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# Evaluation of Gardi *Bangana dero* and Sahar *Tor putitora* with Rohu *Labeo rohita* and Naini *Cirrhinus mrigala* in polyculture at different stocking combinations

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**Abstract**
Conventional multispecies polyculture with compatible native species intercrop augments optimum utilization of the ecological niches in the pond ecosystem, diversity conservation, food value, and poverty alleviation potential through the direct involvement of rural people. Given the conservational value and the aquaculture potential of several indigenous species, Gardi *Bangana dero* and Sahar *Tor putitora* have been identified as important food fish. Rohu *Labeo rohita* and Naini *Cirrhinus mrigala* are two other native fishes that fetch a very high market price and are of high cultural value. A polyculture experiment was carried out on the Rohu, Naini, Gardi, and Sahar with the objectives to evaluate the optimum stocking density in terms of average body weight, specific growth rate, and total fish production of these fishes for nine months. Results showed that the final body weight of Rohu, Naini, Gardi were high in respective major polyculture systems, but Sahar was high in Naini major polyculture system. Also, net fish yield of Rohu was observed significantly higher in Rohu major polyculture system than in Naini major and Gardi major polyculture systems but not with control polyculture systems. Whereas, parameters of Naini, Gardi and Sahar observed similar in all polyculture systems. Apparent Feed Conversion Ratio was found higher in Gardi major polyculture system than others. In case of survival, all fish species had high survival rate in Naini major polyculture system. Thus, the Naini major polyculture system is concluded to be the optimum combination for these particular species.

**Keywords:** Polyculture, stocking, survival, growth performance

## Introduction
The unique inland aquatic habitats within the short north-south axis of Nepal nurtured by four major rivers Mahakali, Karnali, Gandaki, and Koshi along with its tributaries systems cover approximately 5.57% of the total area 147,516 km$^2$; and harbor 252 fish species having 236 indigenous and 16 exotics with 11 aquaculture species representing 120 genera, 40 families and 15 orders (Jha 2006; Shrestha 2008; Gurung 2018; Shrestha 2019; CFPCC 2020) [32, 56, 27, 51, 16]. In the late 1970s after significant achievement in breeding techniques of Indian major carps (IMC), it provided momentum to the polyculture system in Nepal (ADB 1995) [1] in later years, the sub-sector fisheries remained in low profile, and in the last two decades the sector, especially in the areas of indigenous and exotic Carps, Pangas, Tilapia, Rainbow trout and ornamental fishes (Gurung 2008; Rijal and Jha 2020) [24, 54], has commendable progress. Since then, fisheries have been one of the fastest-growing agricultural subsectors in Nepal having an average compound annual fish production growth rate of 5.79% over the last 18 years. The existing intensity of inputs and stocking density-based aquaculture system will not meet the country's demand and target, as proposed by the fisheries perspective plan and ADS (FPP, 2000; ADS 2014) [21, 2] which could be proven by the fact that still significant number of fish, is imported from India, majorly, China, Vietnam, and Bangladesh (Gurung 2021; Ranjan 2019) [28, 48]. The potential for increasing fisheries production can come from the utilization of untapped indigenous fish species. The growing urbanization and opportunities to export markets have been forced to go for more economically high-value indigenous species of our natural water resources (Pradhan *et al*., 2000) [39]. Also, Indigenous fish are of high economic value in the form of food fish as well as sportive and decorative fish (Rajbanshi 2002, 2005) [46-47].

The comparative advantage of the promotion of indigenous species is: they are preferred locally, may have less chance of introducing disease, may grow better under local conditions, may contribute to the preservation of biodiversity, and help maintain the integrity of aquatic communities and ecosystems by appropriate management (FAO, 1997; Vibol and Mattson, 2002) [20, 59]. It is supported by previous surveys conducted at key fishing grounds; Kali Gandaki, Karnali, and Seti River (Swar 2002; Rayamajhi *et al* 2007; Rayamajhi and Lamsal 2010; Rayamajhi *et al*., 2010) [58, 52, 50, 53], upper Sunkoshi (Ranjit 2002) [49], Narayani River basin (Dhital and Jha 2002) [17], Koshi River basin (Yadav 2002; Bhujel *et al*., 2007) [62, 7] which reveals that annual landing solely comprised of indigenous fish species. And, the indigenous fish catch comprised by over 90% with the minor carps (Bista *et al* 2005) [8]. The estimated catch data could be undervaluing, as fishing methods changes with the season, physiography of water body, and the tradition of the specific ethnic community; nature of fishers group is more seasonal with diverse fishing gear practicing fishing in a wider stretch of water sources and fish catches are marked through an informal channel (Wagle and Gurung 2008; Rayamajhi and Pradhan 2011) [60, 51]. All together 22 ethnic groups out of 125 ethnic and caste groups of which 11 broader social groups lived on the bank of water resources and were heavily dependent on the wetland products and services. (IUCN 2004; CBS 2012, CBS 2014; DoFD 2017) [31, 12, 13, 18]. The water resources, being open access to multiple stakeholders at the community level with diverse interests and overlapping government jurisdiction in the federal system, lacks proper policies, programs, and monitoring to support community empowerment for their management are the stage of vulnerable to ecosystem function and fish stock availability. Moreover, anthropogenic activities including dams; diversion of rivers; roads; urbanization; pollution; drying up of wetland; flood plains encroachment, overexploitation, agrochemical run-off; loss of habitats due to riverbed mining, the rampant introduction of invasive alien species as well as natural disaster flash floods, and landslides have been the most critical challenges for self-recruiting fisheries, aquatic genetic resources, micro-organisms, invertebrates genetic resources, and associated biodiversity (Gurung 2017) [26]. This in turn, further marginalized traditional fishers with limited choices either to migrate, adapt and compete on existing fishing pressure at other sites or to change the occupation (Giri 2018) [22]. Moreover, the hill fishery resources of the region are still not explored properly. As such, the region is not developing as per the rest of the country which needs to be understood before the threshold limit. Keeping all these in view, some candidate species suitable for hill fishery aquaculture Gardi and Sahar have been evaluated.

