



On-farm performance of genetically improved scampi (CIFA-GI scampi™) in carp-scampi polyculture system in Odisha, India

DEBABRATA PANDA, BINDU R. PILLAI, KANTA DAS MAHAPATRA, HIMANSHU KUMAR DE, BIBHUDATTA MISHRA, SOVAN SAHU, NAMITA NAIK, PURNAPRIYA SUARA, ABHIJIT NAYAK AND MUKESH KUMAR PATRA

ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar - 751 002, Odisha, India
Aquaculture Production and Environment Division, ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga Bhubaneswar - 751 002, Odisha, India
e-mail: debapnd@yahoo.co.in

ABSTRACT

On-farm performance evaluation of the genetically improved variety of freshwater prawn, *Macrobrachium rosenbergii* christened as CIFA-GI scampi™ was carried out in 14 districts of Odisha State, India during April 2019 to March 2020. Data were collected through personal interview of 46 farmers (28 CIFA-GI scampi™ and 18 non-GI scampi farmers) using a structured questionnaire. Socio-economic profile of two groups of respondents were found to be identical for all the selected variables except education, primary occupation and pond size. Harvest size, absolute growth rate, yield, sale price and gross profit were significantly higher in CIFA-GI scampi™ farmers compared to non-GI scampi farmers though size at stocking, stocking density and survival did not vary between these two groups. It was found that CIFA-GI scampi™ showed 53% higher growth rate, 68% higher yield, fetched 13% higher farm gate price with ₹0.62 lakh ha⁻¹ crop⁻¹ additional profit compared to non-GI scampi in carp-scampi polyculture system. The input and output parameters of carp component were not significantly different between the groups. The findings of this study highlighted the superiority of the CIFA-GI scampi™. Thus, the adoption of culture of this improved strain will not only bridge the yield gap but also help in realisation of higher economic benefit to the farmers.

Keywords: CIFA-GI scampi™, Genetically improved prawn, *Macrobrachium rosenbergii*, Polyculture, Performance assessment, Socio-economic profile

Introduction

Aquaculture has been playing a critical role to meet the increasing demand of fish globally. With the rapid population growth, rising income, shifting consumer preferences towards healthier and nutritious foods is putting lots of pressure on the sector for increasing production of quality fish. Majority of production from agriculture and animal husbandry comes from genetically improved, fast growing and high yielding varieties. However, the present aquaculture production is still based largely on more than 600 unimproved fish species. These species are genetically similar to wild counterparts, with low production efficiency (Ponzoni *et al.*, 2007; FAO, 2019).

Selective breeding is a tool used to effectively improve the production traits of farmed animals. The use of genetically improved farmed fish strains can play an important role in meeting the growing demand for fish by increasing production gains (Acosta and Gupta, 2010; Olesen *et al.*, 2015; Gjerdem and Rye, 2018), improving disease resistance (Houston, 2017; Barriá *et al.*, 2020;

Kjetsa *et al.*, 2020) and enhancing socio-economic and welfare performance of the related aquaculture systems (Dey, 2000; ADB, 2005). In aquaculture, selective breeding has been used with great success to improve various traits like growth, disease resistance and meat quality in species like Atlantic salmon (Kjetsa *et al.*, 2020), Rohu carp (Mahapatra *et al.*, 2007, Gjerdem *et al.*, 2019), Nile tilapia (Dey *et al.*, 2000, Ponzoni *et al.*, 2007, Khaw *et al.*, 2008, Yosef, 2009, Barriá *et al.*, 2020, Tran *et al.*, 2021), Pacific white shrimp (Argue *et al.*, 2002) and giant freshwater prawn (Luan *et al.*, 2012, Hung *et al.*, 2013 and Pillai *et al.*, 2020). Gjerdem and Rye (2018) reported that estimates of genetic gain for body weight ranged from 2.3 to 42% per generation (an average of 12.7%), indicating the potential of selective breeding in the improvement of production traits in commercially important aquaculture species. There are empirical evidences that dissemination and adoption of genetically improved aquatic species increase fish yields (Dey *et al.*, 2000; Ponzoni *et al.*, 2007). Studies on GIFT has shown that culturing GIFT improve economic returns for the farmer (Khaw *et al.*, 2008; Haque

