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Multi-locations and stability evaluation on growth character of the permata hybrid carp

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Abstract
The success of establishing the Indonesian growing fast hybrid carp, namely "Permata", on a controlled environmental test must be followed up with a large-scale test. This study aims to evaluate the phenotypic performance of the Permata hybrid carp in multi-locations with different cultivation systems. The test sites consisted of floating net cages, running-water ponds, semi-concrete ponds, earthen ponds, fully concrete ponds, and static net cages. For 90 days, fish were fed commercial pellets with a 28%–30% protein content. At the end of the test, all fish were harvested and counted. Data on length, weight, survival rate, and harvested biomass were used to analyze the effect of genotype, environment, and their interaction on the phenotypic performance. The growth based on final weight is used to analyze the stability performance in each test location. The results showed that the length and weight of common carp were significantly affected by genotype and the environment, but not by the interaction of both. The genotype, environment, and the interaction of both factors affected common carp's survival and harvested biomass. Common carp reared in floating net cages generally had the best performance, while carp reared in fully concrete tanks and static net cages had the lowest. The growth stability analysis showed that the common carp in this study were unstable genotypes but have a broad adaptability in term of different environments.

Keywords: Adaptability, G × E interaction, Growth stability, Indonesian common carp

Introduction

The development of common carp (*Cyprinus carpio*) cultivation in Indonesia is experiencing serious problems. Farmers have felt the growth rate decline for over two decades. The decrease in the growth rate of carp is thought to be caused by the low genetic variability and the high level of inbreeding in the seed population. Ariyanto et al. (2018) reported that the level of genetic variability of several strains of common carp that the farmers cultured was very low, with heterozygosity values ranging from 0.08 to 0.20. In addition, the level of inbreeding in those carp strains also shows a high value, ranging from 0.79 to 0.91 (Ariyanto et al., 2019a). Nielsen et al. (2010) stated that inbreeding usually implies reduced performance for both fitness traits

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(e.g., survival, resistance to diseases and reproduction) and production traits (e.g., growth rate). The high rate of inbreeding in Indonesian common carp populations is suspected due to the limited number of broodstock in most hatcheries. Besides that, the method of producing new broodstock by farmers also does not follow the brood formation protocol (Ariyanto et al., 2019a).

There are several efforts to improve the quality of carp seeds. One breeding method that relatively quickly combats inbreeding pressure is crosses or hybridization between strains (Falconer & Mackay, 1996). The latest initiation of the formation of the hybrid common carp has been carried out since 2016, when the synthetic carp population was formed as the basic population in the selection program (Ariyanto et al., 2021). As the founder population, five strains of common carp which are dominantly cultivated by farmers, namely Majalaya (Mj), Rajadanu (Rj), Wildan (Wd), Sutisna (St) and Sinyonya (Sy), were used. The use of those strains was based on the research of Ariyanto et al. (2018), who reported that those five common carp strains had quite a long genetic distance, ranging from 0.42 to 0.58. Genetic distance analysis is important in crossbreeding activities because the farther the genetic distance between two different strains, the greater the chance of obtaining high hybrid vigour (Suryani & Arya, 2019; Wang & Xia, 2002).

The staged screening was carried out on 25 populations resulting from crosses to obtain the best hybrid carp population. Based on the best yields in the controlled test, hybrid populations of St >< Sy, Mj >< St and St >< Rj were obtained as candidates for new superior varieties for cultivation (Ariyanto et al., 2022). Based on the considerations of growth rate, yield, farmers, and consumer preferences, the results of the Mj >< St cross were chosen as the best hybrid population, and it was proposed to be named the "Permata" hybrid carp. This new superior population must be tested on a wide scale through multi-site tests and multi-cultivation systems tests. Testing in multiple locations and multi-systems is very important before the farmers with various culture models widely cultivate the new varieties due to the fact that genetic, environmental, and interaction factors influence phenotypic performance. Especially in carp, the influence of the environment on phenotypic performance is very large (Ariyanto et al., 2019b; Wang & Li, 2007). This impacts the cultivation results when carried out in locations with different environmental conditions. Likewise, various cultivation systems will greatly affect the phenotypic performance of common carp.