Gardi (*B. dero*) is one of the important riverine fish species well-favored for food fish and contributes daily income, livelihood, and self-employment in the foothills of Nepal (Prasad and Bista, 2011) [40]. It is a herbivorous fish, that feeds on soft aquatic vegetation and periphyton by licking off algal growth from rocks and hard surfaces (Mohanta *et al*., 2008) [37]. Habitat fragmentation, ecological alteration and physical changes in the natural environment (Swar 2002; Gubhaju 2002) [58, 23] have put this game species (Shrestha 2008) [56] under fishing pressure leads to a decline in natural stocks is in recent years (Shrestha and Chaudhary 2003; Prasad and Bista, 2011) [55, 40]. Domestication success and growth of fish shows it survives well in ponds of the mid-hill valley of Nepal and would be of great value for stock enhancement as well as aquaculture development in cold and warm water domains (Baidya *et al*., 2011; Prasad and Bista, 2011; Prasad *et al*., 2017; CFPCC 2018 & 2019) [5, 40, 41, 14-15].

Sahar (*T. Putitora*) also known as "mahseer," is another high-value indigenous game and food fish that provides a good income source for the fishermen living along the riversides, lakes, and reservoirs (Rai *et al*., 1997; Bista *et al*., 2002; Rai *et al*., 2004) [43, 9, 45]. Despite its high value, the population is declining in its natural habitat for two decades (Baidya *et al*., 2006) [4] and has been declared an endangered species (Shrestha 2019; Jha *et al*., 2017) [57, 33]. Considerable development on artificial propagation and its growth and yield performance in different eco-regions give the new platform for the incorporation of Sahar in carp polyculture in Nepal (Jha *et al*., 2017; Bista *et al*., 2011) [33, 10]. Sahar withstands a wide range of water temperature from 6 ºC to 35 °C (Petr, 2002) [38], 25-29 °C is a suitable water temperature for good growth and shows encouraging growth in warm water region than in cold waters (Rai *et al*., 2004; Rai *et al*., 2006; Bista *et al*., 2011) [45, 44, 10]. Rahman *et al*. (2007) [42] conducted experiments on the polyculture of Sahar with Indian major carps showed Sahar would be the best alternative of Mrigal in the polyculture system. Rohu (*L. rohita*) and Naini (*C. mrigala*) are well-known and well-established fish species of Nepal. Intensive farming of Naini 90% with Rohu 10% under multiple stocking and multiple harvesting to produce smaller size fish, called Chhadi, is gaining popularity among fish farmers for short payback period and high net profit per ha in eastern Tarai and other neighboring regions (Hussain *et al*., 2019) [29]. Furthermore, many indigenous medium and minor carps enjoy better markets and prices than major carps in Nepal. The incorporation of these fish with major carp in polyculture makes them more economical than major carp polyculture alone, although the overall yield characteristics and concepts of competition among these species need to be more fully understood. Moreover, the culture of low-trophic-level fish species having a low carbon footprint increases the climate resilience of small-scale fishers and fish farmers (IFAD, 2014) [30]. And, so far, there is no published report on the polyculture of major-minor carp species in polyculture in Nepal. The number and size of fish in ponds have attracted a considerable amount of criticism when relating to the density of fish with their health and welfare issues. Therefore, an attempt was made to optimize stocking density for polyculture of Gardi and Sahar with Rahu and Naini at different combinations.