et al., 2016); increase survival rate (Khaw *et al.*, 2008), reduce duration of culture (Dey *et al.*, 2000; Haque *et al.*, 2016); reduce production and operational costs (Dey *et al.*, 2000); reduce local fish market prices, improving affordability particularly for low income consumers (Dey, 2000; Yosef, 2009) and generate rural employment and income (ADB, 2005).

The present study focused on giant freshwater prawn (GFP) *Macrobrachium rosenbergii*, a commercially important freshwater prawn species widely cultured in several tropical and subtropical countries across the world. This prawn is commonly called as ‘scampi’ in trade circles. Due to its fast-growing nature, hardiness, requirement of low protein diets, better domestic and export market and higher returns, it is recommended for farming in many tropical and sub-tropical countries (Brown, 1991). Several factors are reported to be affecting the production, especially growth and survival in freshwater prawn farming worldwide (New, 1995). The latest available production data of *M. rosenbergii* revealed that the global aquaculture production stood at 234,400 t which was 2.5% of total global fish production (FAO, 2020). India is currently the 6th largest producer with an annual production of 8,303 t (MPEDA, 2021). However, the production in India declined from 42,800 t in 2005 to 8,303 t in 2020. In India, scampi is mainly cultured in small to medium earthen ponds in West Bengal, Andhra Pradesh, Tamil Nadu and Kerala (Nair and Salin, 2012). However, in recent years Odisha, Gujarat, Maharashtra and Telangana are increasingly contributing to its production.

Due to its high value, several countries started selective breeding programme of this species including India. Hung *et al.* (2013) reported selection response from 4.4 to 7.4% per generation for harvest body weight of GFP in Vietnam, while Luan *et al.* (2012) observed a realised selection response of 6.56% per generation during five generations of selection in China. In India, ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA) has developed a genetically improved and fast-growing strain of *M. rosenbergii* through selective breeding (Pillai *et al.*, 2017). The new improved strain was registered as ‘CIFA GI scampiTM’ in 2020. After five generations of selection, the cumulative selection response (in actual units, g) in the GFP breeding programme ranged from 3.6-6.0% per generation (Pillai *et al.*, 2020). The growth performance of selectively bred *M. rosenbergii* was significantly greater than that of the control line irrespective of region, sexes and generations, indicating the selective breeding had achieved its aim at the farmer level in India (Pillai *et al.*, 2020).

However, despite these potential benefits, sound data on the actual performance of genetically improved strains of fish in farming systems is limited. The lack

of benchmarking information on the performance of these improved strains is limiting consistent and sound investment into genetic improvement programs in aquaculture especially in developing countries (Tran *et al.*, 2021). The absence of information on actual performance of genetically improved species makes it difficult to assess critical yield gaps and identify effective strategies and interventions required to address them. The lack of sound cost benefit analysis related to the use of different inputs or practices prevents more accurate business planning and the assessment of trade-offs. Therefore, reliable data on the on-farm performance of genetically improved species is very much needed for the industry and governments to design appropriate strategies and effective policies for future investment in aquaculture development. The overall objective of this study was thus to assess the on-farm performance of the latest generation of CIFA-GI scampiTM (GI scampi) strain with that of non-improved strains of GFP (local stock) in Odisha. The culture of scampi in carp-scampi polyculture has been widely practiced by most of the farmers in Odisha. Hence, the most prevailing practice of polyculture of scampi with Indian major carps (IMC) *i. e.* catla (*Catla catla*) and rohu (*Labeo rohita*) was considered under this study for comparison.

