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MORPHOLOGICAL CHARACTERISTICS OF A RED STRAIN OF THE EGYPTIAN AFRICAN CATFISH (*Clarias gariepinus* BURCHELL 1822)

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ABSTRACT

Characteristics of the Egyptian African catfish (*Clarias gariepinus*) strain introduced to Indonesia has not been extensively explored yet, especially the red strain. Previous studies suggested that at the same body length, body weight of the red strain was higher and it was more rotund than that of the normal (black) ones. These differences need to be further investigated to find out which parts of the body mainly contributed to shape the differences. The present study was carried out to explore morphological differences of the red strain of Egyptian African catfish compared to the black strain through morphometric and meristic characterizations. Meristic and morphometric characterizations in the present study were carried out following standard method for morphological characterization of *Clarias* catfish. The fish samples consisted of each 35 red and black table-sized fish samples resulted from inbred and outbred spawnings. Results of the morphometric and meristic analysis in the present study revealed that the red strain of Egyptian African catfish resulted from inbred spawning of red strain brooders was morphologically different from that of either parental fishes or the black strains. At the same body length, head of the red strain was bigger (wider and longer) than other strains, and its body was stumpy (more rotund and shorter than other strains), deviated from those normal characteristics of the Egyptian African catfish. Its meristic characters were also differed from those of other strains, assigned by reduced dorsal and anal fin rays number.

KEYWORDS: **meristic; morphometric; red strain of Egyptian African catfish, *Clarias gariepinus***

INTRODUCTION

African catfish (*Clarias gariepinus* Burchell, 1822) has been several times introduced to Indonesia for aquacultural purposes, either directly from African countries or via other countries. One of the African catfish strain introduced to Indonesia was Egyptian strain. It has been introduced into Indonesia by Fisheries and Marine Agency of West Java Province in 2007. In 2011, Research Institute for Freshwater Fish Breeding and Aquaculture Technology (presently Research Institute for Fish Breeding) Sukamandi, West Java, Indonesia has collected the Egyptian African catfish. In 2013, several pairs of that brooders has been spawned, resulted in about 10% progenies with reddish body colour (then were named here as a red strain of Egyptian African catfish).

A red strain (in some publications were also referred to as golden strain) of African catfish *C. gariepinus* also occurred in South Africa, and some of its biological aspects have been reported, *e.g.* catchability and growth of juveniles (Prinsloo & Schoonbee, 1989; Prinsloo *et al*., 1989a), cannibalism at larval and juvenile stages (Prinsloo *et al*., 1989b), fecundity (Prinsloo *et al*., 1990), proximate, fatty acid, amino acid, minerals, and composition of muscle (Hoffman & Prinsloo, 1995; Hoffman *et al*., 1995a; 1995b). Unfortunately, there was no report on morphological characterization of the red strain. On the other hand, characterization study on intraspecific morphological variation of *C. gariepinus* in Africa revealed that there were morphological variations, and the morphological characters of Egyptian strain were different from those of other strains (Teugels, 1998; Rognon *et al*., 1998). Recently, morphological characterization of the African catfish strains introduced to Indonesia also suggested that the Egyptian strain was different from other strains (Iswanto *et al*., 2015). Therefore, studies need to be conducted to explore and evaluate the potentialities of Egyptian African catfish for aquaculture and its other biological traits, including its red strain one. Results of those studies would be beneficial in justifying whether that strain would be favourable for aquaculture purposes (aquaculture potentialities) and further

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for determining the strategy on utilization of that strain for aquaculture purposes.

Studies on evaluation of larval and juvenile growth performance of the Egyptian African catfish resulted from each pair of red and normal (black) coloured brooders revealed that the red strain grew slower than the normal coloured one (Iswanto *et al*., 2013a; 2013b). Results of those studies also indicated that at the same body length, body weight of the red strain was higher than that of the black one. Furthermore, analysis of length-weight relationship, and condition factor analysis carried out for the table-sized (market-sized) fish samples suggested that growth of those Egyptian African catfish were negative allometric, and the red strain was more rotund than the normal coloured ones (Iswanto *et al*., 2014). Those body shape differences need to be further investigated to find out which parts of the body mainly contributed to shape the differences. The present study was carried out to explore morphological differences of the red strain of Egyptian African catfish compared to the normal coloured ones at the table-sized fish samples through morphometric and meristic characterization. Morphometric and meristic characterization has been proved to be suitable method on studying interspecific differentiation in African *Clarias* catfish (Agnese *et al*., 1997; Teugels, 1998; Rognon *et al*., 1998; Teugels *et al*., 1999a; 1999b), as well as on intraspecific differentiation of African catfish, *C. gariepinus* (Teugels, 1998; Rognon *et al*., 1998; Turan *et al*., 2005).

MATERIALS AND METHODS

The present study was conducted at Research Institute for Fish Breeding (RIFB) Sukamandi, West Java, Indonesia in August 2014, using table-sized (100.00-228.04 g of body weight) fish samples of four months old. Each of the red and normal coloured strains of Egyptian African catfish used in the present study consisted of two generation groups, *i.e*. F-1 generation resulted from outbred spawning and F-2 generation resulted from inbred spawning. The F-1 generation was obtained from artificial spawning (outbreeding) of five pairs of collected brooders with black (normal) colour, resulted in black coloured progenies and some (about 10%) red coloured progenies (Figure 1A). Whereas, the F-2 red strain was obtained from artificial spawning of six pairs of inter—F-1 red strain (inbreeding) resulted in all red coloured progenies and the F-2 black strain was also obtained from inbred spawning of six pairs of inter—F-1 black strain resulted in all black coloured progenies (Figure 1B). Specimens examined in the present study consisted of each 35 fish samples of F-1 outbred and F-2 inbred of red and black strains, making totally 140 fish samples.