**Materials and Methods**

Twelve cemented ponds of 100m$^2$ were used for the experiment. The experimental design includes four treatments with three replications. The experiment was conducted in Completely Randomized Design (CRD). Fish species stocked consists of Gardi *B. dero* (6.1±0.3 g); Sahar *T. putitora* (20.3±1.3 g); Rohu, *L. rohita* (27.6±2.2 g); and Naini, *C. mrigala* (27.3±2.7 g. Fish species stocking details used for the experiment are shown in Table 1. The pond water level was maintained at 1 m depth and fish fingerlings were stocked at a rate of 2 fish per sq m with different stocking combinations among treatments. The initial mean weight of fingerlings was recorded and stocked in the respective ponds. Fish was netted monthly for growth observation. Fish of each species (10-20% sample) was netted monthly, weighed to observe growth rate, and feed adjustment was done accordingly. Initial fertilization of the ponds with Urea and DAP @ 0.4 g N/m$^2$/day and 0.2 P/m$^2$/ day was done to produce planktons. The Feeding tray was fixed in each pond and supplementary feed of about 35% CP; at the rate of 3%, total body weight was given 6 days in weeks, once a day at 9.00-9.30 am. Water quality parameters; water temperature, dissolved oxygen, and pH using portable Hanna instrument and Secchi disk transparency, recorded weekly at 6.00-6.30 am and analyzed.

**Table 1:** Species compositions and stocking details

| Polyculture treatments | Pond No. | NO | Mean wt. (g) | No | Mean wt. (g) | No | Mean wt. (g) | No | Mean wt. (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Rohu 25% | | Naini 25% | | Gardi 25% | | Sahar 25% |
| Control | 9 | 10 | 28.4 | 10 | 27.4 | 10 | 6.1 | 10 | 20.6 |
| | 10 | 10 | 24.9 | 10 | 25.7 | 10 | 7.1 | 10 | 21.3 |
| | 12 | 10 | 31.8 | 10 | 31.5 | 10 | 6.3 | 10 | 20.6 |
| | | Rohu 40% | | Naini 20% | | Gardi 20% | | Sahar 20% | |
| Rohu (Major) | 4 | 16 | 29.3 | 8 | 28.2 | 8 | 7.7 | 8 | 21.8 |
| | 14 | 16 | 31.4 | 8 | 32.4 | 8 | 6.9 | 8 | 21.0 |
| | 17 | 16 | 31.7 | 8 | 33.5 | 8 | 6.1 | 8 | 23.8 |
| | | Rohu 20% | | Naini 40% | | Gardi 20% | | Sahar 20% | |
| Naini (Major) | 15 | 8 | 25.1 | 16 | 31.1 | 8 | 7.1 | 8 | 20.2 |
| | 5 | 8 | 26.6 | 16 | 31.7 | 8 | 7.4 | 8 | 19.9 |
| | 18 | 8 | 24.4 | 16 | 29.8 | 8 | 6.5 | 8 | 21.4 |
| | | Rohu 20% | | Naini 0% | | Gardi 40% | | Sahar 20% | |
| Gardi (Major) | 7 | 8 | 23.1 | 8 | 22.8 | 16 | 6.9 | 8 | 20.2 |
| | 8 | 8 | 27.6 | 8 | 28.6 | 16 | 6.6 | 8 | 19.9 |
| | 11 | 8 | 20.8 | 8 | 29.7 | 16 | 6.5 | 8 | 21.4 |

Growth parameter and Feed utilization was calculated from the data obtained using following formulae:

$$\text{Fish growth rate (g/day)} = \frac{\text{Mean final wt (g)} - \text{Mean initial wt (g)}}{\text{Culture period (days)}}$$

$$\text{Specific growth rate (g/day)} = \frac{\text{In final wt (g)} - \text{In initial wt. (g)}}{\text{Culture period (days)}}$$

$$\text{Net fish yield (kg/ha/year)} = \frac{\text{Total harvest weight(kg)} - \text{Total stocked weight (kg)}}{\text{Culture area (ha)xCulture period (days)}}$$

$$\text{Survival (\%)} = \frac{\text{No of fish harvested}}{\text{Number of fish stocked}} \text{x100}$$

$$\text{Net fish yield (kg/ha/year)} = \frac{\text{Total harvest weight(kg)} - \text{Total stocked weight (kg)}}{\text{Culture area (ha)xCulture period (days)}}$$

$$\text{Apparent Feed Conversion Ratio} = \frac{\text{Quantity of feed supplied (g)}}{\text{FIsh weight gain (g)}}$$

The recorded data was analyzed using one-way ANOVA table for difference in water quality parameters, growth and fish production. Gen Stat Discovery Edition 4 was used for analysis of data. Fisher's Protected LSD was carried out to detect the significant differences among means. 5% level of significance was considered to analyze the effect of treatments

## Results and Discussions

### Fish growth

During experimental period, it covered 4 seasons; rainy, spring, winter and summer. When compared to other systems, Rohu fish exhibits continual growth in the the Gardi major polyculture system (Fig 1) where the column feeder to bottom feeder species is 1:1.5. Despite the fact that Rohu and Gardi share the same benthopelagic trophic niche (Shrestha, 2019) [57], the availability of rohu's spatial requirement in this combination may have enabled it to gain better growth than other similar combination, as the Naini major polyculture system. In a previous study, Ellis *et al*., 2002 [19], discovered that decrease in stocking density, increases individual's minimum spatial requirement which in turn influences social interaction and the welfare of farmed fish.