Different agro-climatic conditions can affect the morphological and physiological characteristics of cultured fish. These conditions affect the body's color, shape, growth rate, resistance to disease and environmental stress, and survival. Varied water temperatures, gradations of dissolved oxygen, different current velocities, and various contaminants and mineral contents are some of the physical and chemical characteristics of waters that greatly affect the phenotypic performance of cultured fish. For example, the color of fish reared at low temperatures tends to be lighter than that of fish reared at high temperatures (LanMei et al., 2018). The body shape of fish reared in water with low currents tends to be fatter with flabby muscles than fish reared in waters with strong currents, resulting in a streamlined shape with more compact muscles (Hammar et al., 2013). The different dissolved oxygen, pH values, and mineral content significantly affect the growth rate of fish (Abdel-Tawwab et al., 2015). Likewise, the ability of fish to be cultured in waters with varying levels of contamination will affect the survival rate of the population (Huang et al., 2013; Sarkar et al., 2022).

This study aims to evaluate the phenotypic performance of the Permata hybrid carp in multiple locations and cultivation systems developed in Indonesia, including growth, condition factors, survival, and yield biomass. In addition, the research also aims to evaluate the stability of growth obtained at various locations and cultivation systems. One method to evaluating the stability of plant or animal cultivation that is widely used is repeated testing in various cultivation environments (Singh & Chaudhary, 1979).

Materials and Methods

Tested fish

The tested fish was a population of Permata hybrid carp obtained from the Research Institute for Fish Breeding (RIFB) at Sukamandi station, Subang District, West Java. As the comparison, we used Majalaya carp strain, which is a great strain farmer largely used. This Majalaya carp were obtained from a certified hatchery that had received Majalaya broodstock from the Wanayasa Freshwater Fish Development Center (FFDC) at Pabuaran, Subang District, West Java. The age of the Permata hybrid and Majalaya carp at the time of stocking was two months after hatching, with an average body length of 12.05 ± 1.34 cm and a body weight of 14.28 ± 4.44 g.

The method and location of the test

Multi-location tests were conducted in five locations with six

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models of cultivation systems: floating net cages in Cirata Reservoir (Cianjur), running water ponds in Kasomalang (Subang), semi-concrete ponds in Lundar (Pasaman), earthen ponds in Cilamaya (Karawang), fully concrete ponds in Sukamandi 1 (Subang), and static net cages in Sukamandi 2 (Subang). All test in each location was conducted in two replications. The geographical location of the test locations is presented in Fig. 1. The specific conditions of the locations and the water quality at each test location are presented in Table 1.

Experimental design

The experimental design used was a factorial design, with the first factor being carp genotypes and the second factor being the location with different cultivation systems. Floating net cages in Cirata Reservoir measuring 7 × 7 × 3 m are stocked with a fish density of 5,000 fish per cage. The running water ponds in Kasomalang, measuring 4 × 20 × 2.5 m, are stocked with common carp seeds at a density of 1,500 fish per pond. In Lundar, a 25 × 20 × 1.5 m semi-concrete pond was stocked with fish at a density of 2,200 fish per pond. The earthen pond in Cilamaya, measuring 5 × 5 × 1.5 m, was stocked with 250 fish per pond. In Sukamandi, cultivation model 1 (Sukamandi 1) used a 2.5 × 10 × 1.5 m fully concrete pond stocked with 500 fish, and cultivation model 2 (Sukamandi 2) used a 5 × 5 × 1.5 m static net cage stocked with 250 fish.

During the 90-day test period, fish were fed *ad libitum* commercial pellets with a 28%–30% crude protein content. Seed sampling was carried out every month with a sample size of 50 fish for each replication. Sampling was carried out based on the length and weight of the fish. Before sampling, a water quality test was carried out with temperature, dissolved oxygen, pH, nitrite, and ammonia parameters. At the end of the activity, all seeds were harvested, and the biomass was weighed for analysis.

Data analysis

The effect of genotype, environment, and the interaction between the two on the phenotypic performance of carp was analyzed using analysis of variance (ANOVA). The analysis was carried out on several parameters related to cultivation, namely individual length and body weight, survival rate, and harvested biomass of each test population. In this analysis, if the calculated F is more than the F table, it means that genotype, environment, and the interaction of both have a significant effect on each measured parameter. The analysis was performed using Microsoft Excel 2010 software.