Materials and methods

Sampling and data collection

Based on the geographical demography, agroclimatic pattern and intensity of aquaculture activities, data were collected from 14 districts of Odisha (five districts from eastern region *i.e.* Bhadrak, Kendrapada, Jagatsinghpur, Khordha and Puri; two from central region *i.e.* Cuttack and Jajpur; two from southern region *i.e.* Ganjam and Nayagarh; two from northern region *i.e.* Balasore and Mayurbhanj and three from western region *i.e.* Bolangir, Deogarh and Nuapada) during April, 2019 to March, 2020 (Fig. 1). An interview schedule was prepared for collection of information on carp-scampi polyculture system.

Being the nucleus breeding center, ICAR-CIFA produced the latest 11th generation (G11) of CIFA-GI scampiTM in 2019 and supplied to the multiplier hatcheries and farmers. The contact details of farmers involved in GI scampi farming was collected from these hatcheries. A team of enumerators visited the farm sites and interviewed using a structured interview schedule. During this survey, information on culture of unselected scampi (non-GI scampi) were also collected from the same locality. The survey schedule comprised of the following modules: (1) Basic profile of scampi farmer; (2) Household information; (3) Asset ownership and land use pattern; (4) Aquaculture management, production and marketing activities and (5) Access to information.

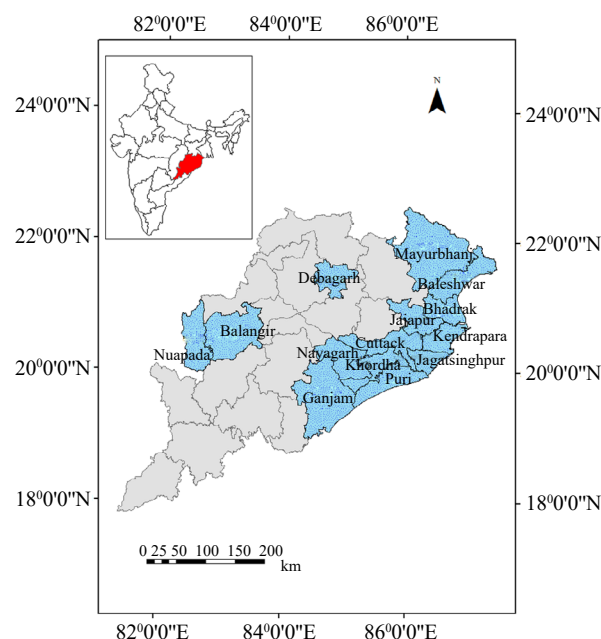


Fig. 1. Map of Odisha showing different districts surveyed

Due to the lack of habit of documenting contacts of seed buyers by the seed suppliers, a few contacts only could be gathered. Moreover, crop loss during the culture, incomplete culture/harvest information as well as inability of the farmer to provide the culture information resulted in reduction in the sample size. About 11 survey schedules had to be excluded due to inconsistencies and incompleteness in the data set. Thus, the final sample size was 46 farm households comprising both GI and non-GI scampi growers. Out of the 46 respondents, 28 farmers were ($n_1=28$) practicing GI scampi while 18 ($n_2=18$) farmers were culturing non-GI scampi in carp-scampi polyculture system. Almost all the farmers were practicing polyculture of scampi with IMC (catla and rohu) as major species in the production system.

Data analysis

The survey captured detailed data about all types of aquaculture production practices including carp-scampi production system. Descriptive and comparative analysis was used to characterise and assess the performance of GI scampi culture in Odisha. Independent sample t-test was employed to find differences between the two groups of respondents.