Morphological characterization of the red and black strains of the Egyptian African catfish in the present study was conducted mainly on morphometric characters, with additional meristic characterization. Meristic characters were identified based on the count of total number of dorsal and anal fin rays. While, for morphometric characters, 30 point to point measurements were undertaken following standard method used in African catfish identification studies (Teugels, 1986; 1992; 1998; Agnese *et al*., 1997; Rognon *et al*., 1998; Teugels *et al*., 1999a; 1999b; 2007; Turan *et al*., 2005; Hanssens, 2009), as follows: total length (TL), standard length (SL), head length (HL), head width (HW), snout length (SNL), nasal barbel length (NBL), maxillary barbel length (MBL), inner mandibular barbel length (IMBL), outter mandibular barbel length (OMBL), interorbital width (IOW), eye diameter (ED), frontal fontanel length (FFL), frontal fontanel width (FFW), occipital process length (OPL), occipital process width (OPW), occipital process to dorsal fin distance (OPDF), predorsal length (PDL), dorsal fin length (DFL), prepectoral length (PPEL), pectoral spine length (PESL), pectoral fin length (PEFL), prepelvic length (PPL), pelvic fin length (PFL), preanal length (PAL), anal fin length (AFL), maximum body depth at anus (MBD), caudal peduncle depth (CPD), caudal fin length (CFL), premaxillary toothplate width (PMW), and vomerine toothplate width (VMW) (Figure 2). Each morphometric character was measured using dial caliper of 0.01 mm precision (KRISBOW, China).

Morphometric and meristic data obtained were subjected to the principal components analysis (PCA) based on covariance matrix (Teugels, 1998; 2003; Agnese *et al*., 1997; Rognon *et al*., 1998; Teugels *et al*., 1999a; 1999b; Pouyaud *et al*., 2009) using SYSTAT 11 (SYSTAT Software Inc., www.systat.com) package software. Analysis of morphometric data was performed on 12 selected morphometric characters (total length, standard length, snout length, pectoral fin length, pectoral spine length, pelvic fin length, caudal fin length, eye diameter, the length and width of frontal fontanel, the width of premaxillary and vomerine toothplates, nasal barbels length, maxillary barbels length, inner mandibular barbels length, and outter mandibular barbels length were excluded) considered as important diagnostic characters in intraspecific differentiation of *C. gariepinus* (Teugels, 1998; Rognon *et al*., 1998), as well as in interspecific differentiation of *Clarias* catfish species (Agnese *et al*., 1997; Teugels *et al*., 1999a; 1999b; Teugels, 2003; Pouyaud *et al*., 2009), plus two additional supported characters expected here would also be important as

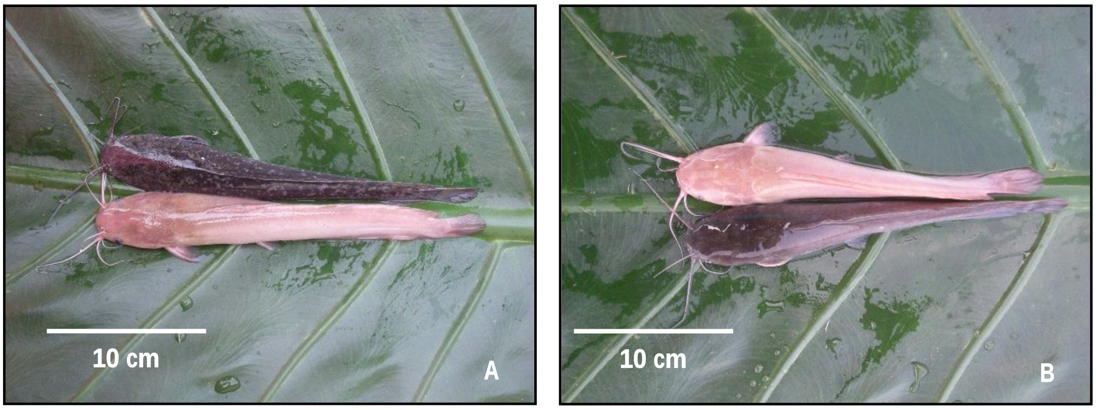

Figure 1. Samples of F-1 red (lower side) and F-1 black (upper side) coloured progenies obtained from outbred spawning of the collected Egyptian African catfish (*Clarias gariepinus*) brooders (A), and samples of F-2 red (upper side) and F-2 black (lower side) progenies resulted from inbred spawning of respectively inter—F-1 red brooders and inter—F-1 black brooders (B)