The relationship between individual length and weight was analyzed to evaluate the population growth rate pattern related to environmental conditions. The analysis was performed using Microsoft Excel 2010 software with the following model:

Fig. 1. Locations map of the multi-location and multi-system test for Permata hybrid carp culture. A. Cirata reservoir (Cianjur); B. Kasomalang (Subang); C. Lundar (Pasaman); D. Cilamaya (Karawang); E. Sukamandi (Subang).

Table 1. General condition and water quality of the site location test for Permata carp along three-month test period

The parameter	Site location					
	Cirata	Kasomalang	Lundar	Cilamaya	Sukamandi 1	Sukamandi 2
Altitude (m asl)	220	200	500	12	16	16
Culture system	FNC	RWP	SCP	EP	FCP	SNC
Turbidity (cm)	35.8–58.8	40.3–60.6	35.0–40.0	20.5–35.0	25.0–40.0	20.5–30.9
Temperature (℃)	27.0–30.0	25.2–28.5	26.5–29.5	27.5–32.5	27.4–31.9	28.0–31.2
Dissolved oxygen (mg/L)	3.5–5.2	2.8–4.8	3.0–5.0	0.8–3.5	0.2–3.2	0.6–5.2
pH	6.5–8.5	6.8–8.0	7.0–8.5	7.0–8.5	6.5–8.0	6.5–7.5
Ammonia (mg/L)	0.0–0.6	0.0–0.3	0.0–0.1	0.0–0.4	0.0–0.08	0.0–0.05
Nitrite (mg/L)	0.0–0.8	0.0–0.6	0.0–0.2	0.0–0.3	0.0–0.1	0.0–0.07

asl, above sea level; FNC, floating net cages; RWP, running water ponds; SCP, semi-concrete ponds; EP, earthen ponds; FCP, fully concrete ponds; SNC, static net cages.

$$W=a.L^b \quad (1)$$

The condition factor (Kn) is the state or plumpness of the fish, which is expressed in numbers based on the individual length and weight. The condition factor can be calculated by the following formula (Le Cren, 1951):

$$K_n = \frac{W}{a.L^b} \quad (2)$$

Explanation:

W = weight
L = length
a, b = constant
K_n = condition factor

The stability of the common carp culture tested was estimated on growth parameters with daily growth rate character indicators. This estimation involves an analysis of the environmental index based on the growth of the fish at each location. In this estimation, stability of a genotype was analyzed using the average value of the sum of the squares of the regression deviations, following Eberhart & Russell (1966). The analysis was performed manually using Microsoft Excel 2010 software, with a linear model as follows:

$$Y_{ij} = \mu + b_i I_j + \delta_{ij} \quad (3)$$

$$I_j = \frac{\sum_i Y_{ij}}{t} = \frac{\sum_i \sum_j Y_{ij}}{tm}$$

Explanation:

Y_{ij} = Average of the i^{th} genotype in the j^{th} location
μ = Average of all genotypes in all locations
b_i = Regression coefficient of the i^{th} genotype on the environmental index indicates the genotype's response to the environment
I_j = Environmental index, namely the deviation from the genotype average in a season on all averages
t = The number of genotypes in each location
m = The seasons
δ_{ij} = Regression deviation of the i^{th} genotype in the j^{th} location.

The genotype is considered stable if the regression coefficient (b_i) is not significantly different from one and the regression standard deviation (S^2_{di}) is not different from zero based on the student's t-test. The following formula approximates the value of b_i:

$$b_i = \frac{\sum Y_{ij} I_{ij}}{\sum I_j^2} \quad (4)$$

The S^2_{di} was obtained by the following formula:

$$S^2_{di} = \frac{\sum \delta^2_{ij}}{I-2} - \frac{S^2_e}{r} \quad (5)$$

Explanation:

S_e^2 = estimation of error variant
r = replication

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Results

Environment at research sites

Based on Table 1, the test locations are at different altitudes. The Cirata reservoir in Cianjur is located 220 meters above sea level, so it has moderate water temperatures. The running water pond in Kasomalang is also located in the semi highlands, around 200 meters above sea level, with moderate water temperatures and fast water flow. These two locations have a higher brightness level than the other four locations because there are fewer suspended solid particles. The semi-concrete pond in Lundar is located at an altitude of 500 meters above sea level and has a low to moderate temperatures with moderate water flow. The research locations in Cilamaya, Sukamandi 1, and Sukamandi 2 have relatively the same characteristics, which are in the lowlands with an altitude of less than 20 meters above sea level. The water temperature at these locations is relatively warm.