The operational costs consist of that of seed, feed, organic and inorganic manure/fertiliser, lime, hiring of labour, netting charges, pond lease value and pond renovation cost. The seed cost of carps, scampi and other species, if any, were summed up to get the total seed cost. Total cost of feed was calculated as sum of product

of total quantity of feed used and unit cost of each feed/ingredient used. The cost of organic fertiliser (cow dung/poultry manure) and inorganic (Single super phosphate, Diammonium phosphate and Urea) were summed up to get the total fertiliser expenses. Similarly, hiring of labour for feeding fishes, cleaning pond periphery, aerator operation, water exchange and netting were added together to get total man-days involvement during the culture period. Mainly three types of labour were encountered *i.e.* family, hired part-time and hired full-time labour. Cost for hired labour was obtained by multiplying the total number of man-days by the daily wage. Cost for family labour was computed as an opportunity cost assuming a daily wage equal to 75% of the wage for hired full-time labour. Pond lease value and pond renovation costs were taken as other pond specific cost. A matching pond lease value was also added as opportunity cost for the ponds which were not on lease but owned by the respondents. The sum of all these six components was computed as total production cost (₹) per ha per crop cycle. Total revenue was computed as the sum of product of yield of carp and scampi harvested in kg ha^{-1} crop cycle⁻¹ multiplied by the unit selling price (₹) for each species. The gross profit was calculated as total revenue less total production cost. The benefit-cost ratio (BCR) was computed as total revenue divided by total production cost. Return on investment (ROI) in % was estimated as:

$$\text{ROI (\%)} = \frac{(\text{Revenue} - \text{Cost of production})}{\text{Cost of production}} \times 100$$

The biological performance of GI and non-GI scampi was also assessed by using various factors *i.e.* growth rate, size at stocking and harvesting, survival rate and feed conversion ratio (FCR). These biological factors directly influence productivity and profitability. The size at stocking and harvesting were recorded along with the stocking density for each species. The survival rate was calculated as:

$$\text{Survival rate (\%)} = \frac{\text{Nos.harvested}}{\text{Nos.stocked}} \times 100$$

The absolute growth rates (AGR) of the species were estimated as per Hopkins (1992) for comparison among the treatments. The AGR was estimated as:

$$\text{AGR (g day}^{-1}\text{)} = \frac{(\text{Wt}-\text{Wi})}{t}$$

where, Wt is the weight in gram in time t (=final weight), Wi is the initial weight in gram and “t” is the length of the culture period in days.

The feed conversion ratio (FCR) was calculated as:

$$\text{FCR} = \frac{\text{Total quantity of feed consumed (kg)}}{\text{Total yield (kg)}}$$

The differences in performance between GI and non-GI scampi were assessed descriptively using two independent samples t-test assuming unequal variances. To test the difference between GI scampi and non-GI scampi, parameters using two sample t-test, μ_1 was considered as mean of GI scampi parameter and μ_2 as mean of non-GI scampi parameter. The following null hypothesis (H0) was tested at 5% level of significance.

Null hypothesis, H0: $\mu_1 - \mu_2 = 0$

Alternate hypothesis, H α : $\mu_1 - \mu_2 \neq 0$

The t-statistic and probability at 5% level of significance was estimated using MS Excel.

The parameters *i.e.* BCR, FCR and ROI do not usually follow normal distribution. Therefore, non-parametric Mann-Whitney (U) test was employed to assess difference in BCR, FCR and ROI between GI and non-GI scampi. The following hypothesis were tested considering mean GI scampi as U1 and mean non-GI scampi as U2.

Null hypothesis, H0: $U_1 = U_2$

Alternate hypothesis, H α : $U_1 \neq U_2$

The U statistic was estimated as:

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

The U-statistics and U-critical were calculated and tested for both 1 and 5% level of significance.

