2 labours	3	day	75	450
d	Dewatering by one pump for 12 hrs	12	hour	75	900
	Total Capital Cost				2025
				Say	*2000*
B	**Operational cost one crop**				
1	Cost of Substrates Palm Leaf Diameter: 60 cm 1no/5m2 Rs 5/Leaf	220	pices	4	880
2	Advanced Fry (1200 @ Rs.3.0/ Fry)	1200	No	3	3600
3	Lime @ 800 Kg/ Ha	80	kg	10	800
4	Miscellaneous Expenditure including insurance of asset and farmer	Not available			0
5	Watch & ward	Self			0
6	Harvesting by 2 labours	1	day	75	150
7	Marketing	Self			o
5	*Operational Cost for one crop*				5430
6	Total Cost /Total Financial Outlay (Capital cost + Operational cost)				7450
	Farmer's contribution @10% of the Total cost	10%	7450		745
	Loan Amount				6705
				Say	6700
	Gross Income				
	From Sale of advance fingerling of 250gm each (1000 Fish@90% survival) @Rs. 60.00/Kg) per crop	250	Kg	60	15000
	Assumption:				
1	The farmers shall be advised to rear the fish seed and take the crops after 4 months. Farmers can be allowed to take such crop twice in a year but he will not be allowed to continue the culture operations to rear upto table size for a year.				
2	The fish seed shall be procured by the farmers through the Implementing Agency (NGO) form nearby Hatchery .				
3	The farmers shall be advised to undertake culture with a species ratio of Catla, Rohu and Calbasu in 34:52:14.				
C	***Repayment Schedule***				
	Bank loan	6700			
	Repayment Period	One year			
E.	**INCOME EXPENDITURE STATEMENT AND REPAYMENT**				
Particulars			*Years*		
			I		
1. Gross Income			15000		
2. Gross expenditure			7450		
3. Gross Surplus : (1 -2)			7450		
4. Add recurring cost capitalised for term loan			5450		
5. Amount available for repayment (3+4)			13000		
6. Repayment Instalment of Bank Loan Rs.6705 @12% Rate of Interest x C.R.F : 1.120000			7510		
7. Net surplus (5 - 6)			5490		
	Years	*1*	*2*	*3*	
	Cost	7450	10900	10990	
	Benefit	15000	30000	30000	
	Net benefit	7550	19100	19100	
	PWC	21887			
	PWB	33566			
	NPW@15 %	11679			
	BCR at 15 %	2			

Cash flow and Economic analysis: The economic analysis as also details of income and expenditure from the unit is given in the annexure II. The summary is as under:

N P W at 15% DF	:	11679
B C R at 15% DF	:	2 : 1
I R R	:	500 %

Unit cost of rearing of Advance Fingerlings by controlled scientific method in 0.1ha i.e 1000 m^2 Water Spread Area (WSA)					
Sl	**Item**				
A	**Capital Cost**	**Quantity**	**Unit**	**Cost (Rs.) per unit**	**Cost**
1	Cost of reclamation				
a	Cost of excavation for 1000 m^3 for 1 m excavation less 20% i.e. for 800 m^3	800	Cum	45	Not required
b	Weed eradication by 3 labours	3	day	75	675
c	Removal of predators by netting by 2 labours	3	day	75	450
d	Dewatering by one pump for 12 hrs	12	hour	75	900
	Total Capital Cost				2025
				Say	*2000*
B	**Operational cost one crop**				
1	Advanced Fry (1200 @ Rs.3.0/ Fry)	1200	No	3	3600
2	Lime @ 800 Kg/ Ha	80	kg	10	800
3	SSP @ 500 kg. /ha.	50		8	400
4	Urea @ 350 kg. /ha.	35		10	350
5	RCD @ 10000 kg. /ha.	1000		0.5	500
6	Micronutrients	L.S.			750
	Supplementary feed				
7	MOC (Mustard Oil Cake)@2000 kg/ha	200	kg	15	3000
8	Rice Bran (polish)@3750/kg	375	kg	0.5	187.5
9	Miscellaneous Expenditure including insurance of asset and farmer	Not available			0
10	Watch & ward	Self			0
11	Harvesting by 2 labours	1	day	75	150
	Operational Cost for one crop				*9737.5*
				Say	9750
C	Total Cost /Total Financial Outlay (Capital cost + Operational cost)				11738
D	Farmer's contribution @10%	10%	11738		1174
E	Loan Amount				10564
				Say	15000
F	**Gross Income**				
	From Sale of advance fingerling of 250gm each (600 Fish@50% survival) @Rs. 60.00/Kg) per crop	150	Kg	60	9000
G	***Repayment Schedule***				
	Repayment Period	Three years with one year grace period			
	Repayment instalments (12% int.)	I year	II year	III year	IV year
	(Annual equated instalments-4 years	4939	3864	3864	3864
	Capital Recovery Factor- 0.329234				
	Net surplus (after repayment)	-6602	4398	4398	4398
H	**Income expenditure statement and repayment**				
	Particulars	....	*Years*	....	
		I	II	III	IV
i	Total Gross Income from fish	9000	18000	18000	18000
ii	Gross expenditure	11738	9738	9738	9738
iii	Gross Surplus : (1 -2)	-2738	8263	8263	8263
iv	Add recurring cost capitalised for term loan	0	0	0	0
v	Amount available for repayment (3+4)	-2738	8263	8263	8263
vi	Repayment Instalment of Bank Loan Rs.15000 @12% x C.R.F : 0.329234	3864	3864	3864	3864
vii	Net surplus (5 - 6)	-6602	4398	4398	4398
I	Financial analysis:				
1	NPW at 15% DF		15763		
2	BCR at 15% DF		1.57		
3	IRR		297.00	%	
	Years	*1*	*2*	*3*	*4*
i	Capital Cost	2000			
ii	Recurring cost	9738	9738	9738	9738
iii	Total Cost	11738	9738	9738	9738
iv	Benefits	9000	18000	18000	18000
v	Gross surplus	-2738	8263	8263	8263
vi	PWC at 15% DF	27800			
vii	PWB at 15% DF	43563.52			