The average oxygen dissolved in Cirata, Kasomalang, and Lundar is relatively higher than that in the other three locations. There is relatively faster current flow compared to the other three locations. In Cilamaya, Sukamandi 1, and Sukamandi 2 the dissolved oxygen was the lowest, even reaching less than 1 mg/L. This condition usually occurs at dawn when the photosynthesis process of phytoplankton has not yet occurred. However, the dissolved oxygen measured is the amount of oxygen content in the water after being used by the fish, so that the fish are still able to survive well. In general, pH levels, ammonia, and nitrite content at all research locations are still within limits that can be tolerated by farmed carp (Suryadi et al., 2022).

Phenotypic performance of the Permata hybrid carp

The phenotype performance of cultivars is influenced by genotype, environment, and the possibility of an interaction between genotype and environment factors. To evaluate the influence of those factors on the performance of the two carp populations in this study, the variance was analysed using the combined data at all experimental sites. The *F*-values obtained from an ANOVA for genotype (G), environment (E), and the interaction between genotype and environment (G × E) on each parameter is presented in Table 2.

Table 2. The calculated *F*-value in the analysis of variance of genotype, the environment, and the interaction of the two for each cultivation character tested (α = 0.05)

Character	Calculated *F*-value		
	Genotype (G)	Environment (E)	G × E
Length	14.48*	32.34*	1.32ns
Weight	11.95*	18.76*	1.69ns
Survival	18.04*	114.03*	12.28*
Biomass	10.48*	61.43*	3.53*

*Asterisk marker showed a significant effect ($p < 0.05$).
ns, not a significant effect.

Based on the analysis in Table 2, the phenotypic performance of carp, particularly in terms of length and body weight, is influenced by genetic and environmental factors. However, the two characters are not influenced by the interaction between the two factors. These results are different from the characteristics of survival and harvested biomass, which are influenced by genetic factors, environmental factors, and the interaction between the two. This difference is suspected because survival and harvested biomass are influenced by more complex external factors, such as individual weight at harvest, the number of seeds sown, and the survival rate obtained at the end of the activity. The complexity of these external factors is thought to cause interactions between genetic factors, which are incidentally internal, and environmental factors, which have a significant effect, especially on the character of harvested fish biomass.

This study's results align with research conducted by Ariyanto et al. (2019b) and Linhart et al. (2002), which reported that environmental influences were the main factor influencing common carp performance, while the influence of genetic factors was relatively smaller. However, genetic factors also determine the performance of cultivated common carp, particularly in the length and weight growth characteristics of individuals. Relatively, the same results were also obtained in analyzing the effects of interactions between genetic and environmental factors, which resulted in relatively low scores. Although it did not significantly affect the growth of weight and length, the interaction of the two internal and external factors significantly affected the survival and harvested biomass, which is the main component of carp farming activities.

Further analysis of the phenotypic performances of the Permata hybrid carp and the Majalaya carp, including average individual length and weight, is presented in Table 3. Growth patterns related to the relationship between length and weight and fish condition factors (Kn) were presented in Table 4. Based on Table 3, the two common carp populations reared in locations with different cultivation models have varied phenotypic performances. In general, common carp reared in floating net cages in Cirata had the best length and individual weight, while

Table 3. The individual length and weight of Permata hybrid carp and Majalaya carp were reared in five locations and six different cultivation systems for three months

Test location	Permata hybrid carp		Majalaya carp	
	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Cirata	25.2 ± 1.9[a]	398.8 ± 58.6[a]	20.6 ± 2.1[a]	233.3 ± 88.2[a]
Kasomalang	20.0 ± 1.6[b]	321.8 ± 72.8[ab]	18.6 ± 0.9[a]	248.0 ± 24.6[a]
Lundar	20.1 ± 2.5[b]	248.7 ± 95.9[ab]	17.0 ± 3.1[a]	153.5 ± 95.2[ab]
Cilamaya	19.7 ± 1.0[b]	266.7 ± 35.1[b]	18.2 ± 1.0[a]	235.2 ± 30.9[a]
Sukamandi 1	13.6 ± 1.0[c]	93.2 ± 21.0[c]	13.0 ± 0.4[b]	79.9 ± 4.6[b]
Sukamandi 2	14.0 ± 0.4[c]	88.2 ± 8.6[c]	12.9 ± 0.4[b]	77.8 ± 4.3[b]

The different superscripts in the same column showed significant differences ($p < 0.05$).