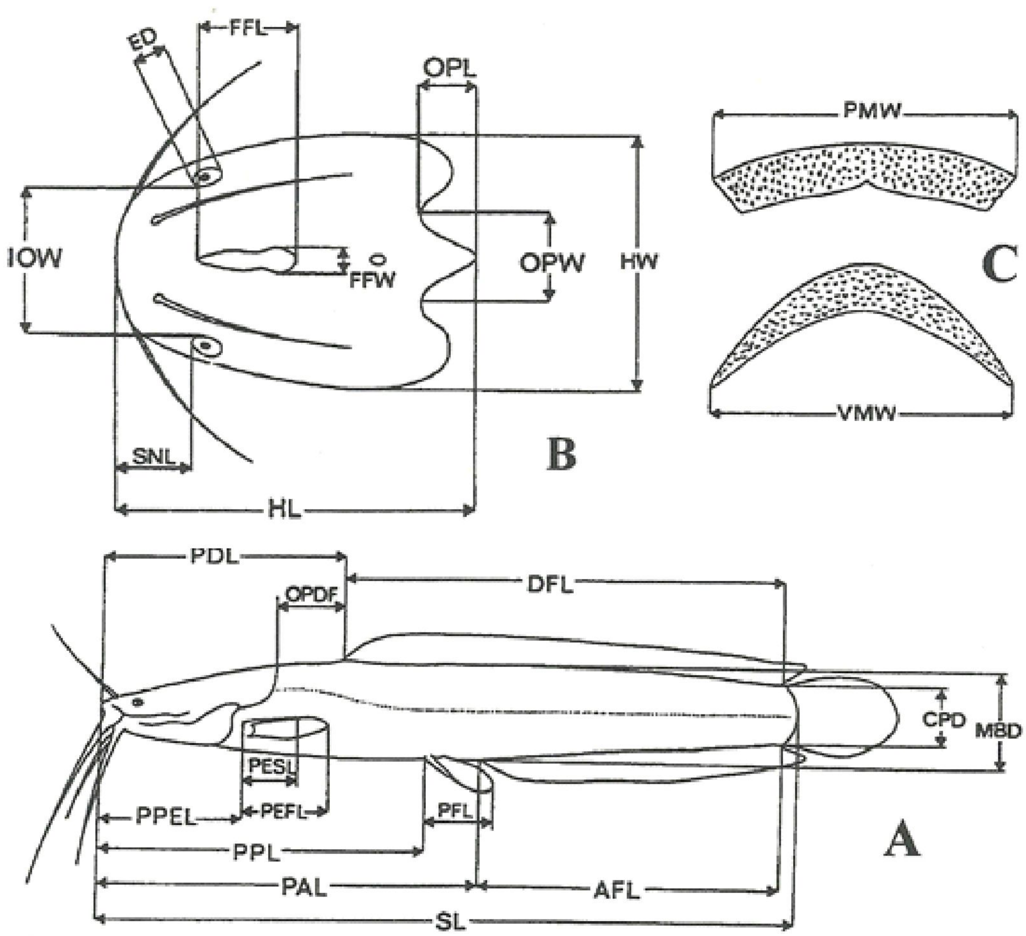

Figure 2. Measurement taken on the body (A), head (B), and toothplates of the Egyptian African catfish (*Clarias gariepinus*) samples (reproduced from Teugels *et al*., 1999a; 1999b)

diagnostic characters, *i.e*. maximum body depth at anus and caudal peduncle depth. Those two characters were included in the present analysis since results of the previous study suggested that body fatness amongst Egyptian African catfish strains was different (Iswanto *et al*., 2014), thus, those characters were assumed to contribute in shaping the body fatness. Effect of slightly fish size difference was corrected using log ratio of each measured morphometric characters to its standard length (Turan, 1999). Scores of principal component pairs obtained were plotted to define the characterizing groups (95% confidence ellips) using SYSTAT 11 package software (www.systat.com). When necessary, the values of individual important morphometric characters expressed as the percentage of each standard length were plotted in pairing to define the characterizing groups, following Teugels *et al*. (1999a; 2001).

RESULTS AND DISCUSSIONS

Results of the measurement of 14 selected morphometric characters analyzed of F-1 outbred and F-2 inbred of red and black strains expressed in percentage of itself standard length (%SL) were presented in Table 1. Result of a principal component analysis performed on the total of 140 (35 each) fish samples using covariance matrix for 14 morphometric characters in the present study was presented in Figure 3 and Table 2. Scatterplot between scores of the first principal component (PC-1) and second principal component (PC-2) clearly enabled to differentiate F-2 inbred red strain from F-1 outbred red strain. PC-1 located F-1 outbred red strain on the positive sector, separated from F-2 inbred red strain on the negative sector, indicated that their morphometric characteristics were different. While, F-1 outbred black strain was almost and partly overlapped with respectively F-1 outbred red strain and F-2 inbred black strain, indicated that its morphometric characteristics was more or less similar to both F-1 red and F-2 inbred black strains. However, F-1 outbred red strain was slightly separated from F-2 inbred black strain, indicated that their morphometric characteristics was slightly different. Then, PC-2 could partly differentiate F-2 inbred black strain from F-2 inbred red strain, indicated that their morphometric characteristics was slightly distinguishable.

Those results revealed that the red strain of Egyptian African catfish resulted from inbred spawning of red strain brooders (F-2 inbred red strain) was morphologically different from that of either parental fishes (F-1 outbred red strain) or the black (F-1 outbred black and F-2 inbred black) strains. On the other hand, morphological characteristic of F-2 inbred black strain was not different from that of parental fishes (F-1 outbred black strain), but slightly differed from that of either F-2 inbred or F-1 outbred red strains. In addition, morphological characteristic of the red and black strains obtained from outbred spawning was not different from each other. The differences of F-1 outbred red strain compared to either F-2 inbred red strain or F-2 inbred

Table 1. Range of morphometric characters of each 35 samples of F-1 outbred red strain, F-2 inbred red strain, F-1 outbred black strain, and F-2 inbred black strain of the Egyptian African catfish (*Clarias gariepinus*) in the percentages of standard length (% SL) itself

Characters	F-1 outbred		F-2 inbred	
	Black strain	Red strain	Black strain	Red strain
Head length	26.29-28.53	25.95-28.86	26.67-28.53	28.53-33.26
Head width	16.10-17.97	15.76-17.75	16.18-18.06	18.09-21.92
Interorbital width	10.38-11.45	10.15-11.64	10.82-12.11	12.03-14.32
Occipital process width	6.89-8.02	6.30-7.80	6.83-8.85	8.30-10.11
Occipital process length	3.63-5.21	3.28-5.16	3.43-5.27	3.18-4.78
Occipital process to dorsal fin distance	4.04-6.91	5.09-6.96	3.27-5.61	2.32-5.00
Predorsal length	31.16-34.23	31.54-35.27	30.55-33.54	31.92-37.97
Dorsal fin length	64.06-68.72	62.94-67.88	64.85-69.16	56.02-67.04
Prepectoral length	17.02-19.25	16.78-19.50	16.53-18.67	17.75-22.27
Prepelvic length	42.36-45.53	42.76-46.38	40.13-44.82	42.26-47.69
Preanal length	51.62-55.85	51.91-57.78	50.28-55.18	50.84-59.06
Anal fin length	39.83-44.43	38.82-45.22	41.41-45.66	36.61-44.28
Maximum body depth	12.40-15.39	12.01-14.68	13.21-15.66	14.22-17.72
Caudal peduncle depth	6.40-7.64	6.32-7.69	6.50-7.39	7.14-9.07