The net surplus works out to Rs. 30,000 from second year onwards on a conservative scale. The internal rate of return of the scheme is more than 50% with Benefit Cost Ratio (BCR) of 2 :1. Thus, the scheme is economically viable and bankable as well. (The repayment schedule indicates that the principal amount of bank loan with interest can be repaid in one year).

DISCUSSION

The field area is socio-economically highly vulnerable and dependent solely on fishery as vocation. Ecological safety and economic sustainability issues affect these sections most. Mainly, most of the small and marginal farmers having homestead fishponds, farmers lack appropriate technology, institutional finance and proper extension support. Farmers using traditional method for fish aggregation and feed supplements which have low productivity. Moreover, necessary inputs required for culture practices viz., lime, RCD, MOC are not available at farms located at remote places and have to be brought from 250-300km. Substrate based aquaculture as an income generation activities, productivity of a fish pond can be enhanced without increasing nutrient inputs through heterotrophic food production. In aquatic environments, bacterial biofilm includes a complex community of other organisms such as algae, protozoa and fungi embedded in the extracellular matrix secreted by bacteria. The role of bacteria as food for both zooplankton and planktophagus fish needs no further emphasis (Kuznestov 1977; Moav *et al*. 1990). Worldwide several substrate-based fish prodcution practices exist, of which Acadja, Athkotu, Samarah, Phum, Aj gnuii assonii, Xeng fishery are popular. These substrate-based fisheries reported higher productivity then conventional supplemental feed-based aquaculture. Herbivorous fish, in general, have natural tendency to graze on periphyton fed environment (Surjya K. Saikia, Debangshu N. Das 2014). In an aquatic system, micro-floral community living attached to the surface of submerged objects which includes bacteria, fungi, protozoa, phytoplankton, zooplankton, benthic organisms, organic detritus, and range of other invertebrates and their larvae is collectively defined as periphyton (1) It may dwell either on a degradable or non-degradable substrates present in an aquatic system (2) Word 'lentic' refers to standing water which includes lakes, ponds, marshes, and ditches. Availability of light, nutrient, substrate and less physical disturbances makes lentic ecosystem as an ideal habitat for periphyton. Usefulness of periphyton in fresh water includes primary productivity, nutrient cycling and food web interaction. (3) In recent years periphyton is of great interest in monitoring water quality and sustainable aquaculture practices. (H.Ganesh, K.C.Pushpalatha. B. Gangadhar 2017).

However, current fertilization practices have little potential to promote sessile biofilm micro-organism. Hence, boosting fish production by promoting bacterial biofilm on suitable substrates in fertilized ponds is possible. Development of an effective food production by submerging locally available and cheap substrate assures the upliftment of resource poor fish farmers. Individual farmers' pond is limited to the rearing of fry to fingerlings over a period of three months. Most of the individual farmers who practiced fish seed rearing in their seasonal ponds are unable to carry out *grow out practices* in their ponds because of unavailability of water throughout the year. Besides, the higher consumptive need of resource poor farmers have been a major hurdle in sustaining the operations for successive years. Farmers use advance fish fry of size 20-40mm to stock in fish ponds from local hatchery. Survival ability of fish seed were ranged from 50-60%. Fish culture was undertaken for 3 months duration.

Conclusion

Since carp polyculture system mostly depends on organic manure, due to insufficient and inadequate application of the same, fish production remains at sub optimal level in farmer's field condition. However, the farmers when start practicing substrate based aquaculture, there shall least dependence of artificial feed and exogenous fertilization which will reduce input cost to a significant level. Thus, the net profit of the farmer shall increase which will lead to increased income from the unit area. The application of this technology evolved by farmers have resulted in the generation of new technologies that are likely to benefit the resource poor who always have difficulty in obtaining pond input resources. Thus it is possible to undertake substrate based aquaculture practices with the use of palm leaves could be effectively utilized for rearing of advance fish fry to advance fingerlings from such low productive fish ponds. Development of such a viable and low cost technology and its application to current farming practices will definitely help increase fish yield in farmer's field and help secure food security.

The application of this technology evolved by farmers have resulted in the generation of new technologies that are likely to benefit the poor who always have difficulty in obtaining pond input resources. The farmers when start practicing substrate based aquaculture, there shall least dependence of artificial feed and exogenous fertilization which will reduce input cost to a significant level. Thus, the net profit of the farmer shall increase which will lead to increased income from the unit area. It is possible to obtain 46% higher profit just by the addition of palmyra as substrate, as compared with the control treatment. Fertilization and supplementary feeding are important in increasing production. This will add up to 40% to 70% of the production cost, depending on the intensity of feeding.

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