Table 4. Coefficient of regression between length and weight (R^2), constant b and condition factor (K_n) of the hybrid Permata and Majalaya carp were reared in six locations and different cultivation systems for three months

Test location	Permata hybrid carp			Majalaya carp		
	R^2	b	K_n	R^2	b	K_n
Cirata	0.9646	2.6393	1.0064	0.9361	2.8127	1.0142
Kasomalang	0.9578	2.6353	1.0052	0.9449	2.4979	1.0048
Lundar	0.7478	2.8305	1.0505	0.9041	3.1530	1.0329
Cilamaya	0.7891	2.2073	1.0072	0.7891	2.2073	1.0072
Sukamandi 1	0.8715	2.4430	1.0091	0.7738	2.1923	1.0068
Sukamandi 2	0.7730	2.4796	1.0147	0.6201	1.8376	1.0128

R^2, regression coefficient; b, constant of regression; K_n, condition factor.

carp reared in Sukamandi, both in concrete tanks (1) and static net cages (2), had the lowest performance in length and weight. These results indicate that the maintenance of carp is influenced by the location and cultivation system being implemented.

Table 4 shows that the correlation between individual length characters and weights is relatively high, ranging from 0.62 to 0.96. The highest correlation was found in carp rearing in floating net cages in Cirata, followed by carp in running water ponds in Kasomalang, and the lowest was in carp rearing in static net cages in Sukamandi 2. Generally, the constant b in carp rearing in several different locations is below 3, except in Lundar at 3.15. This shows that the growth of the common carp is allometric. This indicates that the growth in length is faster than that in weight. This condition produces a relatively long carp with a condition factor of 1.00 to 1.05.

Apart from length and weight parameters, another important parameter in fish farming is survival, which directly affects the harvested yield. The survival and harvested biomass of carp in this study are presented in Table 5. Table 5 also presents the difference in yield (biomass) between Permata hybrid carp and Majalaya carp at each test site. Based on Table 5, the character of harvested biomass has a high degree of variation among sites. Yield biomass is influenced by individual weight and the number of fish harvested. The number of fish harvested in this study varied considerably according to the cultivation system, which was related to the amount of stocking. The number of fish harvested will increase at a high stocking with a high survival rate, so the biomass obtained will be even greater. However, despite the high survival rate, it will not produce a large biomass harvest if the number of stockings is small. Compared to the Majalaya carp, cultivating the Permata hybrid carp provides better yields. The difference in harvested biomass between cultivation using Permata hybrid carp and Majalaya carp is 9.4%–54.4%.

Evaluation of growth stability

Growth is an important parameter in a fish farming business. Fish that have a fast genetic growth rate will shorten the cultivation period, thereby increasing business efficiency. However, besides being influenced genetically, the growth rate of fish is also influenced by external factors, namely the cultivation environment. The meaning of environment in this context is not only related to the physico-chemical quality of the cultivation media but also includes the cultivation system, stocking density, feed, and so on. An environmental index can be used to evaluate the quality of the cultural environment. The environmental index based on the daily growth rate in each location tested in this study is presented in Table 6. Based on Table 6, the Cirata Reservoir location with the floating net cage cultivation system has the highest environmental index. This is indicated by the fastest growth rate of carp seeds in the cultivation system at that location, resulting in the best individual weight at harvest. Successively, the growth rate of the carp was followed by cultivation in the running water pond in Kasomalang, the earthen pond in Cilamaya, the semi-concrete pond in Lundar, the fully concrete pond in Sukamandi 1, and the static net cage in Sukamandi 2. The slower growth rate indicates that the cultivation environment index is getting lower.