Results and discussion

Socio-economic characteristics

The present investigation focused on the most prevalent farming system for scampi *i.e.* carp-scampi polyculture system in Odisha. Comparison of socio-economic characteristics of GI and non-GI scampi farmers revealed that there were significant differences between the two groups in education, primary occupation and size of polyculture ponds (Table 1). However, other socio-economic characteristics like age, total land holding, size of ponds under aquaculture, water depth and fish culture experiences were more or less similar. Farmers practicing GI scampi culture had higher educational attainment. About 71% of the respondents studied matriculation (class X) and above were practicing GI scampi, while only 17% of the respondents under this category were practicing non-GI scampi. More than 71% of respondents above 35 years of age and with higher educational level of above class X were found to be practicing GI scampi culture (Table 2). This might be due to the better exposure of the higher educated farmers on scientific aquaculture practices and about the GI scampi. One third of the GI scampi farmers were having less than 2.0 acre (0.8 ha) of land holdings. The size of the non-GI scampi culture ponds was bigger than the GI scampi ponds. More than 77% of the non-GI ponds sizes were above 2.0 acre (0.8 ha). The GI scampi polyculture pond size was relatively four times smaller (0.47 ha) than non-GI farms (1.98 ha). Interestingly, almost all non-GI farmers were primarily involved in fish culture for their livelihood, while only 54% of the GI scampi farmers had fish culture as primary occupation. Aquaculture was a secondary livelihood for remaining 46% of the respondents practicing CIFA-GI scampi either primarily in agriculture or service or business (Table 2). Therefore, there is ample scope for creating awareness among the farmers on CIFA-GI scampi™ for its wider dissemination as almost all non-GI scampi farmers had no idea about its availability. Thus, it could be seen that the GI scampi was cultured in small size ponds (<0.5 ha) by small scale farmers having higher educational qualifications and primarily engaged in some other occupation.

More than 85% respondents were having more than 2 years of experience in fish culture in both the groups (Table 2). Most of the GI scampi ponds (71%) were near (<1 km) to the residence of the respondents. However,

Table 1. Mean and standard errors (SE) of the socio-economic characteristics of respondents

Variables	GI scampi (Mean± SE)	Non-GI scampi (Mean± SE)	p value
Age	46.5±2.4	45.2±3.4	0.75
Education (1=respondent education > class X)	0.71±0.09	0.17±0.09	0.00002
Primary occupation (1=Aquaculture)	0.54±0.10	1.0±0.00	0.00005
Total size of the landholdings (ha)	3.67±1.07	5.29±1.06	0.29
Size of the land under aquaculture (ha)	1.42±0.70	3.10±0.67	0.09
Size of the land under carp- scampi polyculture (ha)	0.47±0.0.08	1.98±0.0.45	0.0036
Water depth in polyculture pond during culture (ft)	5.71±0.32	5.17±0.25	0.18
Experience in fish farming	8.18±1.10	8.11±1.32	0.97

Significant differences between GI and non-GI scampi farmers at $p < 0.05$.

Table 2. Frequency distribution of different variables of the two categories of respondents

Variables	Category	GI scampi (%)	Non-GI scampi (%)
Age (Year)	20-35	28.6	16.7
	35-50	35.7	50.0
	≥50	35.7	33.3
Education	Primary school (<10 th)	14.3	33.3
	High school (10 th Pass)	14.3	50.0
	College (>10 th)	71.4	16.7
Primary occupation	Agriculture	25.0	-
	Fish culture	53.6	100.0
	Service (Job)	17.9	-
	Business	3.6	-
Experience in fish farming (Years)	Low (≤2.0)	14.3	11.1
	Medium (>2.0 to ≤5.0)	32.1	33.3
	High (>5.0 to ≤10.0)	28.6	33.3
	Very high (>10)	25.0	22.2
Distance of pond from home	<1.0 km	71.4	38.9
	1.0-3.0 km	21.4	38.9
	3.0 km	7.1	22.2
Area under carp-scampi polyculture	<2 acre	75.0	22.2
	2-4 acre	21.4	33.3
	≥4 acre	3.6	44.4
IMC seed source	ICAR-CIFA	17.9	33.3
	Govt. hatchery	17.9	11.1
	Private hatchery	64.3	55.6
Scampi seed source	ICAR-CIFA and its multiplier units	100.0	-
	Other Govt./Private hatchery	-	33.3
	Pond production seed	-	61.1
	Wild seed collection	-	5.6
IMC size at stocking	Advanced fry	45.83	50.0
	Fingerling	54.17	50.0

more than 77% of ponds in both the cases were within a reach of 3.0 km. In both the cases more than 56% of carp seeds were procured mostly from private hatcheries. The source of GI scampi seeds was either from ICAR-CIFA or its multiplier hatcheries. However, the sources of seeds of non-GI scampi were either from private hatcheries, pond seed production or wild collection. The major (61%) source of non-GI scampi seed was from the brackishwater pond production especially from Chandipur area of Balasore District, Odisha. All the respondents stocked

post-larvae of scampi along with either advanced fry or fingerling of carps.