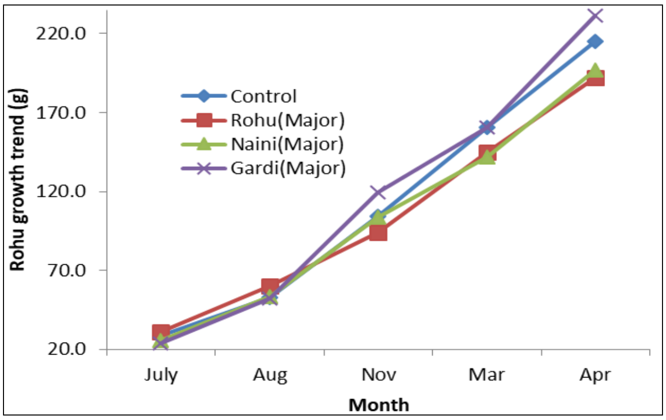


**Fig 1:** Growth of Rohu at different polyculture treatments

In Naini fish, although final growth in all combination is similar, Gardi major and Naini polyculture systems showed a consistent growth trend, whereas Control and Rohu major polyculture systems had a rapid fall from November to March that returned to final growth by April (Fig 2). This could be related to transparency variation across various polyculture systems (Fig 5), where both Control and Rohu major polyculture systems transparency is approximately 57.5-62.3 in November and reaches to optimal range of polyculture system after March.

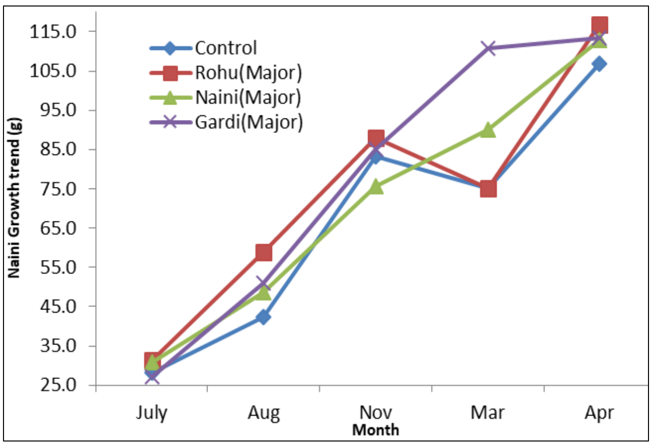


**Fig 2:** Growth of Naini at different polyculture treatments

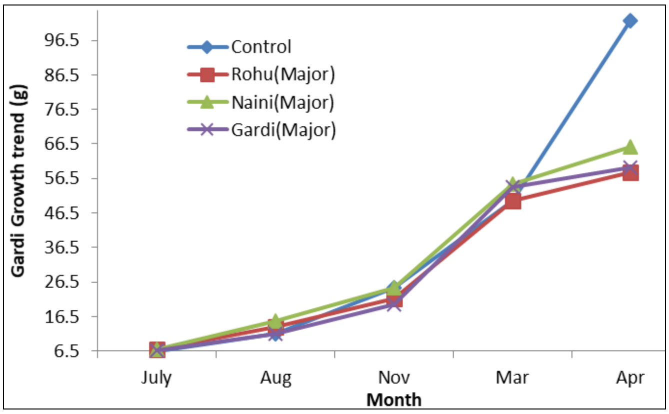


**Fig 3:** Growth of Gardi at different polyculture treatments

Gardi fish growth trend showed constant growth in the control polyculture system (Fig 3) where, water quality parameters (avg± S.E.M) values were temperature 23.3±0.2 (°C) Dissolve Oxygen 1.5±0.7 mg/l; Transparency 50±6 cm and pH value 8.3±0.1 (Table 3). Other reason could be browsing and burrowing for food by bottom feeder fishes in these particular combinations could have optimally increased bioavailability of nutrients and accelerated the plankton production of pond water as observed in study (Milstein *et al*., 2002; Wahab *et al*., 2002) [36, 61]. The overall ratio of column feeder species (herewith Rahu and Sahar) to bottom feeder species (herewith Naini and Gardi) in present study was 1:1. Similarly, supporting result was observed in study by Prasad and Bista (2011) [40] where in comparison to present study monoculture nursing of larger fingerlings i.e., 11g were stocked at lower density, one fish per square meter. Contrarily, in present study the growth of Gardi was found to be comparable in other treatment combinations, such as the Rohu major polyculture system (column feeder species to bottom feeder species is 1.5:1) and the Naini major and Gardi major polyculture system (column feeder species to bottom feeder species is 1:1.5) (Fig 3). This could be due to antagonistic ecological interactions between the species in these systems trophic cascade (Borer *et al*., 2005) [11]. It is difficult to establish specific reason of the slow growth trend for this study in this short period as there could be a number of possibilities and the dearth of papers reporting these particular species in combinations.

