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Full Length Research Paper

Identification of a sequence characterized amplified region (SCAR) marker linked to the *Puccinia psidii* resistance gene 1 (*Ppr1*) in *Eucalyptus grandis*

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While random amplification of polymorphic DNA (RAPD) markers linked to disease resistance genes have been widely used in plant breeding programs, they generally lack reproducibility. To overcome this major disadvantage and other drawbacks, RAPD markers can be converted into sequence characterized amplified region (SCAR) markers, which are genetically defined loci amplified by polymerase chain reaction (PCR) using specific primers. Thus, SCAR markers are typically more reproducible than RAPD markers, due to specific amplification of genomic regions. In this study, a previously identified RAPD marker AT9/917 that is linked to the *Puccinia psidii* Winter (rust) resistance gene 1 (*Ppr1*) in *Eucalyptus grandis* was successfully converted into a specific SCAR marker. Seven specific SCAR primers were designed based on cloning and sequencing of the RAPD marker AT9/917. Different pairs of SCAR primers were tested in an *E. grandis* family from a crossing between a resistant and a susceptible *E. grandis*. Prime pair SCAR AT99151L and AT9915914R produced amplicons of expected size. Restriction enzyme digestion of the amplicon revealed polymorphisms between the resistant and susceptible parents. Association analysis between phenotype (rust resistance) and SCAR genotypes in the *E. grandis* family suggests that this specific SCAR is useful for marker-assisted selection of *E. grandis* trees resistance to *P. psidii* Winter.

Key words: Plant breeding, molecular markers, random amplified polymorphic DNA (RAPD), Mark-assisted selection, sequence characterized amplified region (SCAR).

INTRODUCTION

From as early as the 1970's, eucalyptus rust, caused by *Puccinia psidii* Winter, has posed great threats to eucalyptus trees in Brazil. The biotrophic pathogen *P. psidii* is a parasitic fungus that infects young leaves and the terminal branches of trees, causing deformations, death, hypertrophy, minicancer and meristematic death in

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susceptible genotypes (Alfenas et al., 1989, 2004). The incidence of rust in shoots of susceptible trees is often very severe, requiring the reformation of various settlements after coppicing (Ruiz et al., 1987). The causative fungus *P. psidii* is native to South America (Di Stefano et al., 1998) and is widely distributed in the American continents, being found in Brazil, Argentina, Colombia, Venezuela, Ecuador, Paraguay, Uruguay, Jamaica, Cuba, the Dominican Republic, Puerto Rico, Trinidad and Tobago and Southern Florida in the USA (Coutinho et al., 1998). Recently, *P. psidii* has also been identified in Hawaii (Uchida et al., 2006), California (Mellano 2006), Japan (Kawanishi et al., 2009), Australia (Carnegie et al., 2010; Carnegie and Cooper, 2011) and China (Zhuang and Wei, 2011).

Control of *P. psidii* rust has been successfully accomplished by planting resistant genotypes of trees obtained by intra-and interspecific breeding or by selection of genotypes with fast initial growth. In the latter approach, fast-growing plants experience less time exposed to the *P. psidii* pathogen in the field (Alfenas et al., 2004; Krugner and Auer, 2005). In addition, emergency applications of fungicides have been used sporadically to control the *P. psidii* rust (Alfenas et al., 2004).

The selection of superior matrices for commercial plantations or for use in genetic breeding programs is based on volumetric growth, stem form, wood quality and disease resistance. Under conditions of natural infection, disease susceptible materials may be mistakenly selected as resistant materials, due to inadvertently escaping the disease. Therefore, molecular and genetic detection tools that are independent of infection occurrence are valuable in the selection of disease resistant genotypes. In this context, identification of the molecular markers linked to the disease resistance genes has emerged as an important tool for the selection of disease resistant genotypes. These markers allow us to identify disease resistant characteristics, even in the absence of causative pathogens (Benet et al., 1995).

Investigation of genetic mapping and inheritance of rust resistance in *E. grandis* Hill ex Maiden has been conducted by Junghans et al. (2003). The authors found that rust resistance in *E. grandis* is controlled by the dominant locus *Ppr1*. Based on co-segregation analysis between rust resistance and Random Amplified Polymorphic DNA (RAPD) markers (Williams et al., 1990), they found six markers linked to *Ppr1*. The RAPD marker AT9/917 exhibited complete co-segregation with *Ppr1* in 994 analyzed plants. The AT9/917 marker was then cloned and sequenced, but no significant homology has been found in the GenBank database (Junghans et al., 2003). In addition, few studies have focused on the inheritance of resistance to leaf rust (Zamprogno et al., 2008; Teixeira et al., 2009; Alves et al., 2012).

Molecular markers have been increasingly used as a tool in plant breeding, including genetic mapping of traits of interest and marker-assisted selection of resistant genotypes of plants. RAPD markers are useful for genetic analysis and characterization of the genomes of cultivated species, however, the results obtained with RAPD markers are less reproducible, which may limit its application in marker-assisted selection (Junghans et al., 2003).