Biological and technical characteristics

The stocking density of carps and scampi in both the cases were found to be similar in nature. The stocking densities for carps were 8,311 and 7,918 nos. and for GI scampi and non-GI scampi systems it was 12,831 and 13,521 nos. per ha respectively (Table 3). The size at stocking for both carp and scampi remained similar in both the cases.

On an average 5-6.0 g size of carps and 0.03-0.08 g of post-larvae of scampi was stocked in all the ponds. However, the harvest size of carps and scampi were significantly different. Higher sizes of carps [Average body weight (ABW) 963 g vs. 746 g] and scampi (ABW 68 g vs. 38 g) were reported in GI ponds compared to non-GI ponds after about 278 and 245 days of culture respectively. Paul *et al.* (2016) reported a similar growth for wild or unselected stock of scampi from Bangladesh which ranged from 21.59±2.64 g to 38.71±3.79 g in 150 days. The absolute daily growth rate (AGR) of carps did not differ significantly in carp-non GI scampi polyculture system (Table 3). However, the AGR of GI scampi (0.26 g d⁻¹) was found to be higher than the non-GI scampi (0.17 g d⁻¹). Hence, the growth rate of GI scampi was about 53% higher than that of the unselected scampi. As the carp-scampi polyculture ponds with similar management strategies were included in the survey, it is concluded that the higher growth rate reported in case of GI scampi was due to the improved seed.

Survival of both carps and scampi was more or less similar in both the systems in spite of longer duration of culture (DOC) in case of GI scampi system. Although higher survival (63%) for GI scampi was reported against 59% for non-GI scampi, it was not found statistically significant. In case of carps, 35% survival was reported in GI ponds compared to 45% in non-GI scampi ponds. Although advanced fry or fingerlings were stocked, less than 45% survival of carps was reported by farmers in both the cases.

Yield, profitability and economic characteristics

The GI scampi yield was observed to be significantly higher *i.e.* 416 kg ha⁻¹ crop⁻¹ compared to 218 kg ha⁻¹ crop⁻¹

for non-GI scampi in about 278 and 245 DOC. Most of the farmers culturing scampi practiced cull (partial) harvesting from about 40.0 g and above from 150 DOC onwards leaving less biomass of scampi before final harvesting. Therefore, longer culture duration in case of carp-GI scampi might not suggest that GI scampi needed more time to reach its harvest size. There were about 33 days difference in DOC between GI and non GI scampi in the present study. While considering the DOC of 245 days for both the systems, the scampi yield from GI scampi system was re-estimated as 367 kg ha⁻¹ crop⁻¹, which was about 68% higher than the nonGI scampi system with a yield gap of about 149 kg ha⁻¹ crop⁻¹. The yield of carps from both the systems were not significantly different with 1984 and 2093 kg ha⁻¹ crop⁻¹ for GI scampi and non-GI systems respectively. The average farm gate price of carps was ₹151 from GI scampi and ₹132 from non-GI scampi ponds. The mean GI scampi farm gate price was ₹418/- compared to ₹68/- of non-GI scampi, which was 13% higher. The higher price of carp and scampi harvested from carp-GI scampi system might be due to their higher size at harvest.