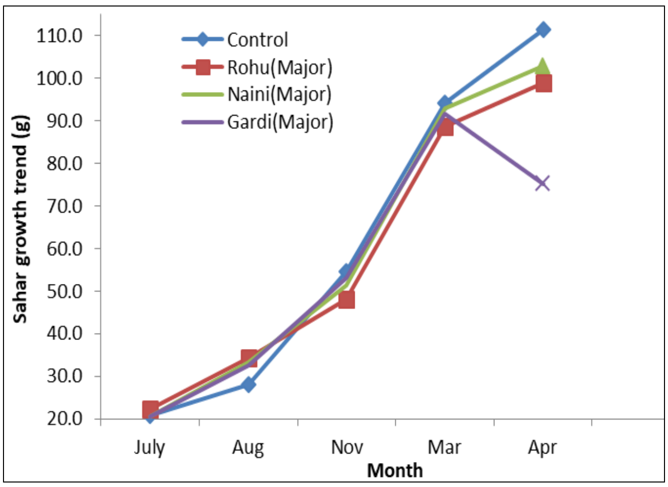


**Fig 4:** Growth of Sahar at different polyculture treatments

The Growth of Sahar showed geometrical ratio during December to February. After then, the growth was steady in control polyculture system; comparable in Rohu major and Naini major polyculture systems; while it was sharp decline in Gardi major polyculture system (Fig 4). The difference in Sahar could be attributed to its feeding habit difference in accordance to its growth as smaller size prefer more animal matter and large size consume more plant material (Bhatta and Pandit, 2015) [6]. Moreover, Sahar feeding activities was found active during pre-monsoon (Mahaseth, 2016) [34]. The overlapping feeding niche could have initiated competition in different system. However, the difference in Sahar growth in different system was observed after February could be due to growth difference as a result of seasonal feeding pattern because Sahar shows higher feeding activity during winter and lower its feeding activity during summer (Alam *et al*., 2002) [3].

**Water quality**

The physico-chemical parameters of water in the experiment ponds were in the following ranges during the study period: Water temperature 15.8$^0$-30.6 °C; Dissolve oxygen 5.8- 15.4 mg/l; Transparency 21.9-93.7 cm and, pH 7.5-9.2. The Temperature values in different stocking combinations did not show any discernible trend throughout the study. In general, Temperature followed a declining trend from august (30.6 °C) coming minimum at January (around 15.8 °C), then increased after February to finally reach 25.4 $^0$C at April (Fig 7). It is empirical that fish growth is temperature dependent, and regardless of combination, steady growth in fishes in this study was recorded from February to April after Fall (Fig 1-4). Similarly, pH of pond water was around 9 during initial period, which decreased to about 8.5 during November, then exhibiting staircase growth trend and reaches around 9 in February, then decreased to a range of 7.5 (Gardi major polyculture system) to 8.7 (Rohu major polyculture system) at end of the experiment (Fig 8). Meanwhile, Dissolve oxygen showed that the initial oxygen was around 12.8 mg/l in August and decreased to about 9.4 mg/l in Gardi and Rohu major polyculture systems, while slightly higher oxygen level 12.2 mg/l in Control and lower oxygen level 7.8 mg/l in Naini major polyculture system were recorded during October, which then steadily increased from 15.4 mg/l in Naini major polyculture system to 11.1 mg/l in Gardi major polyculture system during February and gradually dropped from 5.8 mg/l in Gardi major polyculture system to 7.9 mg/l in Rohu major polyculture system, at the end of the experiment (Fig 6). The difference in oxygen level in different treatments could be a result of plankton's abundance in different stocking combination which is visible from variability of secchi disk transparency reading (Fig 5). Transparency was around 93.7 cm in Gardi major polyculture system and around 78.9 cm in other three systems in August, decreased from 56.8 cm in Gardi major polyculture system to 42.3 cm in Rohu major polyculture system in September, stabilized around 52.2 cm in Gardi major polyculture system to 41.4 cm in Rohu major polyculture system, then increased 62.3 in control system to 42.9 cm in Gardi major polyculture system in November, following twist and turn in January, gradually decreases to final transparency reading from 28.6 cm in Naini major polyculture system to 24.2 cm in Rohu major polyculture system (Fig 5).