To clarify the effect of the environmental index on the growth rate of the two common carp genotypes in this study, it is necessary to evaluate the stability related to the environmental index. This can be explained through the growth stability graph of the population of common carp, which is presented in Fig. 2. The regression coefficient (b_i) values of Permata hybrid

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Table 5. The survival rate and biomass of the Permata hybrid carp and Majalaya carp were reared in five locations and six different cultivation systems for three months

Test location	Survival rate (%)		Biomass of harvest (kg)		Biomass differences (%)
	Permata hybrid carp	Majalaya carp	Permata hybrid carp	Majalaya carp	
Cirata	76.0 ± 4.0	80.0 ± 5.0	1,515.5 ± 222.8	933.3 ± 352.8	39.4
Kasomalang	59.9 ± 5.0	34.1 ± 6.0	289.0 ± 65.4	126.7 ± 12.6	54.4
Lundar	92.4 ± 2.0	94.7 ± 2.0	505.3 ± 194.8	319.8 ± 198.4	28.1
Cilamaya	88.4 ± 3.0	90.8 ± 2.0	58.9 ± 7.7	53.4 ± 7.0	9.4
Sukamandi 1	58.8 ± 7.0	58.9 ± 2.0	27.4 ± 6.2	23.5 ± 1.4	11.1
Sukamandi 2	57.0 ± 10.0	33.2 ± 3.0	12.6 ± 1.2	6.5 ± 0.4	48.1

Table 6. The environmental index of six test sites with different cultivation systems related to daily growth rate characteristics

Location	Environmental index
Cirata	1.25
Kasomalang	0.90
Cilamaya	0.52
Lundar	–0.03
Sukamandi 1	–1,30
Sukamandi 2	–1.34

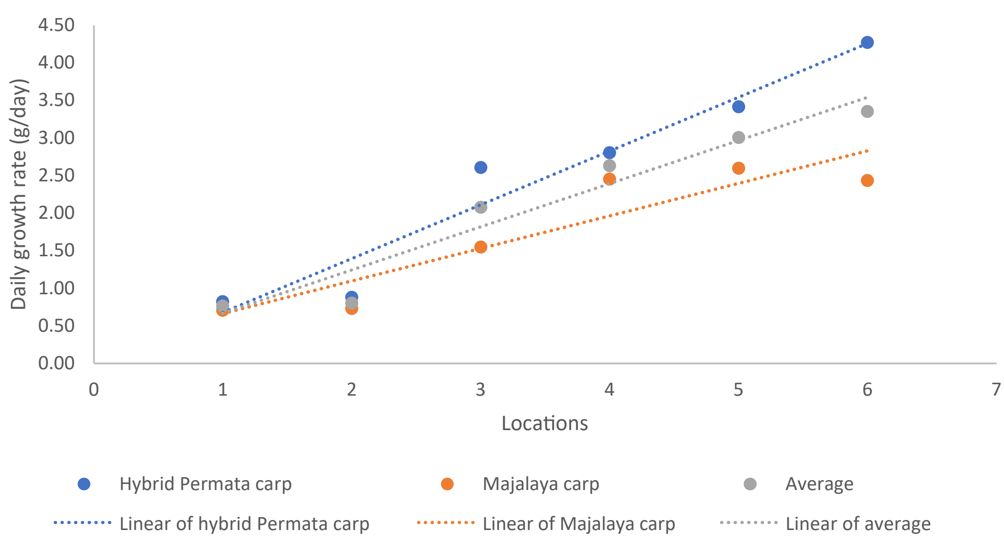

Fig. 2. The daily growth rate of common carp which were reared in 6 culture systems with different environmental indexes. 1: Cirata; 2: Kasomalang; 3: Cilamaya; 4: Lundar; 5: Sukamandi 1; 6: Sukamandi 2.

carp and Majalaya carp are 2.86 and 1.78, respectively. The regression coefficient's positive value indicates that carp's growth performance will improve if cultivated in conditions with a better environmental index. The regression deviation (S_{di}^{2}) value of the Majalaya carp in this study was lower than that of the Permata hybrid carp. These results indicate that the Majalaya carp has more consistently increased growth performance if the environmental index increases. This means adding one unit of environmental index value will increase the growth of the Majalaya carp, which is more stable than the Permata hybrid carp.