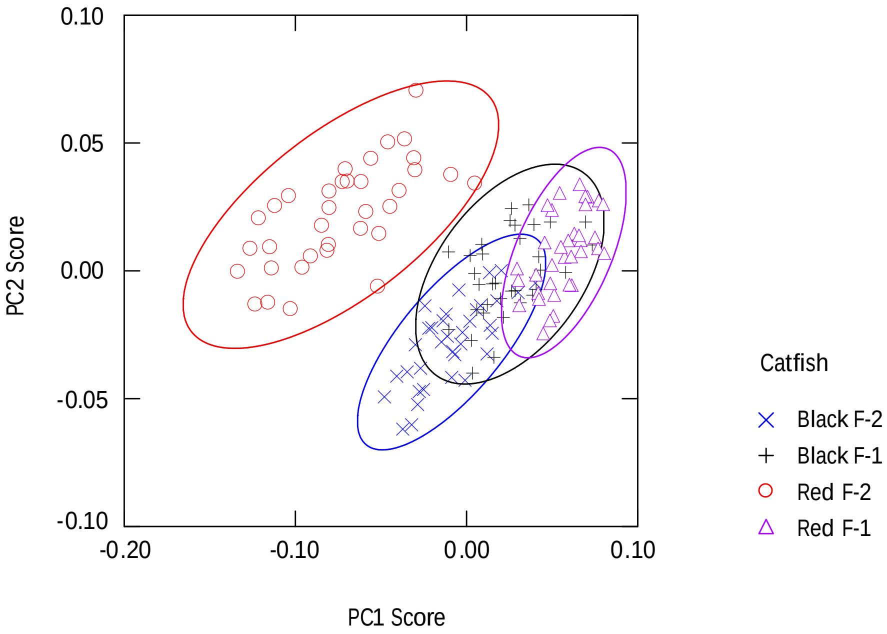

Figure 3. Scatterplot between first principal component (PC-1) and second principal component (PC-2) scores of each 35 samples of F-1 outbred red strain (Δ), F-2 inbred red strain (O), F-1 outbred black strain (+), and F-2 inbred black strain (x) of the Egyptian African catfish (*Clarias gariepinus*) resulted from a principal component analysis (PCA) performed on 14 selected morphometric characters

black strain were mainly defined by (Table 2, PC-1 coefficients in decreasing order of importance) occipital process to dorsal fin distance, occipital process width, interorbital width, head width, head length, maximum body depth at anus, and dorsal fin length. Roles of other morphometric characters were relatively low. PC-2 coefficients of each morphometric character revealed that the slightly differences between F-2 inbred black strain and F-2 inbred red strain were mainly defined by (Table 2, PC-2 coefficients in decreasing order of importance) predorsal length, prepectoral length, caudal peduncle depth, head width, head length, interorbital width, maximum body depth at anus, dorsal fin length, preanal length, and occipital process width. Roles of other morphometric characters were relatively low.

Further analysis of those morphometric characters contributed on the interstrain morphological variation of the Egyptian African catfish strains through plotting of a character against other individual characters in the present study (the results were not wholly shown) suggested that the strongest diagnostic characters were head width, interorbital width, and head length. Scatterplots of those characters values (expressed in the percentage of itself standard length) clearly enabled to differentiate F-2 inbred red strain from other overlapped strains (Figure 4). While, scatterplots for other morphometric characters were only more or less partly differentiated F-2 inbred red strain from other strains (not shown). The strongest diagnostic characters of the body parts which enabled to differentiate the majority samples of F-2 inbred red strain from other overlapped strains were occipital process to dorsal fin distance, dorsal fin length, maximum body depth at anus, caudal peduncle depth, predorsal length and prepelvic length (not shown). Measurement values of those morphometric characters contributed on the interstrain morphological variation of Egyptian African catfish (Table 1) suggested that F-2 inbred red strain has bigger (wider and longer) head than other strains (as expressed by the values of head width, interorbital width and head length). Then, F-2 inbred red strain has more rotund and shorter body (stumpy) than other strains (as expressed by the values of occipital process to dorsal fin distance, dorsal fin length, maximum body depth at anus caudal peduncle depth, predorsal length, and prepelvic length).

Scatterplot between scores of PC-1 and PC-2 resulted from a principal component analysis performed on the total of 140 fish samples using covariance matrix for meristic count of dorsal and anal fin rays number in the present study was presented in Figure 5. Contribution of both meristic

Table 2. Principal component coefficients of each morphometric characters obtained from a principal component analysis (PCA) performed on 14 selected morphometric characters of each 35 samples of F-1 outbred red strain, F-2 inbred red strain, F-1 outbred black strain, and F-2 inbred black strain of the Egyptian African catfish (*Clarias gariepinus*)

Characters	PC-1	PC-2
Head length	-0.6951	0.5975
Head width	-0.7194	0.6220
Interorbital width	-0.7384	0.5492
Occipital process width	-0.7525	0.4524
Occipital process length	0.4318	-0.1330
Occipital process to dorsal fin distance	0.9751	0.2172
Predorsal length	-0.0407	0.8385
Dorsal fin length	0.5198	-0.4873
Prepectoral length	-0.3712	0.7036
Prepelvic length	0.2628	0.3133
Preanal length	-0.0206	0.4715
Anal fin length	0.4393	-0.2592
Maximum body depth at anus	-0.5967	0.5194
Caudal peduncle depth	-0.4147	0.6396
Cumulative explained variances (%)	**67.83**	**82.23**

characters in differentiating F-2 inbred red strain from other strains were high. PC-1 located F-2 inbred red strain totally separated from other strains, indicated that its dorsal fin and anal fin rays number (respectively, ranged 49-63 and 33-43) differed from those of other strains. The other three strains overlapped each other, indicated that their dorsal and anal fin rays number were more or less similar, which respectively ranged 71-77 and 50-57 in F-1 outbred red strain, ranged 68-77 and 49-55 in F-1 outbred black strain and ranged 67-73 and 46-54 in F-2 inbred black strain.