In aquaculture, faster growth rate is associated with higher yield and better FCR. The stocked animals were fed with either floating feed or mixture of GNOC and rice bran or combination of both floating feed and GNOC-rice bran mixture. Feeding ration was decided based on the stocked fish biomass. No separate feeding strategy was adopted for scampi. As there were different feeding strategies followed even within one polyculture system, it was assumed that there was no significant difference in use of different feeds on growth performance. Further, it was also considered as scampi got its nutrition from

Table 3. Mean and standard errors (SE) of size at stocking and harvesting, with growth, yield and economic characteristics

Variables	GI scampi (Mean±SE)		Non-GI scampi (Mean±SE)	
	Carp	Scampi	Carp	Scampi
Stocking density (ha)	8311.2±1137	12831±1585	7918.3±1377	13521.7±2482
Size at stocking (g)	6.14±1.1	0.03±0.0	5.39±1.2	0.08±0.05
Size at harvesting (g)	962.96±48.42*	67.79±3.97*	745.83±30.71*	38.33±5.07*
Survival (%)	35.00±5.61	62.76±8.18	44.72±10.51	58.8±11.86
AGR (g day ⁻¹)	3.37±0.24	0.26±0.02	3.34±0.20	0.17±0.02
Yield per ha per crop cycle (kg)	1984.82±255.08	415.87±46.34*	2093.65±250.41	217.79±28.18*
Sale price (₹ kg ⁻¹)	150.73±6.27*	417.86±16.91*	131.53±4.01*	368.33±12.77*
Polyculture feed conversion ratio (FCR)	1.81±0.10	-	1.71±0.14	-
Days of culture	278.57±10.79*		245.0±10.07*	
Yield (Carp+Scampi+other species) per ha per cycle	2455.07±258.49		2570.39±232.89	
Production revenue (₹)	474577.47±39095.36		413045±36631.02	
Production cost (₹)	272439.96±14207.67*		345481.00±22180.84*	
Gross profit (₹)	202137.50±28051.25*		67564.03±19434.97*	
Benefit-cost ratio (BCR)	1.69±0.08**		1.17±0.04**	
Return on investment (ROI) %	69.30±7.76**		17.35±4.30**	

Significant differences between GI and non-GI scampi farmers at: *p<0.05 and **p<0.1 but >0.05.

the excess feed and bottom biota in the pond system. Therefore, the FCR was estimated for carps only, which was 1.81 in GI scampi system as compared to 1.71 in non-GI system in 278 and 245 DOC respectively. Employing Mann Whitney test it was found that FCR for carps did not show any significant difference between the two groups.

The surveyed farmers followed extensive/traditional polyculture practice with lower level of input use, which prevails in many parts of the state. The majority of the surveyed farms belonged to the small and marginal category with limited resources for investment in fish culture. Total yield including carp, scampi and other compatible miscellaneous species was estimated as 2455 kg ha⁻¹ crop⁻¹ in carp-GI scampi system compared to 2570 kg ha⁻¹ crop⁻¹, which did not show any significant difference (Table 3). However, this productivity level was reported to be less than the present national average pond productivity (3000 kg ha⁻¹ year⁻¹) of carps (Ayyappan, 2021) due to the traditional mode of culture practiced by the surveyed farmers. Total revenue generated from carp-GI scampi and carp-non-GI scampi system was estimated as ₹4.75 lakh and ₹4.13 lakh ha⁻¹ crop⁻¹ respectively. An additional GI scampi production of about 149 kg ha⁻¹ crop⁻¹ with added profit of ₹0.62 lakh ha⁻¹ crop⁻¹ in 245 DOC was realised in carp-GI scampi polyculture system.

The economic parameters like BCR and ROI estimated for carp-GI scampi system was 1.69 and 69% respectively. However, in case of carp-non GI scampi polyculture, BCR and ROI were estimated to be 1.17 and 17.35% respectively. The ROI was higher (69%) in GI scampi compared to 17% in non GI scampi system in spite of higher culture duration. Employing Mann Whitney test it was observed that BCR and ROI of GI scampi system was significantly higher.