Fig. 2 shows that the daily growth performance of the Permata hybrid carp was above the overall growth average for common carp in this study, while the Majalaya carp was below the average growth performance line. Increasing the environmental index values for the two common carp genotypes will improve the growth performance of each common carp. In Majalaya carp, an increase in the environmental index value unit will increase growth performance, which is relatively the same. In contrast, in Permata hybrid carp, an increase in the environmental index value will result in a more diverse increase in growth performance. However, the various performance improvements in Permata hybrid carp are consistently above the performance of Majalaya carp. The results of this study indicated that the growth performance of the Permata hybrid carp was better than that of the Majalaya carp in all test locations.

Discussion

The effect of genetics, environment, and the interaction of the two on the phenotypic performance of farmed fish has been widely reported, namely in tilapia (Khaw et al., 2012), catfish (Tahapari et al., 2017), sea bass (Dupont-Nivet et al., 2008), salmon (Gjedrem, 2005), cod (Bangera et al., 2015), and others. In carp, it was reported that environment has a more significant influence than genetics on several phenotypic characteristics, such as growth, survival, and yield biomass (Ariyanto et al., 2018; Wang & Li, 2007). This study on the Permata hybrid carp also showed the same results, where environmental influences were greater than genetic influences on the phenotypic performance of all the characters observed, namely length, weight, survival, and harvested biomass. There is an interaction between genetic and environmental factors that appears to influence survival and harvest biomass characteristics, in line with those studies that report that genetic and environmental factors and the interaction of both influence yields of carp culture.

The results of this study align with Linhart et al. (2002), who reported that the influence of the rearing environment was the main factor influencing the performance of carp, followed by the relatively smaller influence of genetic factors and the interaction between the two. Ariyanto et al. (2020) and Wang & Li (2007) confirmed that the effect of genetic interactions with the environment on carp rearing is very small.

This research indicates that environmental conditions are a very important factor in common carp farming. Although not as big as the influence of the environment, the use of superior strains also affects the performance of carp cultivation. The third factor is the interaction between the genetic factors of the seed and the cultivation environment. This needs to be considered because not all carp strains or varieties are suitable for different cultivation environments. Some types of carp have good performance in a location with a certain cultivation model but do not produce maximum survival and harvest biomass in other locations or cultivation models (Ariyanto et al., 2019a; Ponzoni et al., 2008). Therefore, farmers must know the characteristics of the seeds and the cultivation system that will be carried out to obtain the best harvest yields.

In this study, as a new variety for cultivation, the Permata hybrid carp has good genetic quality and will produce a high yield if cultivated under suitable environmental conditions, such as in the Cirata reservoir and semi-concrete ponds in Lundar. In both locations, good environmental conditions, such as brightness, dissolved oxygen, and pH values, supported by low ammonia and nitrite, will result in a high growth rate and survival rate to achieve the maximum harvested biomass. The running water ponds in Kasomalang have good potential for carp cultivation and produce fast growth, as indicated by individual weight at harvest. However, the survival rates in this location test were relatively low, namely 59.9 ± 5.0 in the Permata hybrid carp and 34.1 ± 6.0 in the Majalaya carp. This low survival rate results in lower harvested biomass than Cirata and Lundar cultivation. The low survival rate in running water ponds in Kasomalang is thought to be caused by the size of the seeds used, which were too small, with a body length of 12.05 ± 1.34 cm and a body weight of 14.28 ± 4.44 g/fish. With this size, some of the seeds escaped from the grate as the barrier of the pond and others could not keep up with the water flow, so they were carried out of the pond by the current. According to Jayalaksana et al. (2016) and Radona et al. (2012), common carp cultivation in running water ponds usually uses seeds weighing more than 50.00 g per fish. However, the results of this study indicate that the hybrid Permata carp has better yield biomass than Majalaya carp in all test locations. In general, the high genetic quality of Permata hybrid carp can be a substitute for varieties that have been cultivated by farmers, most of which have experienced a decrease in genetic quality (Arifin & Kurniasih, 2016; Ariyanto et al., 2019a).