Numerous studies on the identification and characterization of *Clarias* catfish based on the morphometric characters have been reported. However, morphometric study on intraspecific variation of *C. gariepinus* was scarce. Morphometric characterizations of *C. gariepinus* strains in Africa has been reported in Teugels (1998) and Rognon *et al.* (1998), and the results suggested that there was a considerable morphometric variation. Those variation were merely defined by the width of premaxilla toothplate, the width and length of occipital process, and the dorsal fin length. Morphometric characterization of *C. gariepinus* populations in Turkish waters has been reported by Turan *et al*. (2005), and the results revealed that the morphometric differentiation was observed. Those differences were mainly defined by the morphometric characters of the head parts, *i.e*. the length and width of occipital fontanel, the length and width of head, prepectoral length, the distance of occipital process to dorsal fin origin, and the length of dorsal fin. Results of those morphometric variation studies in the intraspecific of *C. gariepinus* corresponded to the results of the present study, for which also revealed that morphological differences in the Egyptian African catfish *C. gariepinus* strains were also mainly defined by morphometric characters of the head parts, and supported by the body proportion (body shape).

Results of morphometric and meristic analysis in the present study corresponded to the results of previous analysis of length-weight relationship and condition factor, for which suggested that at same body length, F-2 inbred red strain was heavier and more rotund than other strains (Iswanto *et al*., 2014). Results of the present study clearly revealed that those were due to at the same length size (after the difference of length size was eliminated through size correction), head proportion of F-2 inbred red strain was bigger (wider and longer) and the body was more rotund (deeper) but shorter than those of other strains. Consequently, at the same length size, F-2 inbred red strain was heavier than other strains.

Except for F-2 inbred red strain, morphological characteristics of the other strains were normal and corresponded to morphological characteristics of Egyptian African catfish reported by Teugels (1998)

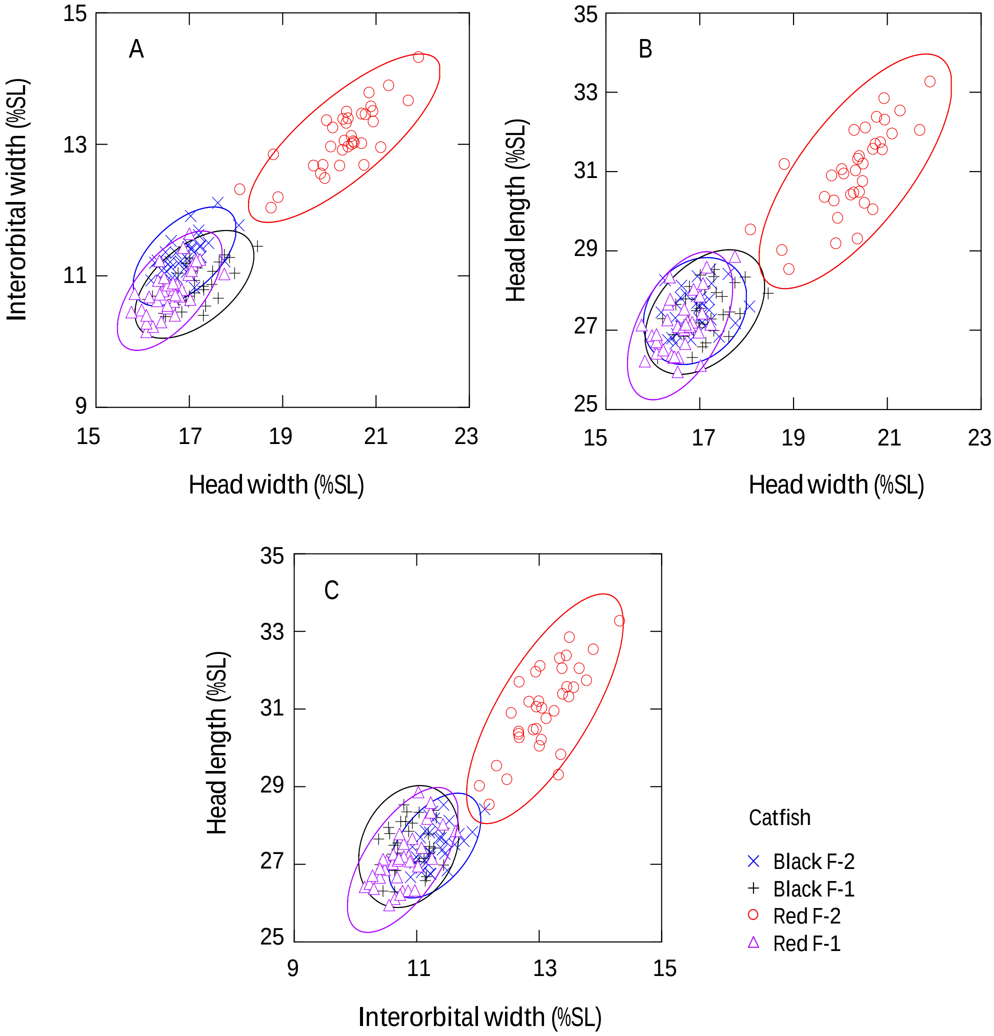

Figure 4. Scatterplot of the head width against interorbital width (A), the head width against head length (B), and the interorbital width against head length (C) of each 35 samples of F-1 outbred red strain (Δ), F-2 inbred red strain (O), F-1 outbred black strain (+), and F-2 inbred black strain (x) of the Egyptian African catfish (*Clarias gariepinus*)