To improve the specificity and in order to better assess segregation of markers linked to the characteristics of interest, the less-specific RAPD markers can be converted into highly specific sequence characterized amplified region (SCAR) markers (Paran and Michelmore, 1993). Briefly, the RAPD markers are cloned and sequenced and the obtained DNA sequences are used to design specific primers for amplification of particular polymorphic regions (Paran and Michelmore, 1993). The SCAR markers have been applied in different studies for a variety of plant species and exhibited highly specific amplification and high reproducibility (Martins Filho et al., 2002; Milla et al., 2005; Masuzaki et al., 2008; Sen et al., 2010; Truong et al., 2011). For example, SCAR markers linked to the resistance gene, *Rpf1*, were identified and characterized to select strawberry plants that are resistant to red stele root rot caused by *Phytophthora fragariae* (Haymes et al., 2000). In this study, we converted a previously identified RAPD marker into a SCAR marker, and evaluated its usefulness in selection of rust resistant genotypes.

MATERIALS AND METHODS

Plant materials

Forty-one F1 individuals from a cross between an array of *E. grandis* rust-resistant (G21) and susceptible (G38) (Junghans et al., 1999, 2003) plants were used in this study. Previous studies have proved that recombination events occurred in these 41 individuals between markers AC8/1180 and AV10/765 that flank the rust resistant gene *Ppr1* (Junghans et al., 1999, 2003).

DNA extraction and RAPD assay

DNA extraction and RAPD assay were conducted according to the protocol described by Grattapaglia and Sederoff (1994) using RAPD primer AT9.

Cloning and sequencing of the RAPD fragment

Based on the results from Junghans et al. (2003), a fragment of 917 bp, generated by RAPD primer AT9, was able to discriminate rust susceptible and resistant genotypes. However, the authors did not identify more than one type of DNA sequence in the 917 bp fragment. Thus, we started a new cloning with this 917 bp fragment. The DNA band of 917 bp linked to the resistant gene *Ppr1* was extracted from agarose gel and purified using the Concert kit™ Rapid Gel Extraction System (Life Technologies). The purified DNA was then cloned into the pGEM-T Easy vector (Promega), according to the manufacturer's recommendations. The cloned fragments were transformed to competent cells of *Escherichia coli*

Table 1. PCR primers used for the development of SCAR markers.

Primer name	Primer sequence (5'->3')	Length (bp)	Direction
AT9 R	TAGCGTCATCAGTAGGTCACCAGG	24	Reverse
AT9 F	CGAGATTTTGTGGAAGCGAAGCATTG	26	Forward
SCAT9 L	CCCTCACGTACGAAGTGGTT	20	Forward
SCAT9 R	GCGTCATCAGTAGGTCACCA	20	Reverse
AT9 915 1 L	CCGTTAGCGTGAGTAGATGTAGAG	24	Forward
AT9 915 914 R	CGTTAGCGTCATCAGTAGGTCA	22	Reverse
AT9 915 71 L	GAAGCGAAGCATTGCATGTC	20	Forward

DH5α, using the heat shock transformation method that has been previously described (Sambrook et al., 1989). The transformed cells were plated on LB medium containing ampicillin (0.1 mg / ml), IPTG (200 mg / ml) and X-GAL (20 mg / ml) and incubated at 37°C for 12 h. Colonies containing recombinant plasmids were identified by white color and were transferred to tubes containing 3 ml of LB medium with ampicillin (0.1 mg / ml) and incubated at 37°C for 12 h, under constant agitation (250 rpm). Plasmid DNA was isolated by the previously described alkaline lysis method (Sambrook et al., 1989) and quantified. Next, to confirm successful transformation, plasmid DNA was amplified via PCR, using primers M13F and M13R (Life Technologies) or digested with the enzyme *EcoRI*, which has cleavage sites in the ends of the vector cloning sites. The nucleotide sequence of the insert was determined in a Perkin-Elmer automated sequencer ABI model 310, using the Thermo Sequenase kit Dye Terminator Cycle Sequencing (Amersham), according to manufacturer's instructions.

Design of SCAR primers and SCAR amplification

The nucleotide sequence of the 917 bp RAPD fragment was used as a template to design the SCAR primers longer than those used in RAPD assay. The computer program DNAMAN was used for primer design, including the amount of bases, Tm (melting temperature), and the GC content. Finally, seven primers, including four forward and three reverse primers, were designed. These are listed in Table 1. Primers AT99151L and AT9915914R share ten and nine nucleotides with the RAPD primer AT9, respectively.