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The cultural environment's influence also affects the cultivated carp's morphological performance (Nasir & Khalil, 2016; Shuai et al., 2018; Siegers et al., 2019). This multi-site test showed this by the relationship between the length and weight of the individual common carp at each location. R^2 correlation values ranged from 0.7730 to 0.9646 for the Permata hybrid carp and 0.6201 to 0.9449 for the Majalaya carp. The negative allometric growth model shows that the growth of common carp in length is faster than its weight. These results are in line with previous studies conducted by Rashıd et al. (2018) and Vilizzi et al. (2013) but different from the study conducted by Taher et al. (2021), which reported positive allometry on common carp growth. In more suitable environments, such as Cirata and Kasomalang, R^2 and constant b values tend to be higher, indicating that the correlation between length and body weight is very high. More than 90% of body weight is determined by body length. This indicates that the growth in length is also followed by the addition of a relatively equal weight. This condition impacts the weight of individuals in the two locations, which has a higher value than the other locations.

In the case of common carp farming in Lundar, where the constant b value is greater than 3, it indicates that the growth in length of individual carp at that location is not faster than the growth in weight. This results in a common carp with a more rounded shape and a short length with a high weight. The different results at this test site were thought to be caused by the excess availability of high-protein feed, which earlier spurred the gonadal maturity level. Taher et al. (2021) reported that variations in the allometric pattern (b value) in common carp may be attributed to different factors such as environmental conditions, feeding management, the size of the fish, sex, and maturity. The gonadal maturation speed in a population result in faster body weight growth than immature fish. It results in a positive allometric growth pattern. In general, the value of the condition factor (K_n) for the two carp populations reared in five locations with six cultivation models is 1, which indicates that the environmental conditions for common carp rearing are still quite good, as seen from the availability of feed and nutrients as well as the agro-climatological conditions. The condition factor is a number that indicates fish fatness. From a nutritional point of view, the conditional factors are fat accumulation and gonadal development. The condition factor indirectly shows that the physiological condition of the fish receives influence from intrinsic factors (gonadal development and fat reserves) and extrinsic factors (availability of food resources and environmental pressures) (Ibrahim et al., 2017; Kusmini et al., 2018).

The stability analysis results showed that the parameter values measured for both genotypes in this study were unstable with the increased environmental index. According to Ariyanto et al. (2020), a genotype is called stable if it has a regression coefficient that is not significantly different from one and the regression deviation is equal to zero. Based on these criteria, Majalaya carp have better stability than Permata hybrid carp. However, the stability of the better growth performance of the Majalaya carp does not necessarily give a better result than the Permata hybrid carp. These results show that the improvement in environmental quality is not linear for both genotypes. However, any improvement in environmental quality will be followed by an increase in phenotypic appearance, especially in the growth character. The genotype with such a character is not specific to its development location. This indicates that farmers with varying environmental conditions can use both genotypes. However, farmers should also consider the technology used to ensure that the crops produce the best growth rate so that the maximum harvest is produced.

The Permata hybrid carp has higher stability parameter values than the Majalaya fish. It indicates that the Permata hybrid carp responds more to change than the Majalaya carp. The response of a genotype to changes in the environment has a strong influence on the phenotypic performance of the population. This genotype will give maximum results if cultivated in the best environment, such as appropriate agroclimatic conditions, high protein feed, and other cultivation technologies. Based on the test results, this genotype has adaptive varieties in a wide range of environments. Genotypes with this character allow cultivation to be carried out in all locations with various cultivation systems (Ariyanto & Listiyowati, 2015).

Conclusion

The environmental conditions of the cultivation strongly influence the phenotypic performance of carp. The Permata hybrid carp is a fish genotype widely adapted to different environmental conditions. Permata hybrid carp had the best growth rate in the floating net cage culture system in Cirata, which had the best environmental index compared to other locations. The growth and productivity of Permata hybrid carp were better than that of Majalaya carp in all test locations. Based on these results, the Permata hybrid carp has the potential to replace other cultivated common carp in Indonesia whose genetic quality has declined.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

This study has complied with the guidelines of animal ethical treatment for the management and use of experimental animals. There is no specific treatment that can harm the fish. All fish are cultivated with optimal feed and water conditions.
This article also does not require IRB/IACUC approval because there are no human and animal participants.

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