and Rognon *et al*. (1998), for which possessed smaller head and slimmer body than other strains. While, morphological characteristics of F-2 inbred red strain deviated from those normal characteristics, since its head was bigger and its body was more rotund and shorter (stumpy) compared to other strains. In other words, morphological characteristics of that F-2 inbred red strain was abnormal or has experienced morphological deformity or malformation. Besides its morphometric characters, abnormality of F-2 inbred red strain in the present study was also expressed by its meristic characters, which lower than those of the normal African catfish species. Normally, dorsal fin rays number of *C. gariepinus* in Africa ranged 61-79, with anal fin rays number ranged 45-60 (Teugels, 1986; 1992; Teugels *et al*., 2007; Hanssens, 2009; FishBase, 2015). Similarly, dorsal and anal fin rays number of *C. gariepinus* cultured in Bangladesh were respectively 70.4 ± 0.4 and 57.8 ± 0.6 (Khan *et al*., 2002). The number of dorsal and anal fin rays of *C. gariepinus* introduced to Indonesia ranged 57-71 and 45-53, respectively (Hamsyah, 2004). Dorsal fin rays number of *C. gariepinus* in Polish waters ranged 55-75 and anal fin rays number ranged 36-59 (Wiecaszek *et al*., 2010).

Morphological abnormalities in African catfish *C. gariepinus* has been reported by several workers, including stumpy body as in this F-2 inbred red strain, deformation of upper jaw, skeletal protuberances and

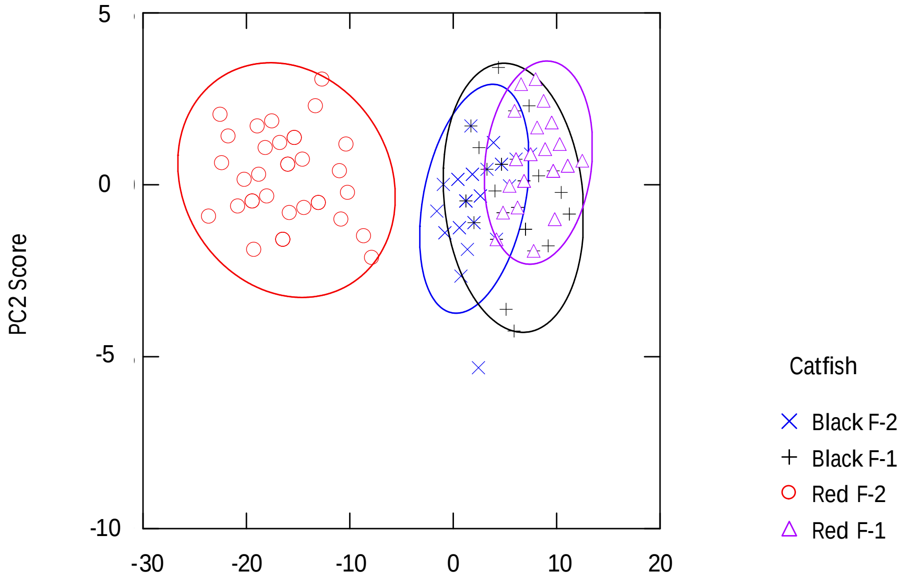

Figure 5. Scatterplot between first principal component (PC-1) and second principal component (PC-2) scores of each 35 samples of F-1 outbred red strain (Δ), F-2 inbred red strain (O), F-1 outbred black strain (+), and F-2 inbred black strain (x) of the Egyptian African catfish (*Clarias gariepinus*) resulted from a principal component analysis performed on the dorsal and anal fin rays number

depression on the head with associated jaw deformity, gap on the dorsal fin, absence of the pectoral and pelvic fins, absence of the eye, deformed mouth, big head, and multiple vertebral deformities (Nurhidayat, 2000; Hamsyah, 2004; Subba, 2004; Eissa *et al*., 2009; Olatunji-Akioye *et al*., 2010; Fagbuaro, 2011; Fagbuaro & Abayomi, 2011). Specifically, the stumpy body was believed to occur as a result of reduction in the number of vertebrae (Fagbuaro, 2011; Fagbuaro & Abayomi, 2011). The stumpy body of F-2 inbred red strain in the present study was probably also as a result of reduction of the vertebrae number, since the number of dorsal and anal fin rays were much reduced.

The exact causes of such morphological abnormalities in African catfish *C. gariepinus* have not been properly determined. Nevertheless, some possible causes responsible for those morphological abnormalities have been suggested by several workers, either environmental disturbance, stress, disease, nutritional imbalance and deficiency, inbreeding, genetic mutation or other mutagens (Nurhidayat, 2000; Subba, 2004; Eissa *et al*., 2009; Fagbuaro, 2009; 2011; Olatunji-Akioye *et al*., 2010; Fagbuaro & Abayomi, 2011). Amongst those factors, environmental, nutritional, stress, and disease were not the possible factors caused morphological abnormalities in the F-2 inbred red strain, since culture management during larval rearing, nursery and grow-out phases of this strain, as well as other strains, were well practiced. Although inbreeding was considered as one of the factors responsible for the morphological abnormalities, in the case of F-2 inbred red strain, however, it was not seemingly caused by inbreeding. This was supported by the fact that morphological characteristics of F-2 inbred black strain, which also resulted from inbreeding was relative normal. However, morphological abnormalities in F-2 inbred red strain might be due to other genetic factor rather than those external factors. Those are the subjects of our forthcoming genetic studies.

Whether such morphological abnormalities in the red strain of Egyptian African catfish were inherited or not, and whether those abnormalities linked to body colour pigmentation or not, still needed further studies. Those are the subjects of our forthcoming studies. Hopefully, those understandings would be accomplished through interbreeding of either inter-F-2 inbred red strain to produce F-3 inbred progenies or between F-1 outbred red strain and F-1 outbred black strain. According to Smitherman *et al*. (1996), if the abnormalities had a genetic basis and were recessive, crossbreeding should eliminate the abnormalities, while were dominant, all individuals possessing a copy of the gene would express it.