**Table 2:** Water quality parameters as range and (Avg± S.E.M) value observed during experimental period

| Polyculture treatments | Temperature (°C) | Dissolve Oxygen (mg/l) | Turbidity (cm) | pH |
|---|---|---|---|---|
| | 15.8-30.5 | 7.3-14.8 | 25.8-80.6 | 7.7-9.2 |
| Control | 23.3±0.2 | 11.5±0.7 | 50±6 | 8.3±0.1 |
| | 15.8-30.6 | 7.9-14 | 21.9-80 | 8-9.1 |
| Rohu (Major) | 23.5±0.1 | 11.2±0.3 | 45±4 | 8.5±0.1 |
| | 16-30.6 | 7.1-15.4 | 25.8-78.9 | 8.1-9.1 |
| Naini (Major) | 23.4±0.1 | 11.5±0.4 | 42±1 | 8.4±0.0 |
| | 16.1-30.6 | 5.8-12.8 | 24.2-93.7 | 7.5-8.7 |
| Gardi (Major) | 23.6±0.1 | 10.6±0.2 | 49±5 | 8.1±0.1 |

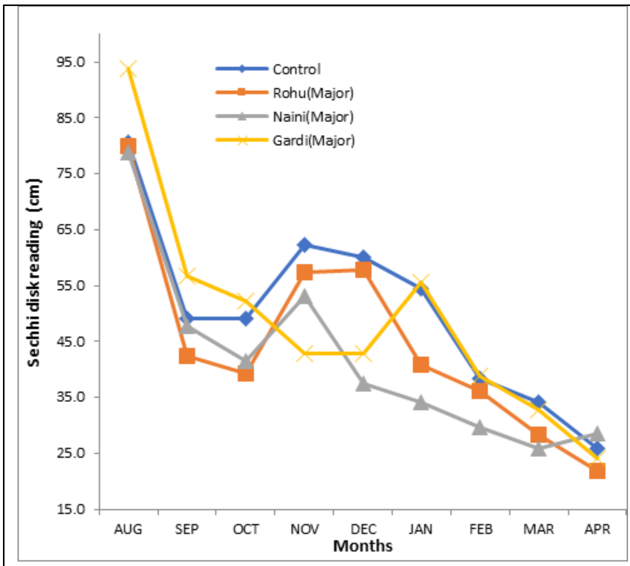


**Fig 5:** Transparency (cm) variation at different polyculture treatments

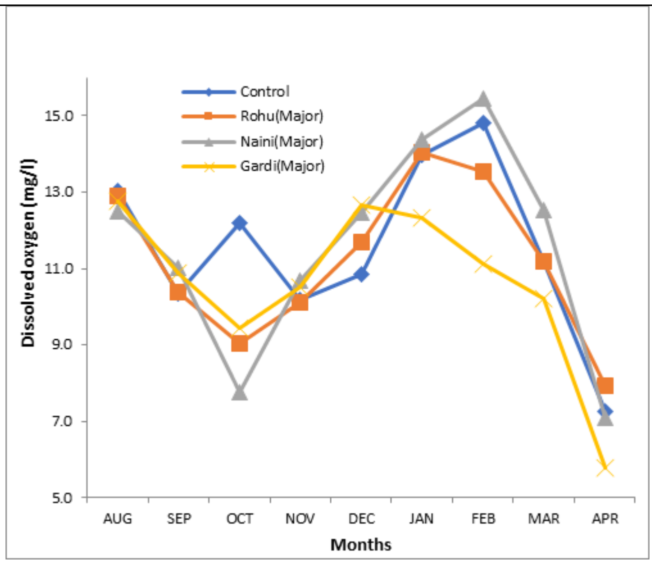


**Fig 6:** Dissolved oxygen (mg/l) variation at different polyculture treatments

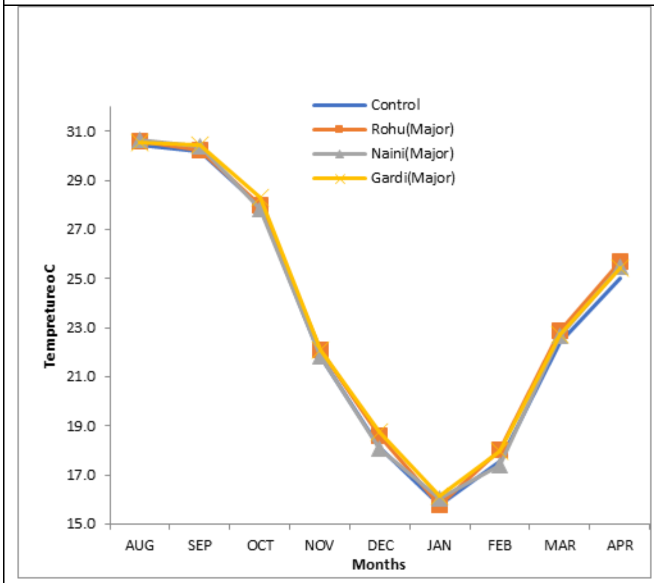


**Fig 7:** Temperature (°C) variation at different polyculture

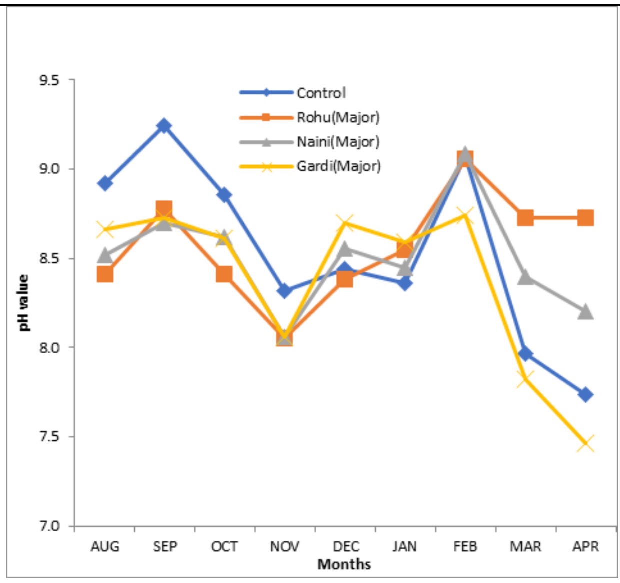


**Fig 8:** pH variation at different polyculture

Overall, no significant between in mean Temperature, Dissolve oxygen, Transparency and pH values across different polyculture system was recorded.

**Table 3:** Fish growth rate (g/day), Specific growth rate, Final body weight (g), Survival (%), Net fish Yield (Kg/ha/yr) and Apparent feed conversion ratio of different fish species as range and (Avg± S.E.M) value during experimental period

| Polyculture treatments | Rohu | | | | | Naini | | | | | Gardi | | | | | Sahar | | | | | AFCR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FGR (g/day) | SP. GR (g/day) | FINAL WT(g) | Survival % | NFY (kg/ha/year) | FGR (g/day) | SP. GR (g/day) | FINAL WT(g) | Survival % | NFY (kg/ha/year) | FGR (g/day) | SP. GR(g/day) | Final WT(g) | Survival % | NFY (kg/ha/year) | FGR (g/day) | SP. GR(g/day) | Final WT(g) | Survival % | NFY (KG\HA\YEAR) | |
| Control | 0.69 ± 0.08 | 0.0032± 0.0002 | 2080.10± 222.04 b | 96.67± 3.33 | 0.00024± 0.00003 ab | 0.29± 0.04 | 0.0021± 0.0002 | 1037.97± 119.10 a | 96.67± 3.33 | 0.00010± 0.00002 | 0.35± 0.11 | 0.0043± 0.0005 | 743.40± 268.44 | 70.00± 5.77 | 0.00009± 0.00004 | 0.33± 0.07 | 0.0026± 0.0002 | 1033.20± 159.07 | 93.33± 3.33 | 0.00011± 0.00002 | 2.78± 0.36 |