The production cost in carp-GI scampi system was estimated 27% less (₹2.72 lakhs) than the carp-non-GI scampi system (₹3.45 lakh) as given in Table 4. Hence, culture of carp-GI scampi yielded significantly higher profit of ₹2.0 lakh compared to ₹0.68 lakh from culture

of carp-non-GI scampi in 278 and 245 DOC respectively. Out of the total profit of ₹2.0 lakh, more than 65% of the profit was contributed by the GI scampi. The seed, feed and fertiliser constituted more than ₹0.35 lakh (13 %), ₹1.12 lakh (41%) and ₹0.19 lakh (7%) of total cost in GI scampi as compared to ₹0.51 (15%), ₹1.28 lakh (37%) and 0.30 (9%) respectively in case of non-GI scampi system. However, no significant difference in application of basic inputs *i.e.* seed, feed and fertiliser/manure across the two groups of farms were observed. This clearly shows that the improved variety of scampi does not warrant any special or higher cost in procurement of seed, feed or manure. Significant differences were observed in case of application of lime, engagement of labour, netting and pond renovation, which were higher for non-GI scampi systems. However, costs towards liming, labour, netting and pond renovation can be effectively reduced by adopting scientific culture practices and also by bringing more area under culture.

Higher benefit to cost ratio and returns on investment of GI scampi indicates the cost-effectiveness of GI scampi farming in polyculture. GI scampi generates higher returns relative to cost of production indicating the potential of this improved strain to enhance the livelihoods of small and marginal farmers. Tran *et al.* (2021) reported higher profitability, performance and cost effectiveness of GIFT over non-GIFT in Bangladesh. Genetically improved strains are getting popular due to their higher growth potential in aquaculture and GI-scampi is not an exception. However, further studies with larger sample size, spread over a few production cycles will give more concrete results on the performance of GI scampi in comparison with unimproved stock of scampi.

The present study revealed that CIFA-GI scampi™ culture is being undertaken in small size ponds (<0.5 ha) by small scale farmers having higher educational attainment primarily engaged in some other occupation. CIFA-GI scampi™ performed better than non-GI scampi in terms of harvest size, growth rate, yield, sale price and gross profit in carp-scampi polyculture system in Odisha. The genetically improved variety showed 53% higher

Table 4. Cost composition of production of GI and non-GI scampi in polyculture system

Cost category (₹I)	GI Scampi	Non-GI Scampi	p-value
Seed	35557.66±4443.96	51477.37±11046.52	0.19
Feed	111965.99±10092.50	127522.17±19749.87	0.49
Fertiliser	18987.95±5404.77	29817.36±8326.54	0.28
Lime	3207.83±520.75	6191.88±1245.86	0.03
Labour and netting	68401.79±5242.71	91305.56±8398.97	0.03
Other pond specific cost	34318.75±1408.96	39166.67±1604.22	0.03
Total production cost	272440±14207.67*	345481±22180.84*	

*Significant difference between GI and non-GI scampi farmers at p<0.05.

growth rate, 68% higher yield, fetched 13% higher farm gate price, about 0.62 lakh ha⁻¹ crop⁻¹ additional profit and higher rate of return on investment as compared to non-GI scampi in carp-scampi polyculture system. The findings of this study have several important implications for policy and aquaculture development. This is the first of its kind and benchmarking information available on a genetically improved scampi to support investment and upscaling of CIFA-GI scampiTM, which would be ultimately translated to realisation of higher production and profitability to the aquaculture farmers. There is ample scope of creating awareness among the farmers on CIFA-GI scampiTM for its wider dissemination as almost all non-GI scampi farmers have no idea about its availability. Therefore, authors argue for wider scale dissemination of the new strain of scampi coupled with training and capacity building of farmers enabling them to realise its fullest potentials.

Acknowledgements

The authors are thankful to the Director, ICAR-CIFA, Bhubaneswar for providing necessary facilities to undertake this study. This study was carried out under a collaborative research project between Indian Council of Agricultural Research (ICAR), New Delhi, India and WorldFish, Penang, Malaysia.

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