CONCLUSIONS

Morphometric and meristic analysis conducted in the present study revealed that the red strain of Egyptian African catfish resulted from inbred spawning of red strain brooders was morphologically different from that of either parental fishes or the black strains. This strain has bigger (wider and longer) head and its body was more rotund and shorter (stumpy) than the other strains, deviated from normal characteristics of Egyptian African catfish. Its meristic characters was also abnormal, assigned by reduced dorsal and anal fin rays number.

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REFERENCES

Agnese, J.F., Teugels, G.G., Galbusera, P., Guyomard, R., & Volckaert, F. (1997). Morphometric and genetic characterization of sympatric populations of *Clarias gariepinus* and *C. anguillaris* from Senegal. *Journal of Fish Biology*, 50, 1143-1157.

Eissa, A.E., Moustafa, M., El-Husseiny, I.N., Saeid, S., Saleh, O., & Borhan, T. (2009). Identification of some skeletal deformities in freshwater teleosts raised in Egyptian aquaculture. *Chemosphere*, 77, 419-425.

Fagbuaro, O. (2009). Interbreeding of mouth malformed and crooked-back *Clarias gariepinus* (Burchell, 1822). *Journal of Agricultural Science and Technology*, 3(12), 44-50.

Fagbuaro, O. (2011). Morphological deformities in the wild population of *C. gariepinus* in Ado-Ekiti, Nigeria. *Journal of Agricultural Science and Technology*, 5(3), 342-345.

Fagbuaro, O., & Abayomi, O.J. (2011). Skeletal malformations among the *Clarias* species from fish mongers in Ekiti State. *Continental Journal of Fisheries and Aquatic Science*, 5(2), 32-37.

FishBase. (2015). Morphology data of *Clarias gariepinus*. Accessed on 1 June 2015 from: http://fishbase.org/physiology/MorphDataSummary.php?genusnam=Clarias&speciesname=gariepinus&autoctr=1499

Hamsyah, I. (2004). *Characteristics difference between Dumbo clariid catfish and the African catfish (Clarias gariepinus Burchell)*. Thesis. Bogor Agricultural University. Bogor, 42 pp (in Indonesian).

Hanssens, M. (2009). A review of the *Clarias* species (Pisces; Siluriformes) from the Lower Congo and the Pool Malebo. *Journal of Afrotropical Zoology*, 5, 27-40.

Hoffman, L.C., & Prinsloo, J.F. (1995). Genetic and nutritional influence on the total lipid fatty acid profile of *Clarias gariepinus* muscle. *Aquatic Living Resources*, 8, 415-421.

Hoffman, L.C., Prinsloo, J.F., Theron, J., & Casey, N.H. (1995a). A chemical comparison between the golden and normal coloured strains of the African sharptooth catfish, *Clarias gariepinus* (Burchell 1822). *Journal of Applied Ichthyology*, 11, 71-85.

Hoffman, L.C., Prinsloo, J.F., Theron, J., & Casey, N.H. (1995b). The genotypic influence of four strains of *Clarias gariepinus* on the larvae body proximate, total lipid fatty acid, amino acid and mineral compositions. *Comparative Biochemistry and Physiology*, 110B(3), 589-597.

Iswanto, B., Suprapto, R., Marnis, H., & Imron. (2013a). Growth performance of a red strain of Egyptian African catfish (*Clarias gariepinus* Burchell, 1822) at larval rearing and nursery phases. *In* Haryanti, Rachmansyah, Radiarta, I N., Kristanto, A.H., Imron, Sugama, K., Pantjara, B., & Azwar, Z.I. (Eds.). *Proceedings Forum Inovasi Teknologi Akuakultur 2013*, Mataram, 12-13 Juni 2013, p. 639-647 (in Indonesian).

Iswanto, B., Suprapto, R., Marnis, H., Ridzwan, N.S., & Imron. (2013b). Larval growth performance of a red strain of Egyptian African catfish (*Clarias gariepinus* Burchell, 1822) strain merah. *In* Suwardjo, D., Syamsuddin, S., Nainggolan, C., Sudrajat, A., Masengi, S., Raharjo, P., & Sipahutar, Y.H. (Eds.). *Proceedings Seminar Nasional Perikanan Indonesia 2012*, Jakarta, 13-14 November 2012, p. 42-48 (in Indonesian with English abstract).

Iswanto, B., Suprapto, R., Marnis, H., & Imron. (2014). Total length-weight relationship and condition factor of a red Egyptian African catfish (*Clarias gariepinus* Burchell, 1822) strain at the table-size. *In* Hidayat, T.T., Syamsuddin, S., Sudrajat, A., Masengi, S., Nainggolan, C., Rahardjo, P., & Sipahutar, Y.H. (Eds.). *Proceedings Seminar Nasional Perikanan Indonesia 2013*, Jakarta, 21-22 November 2013, p. 76-81 (in Indonesian).

Iswanto, B., Suprapto, R., Marnis, H., & Imron. (2015). Morphological characterization of the African catfish (*Clarias gariepinus* Burchell, 1822) strains introduced to Indonesia. *Indonesian Aquaculture Journal*, 10(2), 91-99.

Khan, M.M.R., Cleveland, A., & Mollah, M.F.A. (2002). A comparative study of morphology between F1 hybrid magur (*Clarias*) and their parents. *OnLine Journal of Biological Sciences*, 2(10), 699-702.

Nurhidayat, M.A. (2000). *Asymetry fluctuation and abnormality of Dumbo clariidae catfish from three central clariidae catfish culture in Java*. Master Thesis. Bogor Agricultural University. Bogor, 26 pp (in Indonesian).