| | 0.54-0.83 | 0.0029-0.0037 | 1745.00-2500.00 | 90.00-100.00 | 0.00020-0.00031 | 0.22-0.36 | 0.0017-0.0025 | 819.90-1230.00 | 90.00-100.00 | 0.00007-0.00013 | 0.23-0.57 | 0.0037-0.0052 | 460.20-1280.00 | 60.00-80.00 | 0.00005-0.00017 | 0.26-0.47 | 0.0024-0.0031 | 849.60-1350.00 | 90.00-100.00 | 0.00009-0.00015 | 2.22-3.44 |
| Rohu (Major) | 0.60± 0.05 | 0.0029± 0.0001 | 2650.00± 145.72 c | 87.50± 9.55 | 0.00029± 0.00002 a | 0.32± 0.01 | 0.0021± 0.0001 | 856.77± 44.02 a | 91.67± 4.17 | 0.00008± 0.00001 | 0.19± 0.04 | 0.0034± 0.0004 | 426.80± 38.30 | 95.83± 11.02 | 0.00005± 0.00001 | 0.28± 0.06 | 0.0024± 0.0002 | 763.03± 149.79 | 95.83± 4.17 | 0.00008± 0.00002 | 3.09± 0.14 |
| | 0.53-0.69 | 0.0027-0.0031 | 2420.00-2920.00 | 68.75-100.00 | 0.00026-0.00033 | 0.30-0.33 | 0.0020-0.0023 | 790.30-940.00 | 87.50-100.00 | 0.00007-0.00010 | 0.13-0.26 | 0.0028-0.0041 | 350.40-469.80 | 75.00-112.50 | 0.00004-0.00006 | 0.22-0.40 | 0.0021-0.0028 | 580.30-1060.00 | 87.50-100.00 | 0.00006-0.00012 | 2.85-3.35 |
| Naini (Major) | 0.63± 0.03 | 0.0033± 0.0000 | 1507.17± 19.68 a | 95.83± 4.17 | 0.00018± 0.00000 b | 0.30± 0.01 | 0.0021± 0.0001 | 1736.00± 129.73 b | 95.83± 4.17 | 0.00017± 0.00002 | 0.22± 0.01 | 0.0036± 0.0001 | 413.20± 3.40 | 79.17± 4.17 | 0.00005± 0.00000 | 0.41± 0.02 | 0.0030± 0.0001 | 1045.33± 39.28 | 100.00± 0.00 | 0.00012± 0.00001 | 3.02± 0.12 |
| | 0.59-0.69 | 0.0032-0.0033 | 1484.80-1546.40 | 87.50-100.00 | 0.00017-0.00018 | 0.28-0.33 | 0.0020-0.0021 | 1489.60-1929.60 | 87.50-100.00 | 0.00014-0.00019 | 0.20-0.23 | 0.0034-0.0038 | 409.80-420.00 | 75.00-87.50 | 0.00005-0.00005 | 0.37-0.43 | 0.0029-0.0031 | 968.00-1096.00 | 100.00-100.00 | 0.00011-0.00013 | 2.89-3.27 |
| Gardi (Major) | 0.77± 0.05 | 0.0036± 0.0002 | 1606.90± 69.95 ab | 87.50± 7.22 | 0.00019± 0.00001 b | 0.32± 0.05 | 0.0023± 0.0003 | 641.67± 198.75 a | 75.00± 25.00 | 0.00006± 0.00003 | 0.20± 0.03 | 0.0035± 0.0002 | 430.27± 355.31 | 39.58± 30.26 | 0.00004± 0.00005 | 0.30± 0.05 | 0.0017± 0.0009 | 724.30± 141.06 | 87.50± 7.22 | 0.00008± 0.00002 | 4.20± 0.85 |
| | 0.66-0.82 | 0.0032-0.0039 | 1470.00-1700.30 | 75.00-100.00 | 0.00018-0.00021 | 0.22-0.38 | 0.0018-0.0026 | 265.00-940.00 | 25.00-100.00 | 0.00000-0.00010 | 0.13-0.24 | 0.0030-0.0037 | 65.00-1140.80 | 6.25-100.00 | -0.00001-0.00014 | 0.22-0.39 | 0.0000-0.0029 | 557.90-1004.80 | 75.00-100.00 | 0.00005-0.00011 | 2.62-5.53 |