Olatunji-Akioye, A.O., Adeyemo, O.K., & Akomolafe, O.T. (2010). Photographic and radiographic study of osteological abnormalities of the head of adult African catfish (*Clarias gariepinus*). *International Journal of Morphology*, 28(3), 719-722.

Pouyaud, L., Sudarto, & Paradis, E. (2009). The phylogenetic structure of habitat shift and morphological convergence in Asian Clarias (Teleostei, Siluriformes: Clariidae). *Journal of Zoological Systematics and Evolutionary Research*, 47(4), 344-356.

Prinsloo, J.F., & Schoonbee, H.J. (1989). Notes on a comparison of catchability and growth of a red and normal variety of the sharptooth catfish *Clarias gariepinus* (Burchell) stocked together in fish production ponds (Short Communication). *Water SA*, 15(3), 191-194.

Prinsloo, J.F., Schoonbee, H.J., & Theron, J. (1989a). The use of a red strain of the sharptooth catfish *Clarias gariepinus* (Burchell) in the evaluation of cannibalism amongst juveniles of this species. *Water SA*, 15(3), 179-184.

Prinsloo, J.F., Schoonbee, H.J., & van der Walt, I.H. (1989b). Production studies with red and normal varieties of the sharptooth catfish *Clarias gariepinus* (Burchell) using a mixture of minced fish, bakery-floor sweepings and a formulated pelleted diet. *Water SA*, 15(3), 185-190.

Prinsloo, J.F., Schoonbee, H.J., & Hoffman, L.C. (1990). A comparison of the fecundity of two strains of the sharptooth catfish *Clarias gariepinus*. *South African Journal of Wildlife Resources*, 20(3), 100-103.

Rognon, X., Teugels, G.G., Guyomard, R., Galbusera, P., Andriamanga, M., Volkcaert, F., & Agnese, J.F. (1998). Morphometric and allozyme variation in the African catfishes *Clarias gariepinus* and *C. anguillaris*. *Journal of Fish Biology*, 53, 192-207.

Smitherman, R.O., Dunham, R.A., & Whitehead, P.K. (1996). Selection, hybridization and genome manipulation in Siluroidei. *Aquatic Living Resources*, 9, 93-102.

Subba, B.R. (2004). Anomalies in bighead carp *Aristichthys nobilis* and African catfish *Clarias gariepinus* in Biratnagar, Nepal. *Our Nature*, 2, 41-44.

Teugels, G.G. (1986). A systematic revision of the African species of the genus *Clarias* (Pisces: Clariidae). *Annales Musee Royal de l'Afrique Centrale*, 247, 1-199.

Teugels, G.G. (1992). Clariidae. *In* Leveque, C., Paugy, D., & Teugles, G.G. (Eds.). *The Fresh and Brackish Water Fishes of West Africa*, Volume 2. ORSTOM-MRAC. Paris, p. 468-495.

Teugels, G.G. (1998). Intra- and interspecific morphometric variation in *Clarias gariepinus* and *C. anguillaris* (Siluroidei, Clariidae). *In* Agnese, J.F. (Ed.). *Genetics and Aquaculture in Africa*. Actes du colloque Génétique et aquaculture en Afrique, Abidjan, 1er-4 avril 1997. Institut Francais de Recherche Scientifique pour le Developpement en Cooperation, Paris. France, p. 241-248.

Teugels, G.G. (2003). *Clarias lamoetti* (Silurifromes, Clariidae), a natural intergeneric hybrid from West Africa. *Cybium*, 27(1), 11-15.

Teugels, G.G., Adriaens, D., Devaere, S., & Musschoot, T. (2007). Clariidae. *In* Stiassny, M.L.J., Teugels, G.G., & Hopkins, C.D. (Eds.). *The Fresh and Brackish Water Fishes of Lower Guinea, West-Central Africa*, Volume I. IRD-MNHN-MRAC, Paris. France, p. 653-691.

Teugels, G.G., Gustiano, R., Diego, R., Legendre, M., & Sudarto. (1999a). Preliminary results on the morphological characterisation of natural population and cultured strains of *Clarias* species (Siluriformes, Clariidae) from Vietnam. *In* Legendre, M., & Parisele, A. (Eds.). *The Biological Diversity and Aquaculture of Clariid and Pangasiid Catfishes in South-East Asia*. Proceeding of The Mid-Term Workshop of the Catfish Asia Project, 11-15 May 1998, Cantho. Vietnam, p. 31-36.

Teugels, G.G., Legendre, M., & Hung, L.T. (1999b). Preliminary results on the morphological characterisation of natural population and cultured strains of *Clarias* species (Siluriformes, Clariidae) from Vietnam. *In* Legendre, M., & Parisele, A. (Eds.). *The Biological diversity and aquaculture of Clariid and Pangasiid Catfishes in South-East Asia*. Proceeding of The Mid-Term Workshop of the Catfish Asia Project, 11-15 May 1998, Cantho. Vietnam, p. 27-30.

Teugels, G.G., Sudarto, & Pouyaud, L. (2001). Description of a new *Clarias* species from Southeast Asia based on morphological and genetical evidence (Siluriformes, Clariidae). *Cybium*, 25(1), 81-92.

Turan, C. (1999). A note on the examination of morphometric differentiation among fish populations:

the truss system. *Turkish Journal of Zoology*, 23, 259-263.

Turan, C., Yalcin, S., Turan, F., Okur, E., & Akyurt, I. (2005). Morphometric comparisons of African catfish, *Clarias gariepinus*, in Turkey. *Foolia Zoologica*, 54(1-2), 165-172.

Wiecaszek, B., Krzykawski, S., Antoszek, A., Kosik, J., & Serwotka, P. (2010). Morphometric characteristics of the juvenile of North African catfish *Clarias gariepinus* (Burchell, 1822) from the heated water aquaculture. *Electronic Journal of Polish Agricultural Universities*, 13(2). url: http://www.ejpau.media.pl/volume13/issue2/art-02.html.