**Note:** a. Means with different superscripts within treatments within each group differ significantly at $p<0.05$.
b. Polyculture systems
Control = Rohu25%, Naini 25%, Gardi25% and Sahar 25%
Rohu (Major) = Rohu40%, Naini 20%, Gardi20% and Sahar 20%
Naini (Major) = Rohu20%, Naini 40%, Gardi20% and Sahar 20%
Gardi (Major) = Rohu20%, Naini 20%, Gardi40% and Sahar 20%

Fish growth rate (g/day, Specific growth rate, Final body weight (g), Survival (%) and Net fish Yield (Kg/ha/yr) of different fish species during experimental period in different treatments are shown details in table 3. Fish growth rate, specific growth rate, survival rate of Rohu was found similar (*p*<0.05) among all treatments. Similarly, fish growth rate, specific growth rate, survival rate and net fish yield of Naini was found similar (*p*<0.05) among all treatments. But, final body weight of Rohu was observed significantly higher (*p*<0.05) in Rohu major (2650.00±145.72) polyculture system than others. Also, net fish yield of Rohu was observed significantly higher (*p*<0.05) in Rohu major (2650.00±145.72) polyculture system than in Naini major and Gardi major polyculture systems but not with control polyculture systems. Whereas, parameters of Gardi and Sahar observed similar in all polyculture systems. AFCR$^{ns}$ was found higher in high in Gardi major polyculture system and non-significant with other polyculture systems. The AFCR was found to be negatively influenced by stocking densities (Mehta *et al*., 2018) [35], and in Gardi major polyculture system both Rohu and Gardi shares benthopelagic trophic niche (Shrestha, 2019) [57]. Probable explanation of higher AFCR of fish maintained at Gardi major polyculture system might be due to the slow growth rate, high competition and space among the fishes.

## Conclusion

On the basis of aforementioned findings, we found that fish growth rate and specific growth rate of Rohu$^{ns}$ and Naini$^{ns}$ were high in Gardi major polyculture system and Gardi$^{ns}$ in control polyculture system. Even though, Rohu and Gardi have the same benthopelagic trophic niche, and the column to bottom feeder stocking ratio in Gardi as well Naini Major polyculture system is same, the better compatibility of Gardi with Rohu with lesser Naini could helped Rohu and Naini attain high Growth rate in Gardi major polyculture system. This suggests Gardi could be a substitute to Naini as "bottom feeder" in the polyculture system without compromising the overall production. And, Sahar$^{ns}$ fish growth rate was high in control polyculture system whereas specific growth rate was high in Naini major polyculture system. Furthermore, Sahar growth performance in Gardi major polyculture systems was comparatively lower than other systems. The difference in growth indices suggests that Gardi and Sahar are incompatible or have no mutually beneficial connection in the same polyculture system, since the column to bottom feeder stocking ratio in both the Gardi and Naini Major polyculture systems is the same, and both have similar water quality parameters. Moreover, Final body weight and net fish yield of Rohu$^{s}$, Naini$^{s}$; Gardi$^{ns}$ were high in respective major polyculture systems, but Sahar$^{ns}$ was high in Naini major polyculture system. In case of survival, all fish species had high survival rate in Naini major polyculture system. Thus, the Naini major polyculture system is concluded to be the optimum combination for these particular species.

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