A maximal combination of 12 pairs of primer was tested by PCR for the parental *E. grandis*, G38 (rust susceptible) and G21 (rust resistant). The PCR reaction was standardized to 25 µl, containing 30 ng of genomic DNA, 0.2 mM of each dNTP (dATP, dTTP, dCTP and dGTP), 0.25 mM of each primer, 2.0 mM $MgCl_2$, 50 mM KCl, 10 mM Tris-HCl (pH 8.3 at 25°C) and one unit of Taq DNA polymerase. The reactions were then submitted to amplification in a PTC-100 thermal cycler (MJ Research Inc.). The PCR program ran for 3 min at 94°C for initial denaturation, followed by 40 cycles, each consisting of 30 s at 94°C, 1 min at 58°C and 1 min at 72°C, with a final extension of 5 min at 72 °C. The PCR reaction was kept at 4°C after completion. Confirmation of amplification was conducted by visual observation of DNA bands on agar. The PCR productions were separated on 1.4% agarose gel in TBE buffer, containing 0.2 mM bromide ethidium by electrophoresis (Sambrook et al., 1989). A DNA ladder of known size was used to identify the fragment of interest.

Each of the three units of restriction enzymes, *HinfI*, *TaqI*, *HaeIII* *PstI* or *CfoI* (Promega) was added into 20 µl of the PCR reaction to digest DNA fragments. The enzyme digestion solution was changed to 50 µl by adding an appropriate volume of 10X restriction buffer and water. The enzyme digestion solution was kept separately at the optimum temperature for 5 h for each of the enzymes. After digestion, the products were separated on agarose gel by electrophoresis, stained with ethidium bromide and visualized under an ultraviolet light transilluminator. The gel image was captured and digitized in the computer.

RESULTS AND DISCUSSION

Genetic markers represent an excellent tool in plant breeding, since the presence of genes of interest can be detected at any stage of plant development. RAPD is widely used in plant breeding, because it is easy to conduct, inexpensive and quick. However, RAPD cannot be applied to DNA samples of contamination that may generate non-specific amplification. In addition, RAPD generally has low reproducibility and results from different laboratories are difficult to compare with each other, limiting its application. To overcome the disadvantages, including low reproducibility, RAPD molecular markers have been converted into highly specific SCAR markers (Paran and Michelmore, 1993). The SCAR markers have been widely used in genotyping, marker-assisted selection, and high-resolution genetic mapping of plants (Paran and Michelmore, 1993; Xu et al., 1995; Rameau et al., 1998; Nietsche et al., 2000; Guo et al., 2003; Asif et al., 2005; Shi et al., 2009; Srivastava et al., 2012). In this study, we converted a previously identified RAPD marker linked to rust resistance gene *Ppr1* to a SCAR marker for genetic identification of rust resistance in *E. grandis*.

Nine recombinant clones were randomly selected in follow-up analyses after the RAPD fragment of 917 bp was cloned into the pGEM-T Easy vector. Since all clones showed the same pattern of enzyme digestion of four restriction enzymes, only one was sequenced and compared with the sequence previously obtained by Junghans et al. (2003). No difference has been identified between DNA sequences obtained by Junghans et al. (2003) and the one obtained in this study. Based on the DANA sequence of the 917 bp fragment, amplified by RAPD primer AT9, seven oligonucleotide primers were designed, including four forward and three reverse primers. The location of these primers on fragment AT9 (917 bp) is shown in Figure 1 and the primers sequences are listed in Table 1.

Twelve pairs of SCAR primers were tested on parental

Figure 1. Nucleotide sequence (917 bp) fragment linked to *Ppr1* and SCAR primers anneling. Regions where RAPD AT9 primers are located are underlined.

G21 (resistant) and G38 (susceptible) *E. grandis*. However, only some of the tested primer pairs generated amplicons of expected size. Positive amplifications occurred on both resistant and susceptible *E. grandis,* likely suggesting that the polymorphism obtained with the original primer AT9 must be due to one or a few unpaired nucleotides (mismatches) at the site of primer complementary regions, similar to that found by Xu et al. (2001) in tomatoes. It was noted that six primer pairs did not generate expected band patterns at 56°C of extension temperature, even in positive controls. By increasing extension temperature to 58°C, we observed that these reactions generated amplification patterns different from expected patterns or no bands were produced at all. In addition, it was observed that some primer pairs generated only one band in the region of 917 bp. However, none of the possible combinations of primers, at all temperatures tested, revealed polymorphisms between resistant and susceptible *E. grandis*. Thus, the restriction enzyme was used to identify sequence polymorphisms of PCR products generated by SCAR primers.

The AT99151L and AT9915914R pair of SCAR primers, which showed an amplification pattern of expected size, was selected for enzyme digestion analysis. The PCR product was then digested with restriction enzymes to check for the presence of polymorphisms between the two parental *E. grandis* (Figure 2). Enzymes *Hinf*I, *Taq*I, *Hae*III, *Cfo*I and *Pst*I showed the existence of several polymorphic bands between the resistant and susceptible parents on the amplified region. To verify whether or not these markers were linked to *Ppr1*, segregation was evaluated in individuals with recombination events between markers AC8/1180 and AV10/765, flanking *Ppr1* (Junghans et al., 1999, 2003).

Most polymorphic bands do not co-segregate with *Ppr1*. However, the products of the digestion of PCR products, using the enzyme *CfoI,* showed a band at lower intensity, of approximately 800 bp, which co-segregated with the *Ppr1* gene (Figure 3). Among all F1 progeny tested, only in four cases the marker $SCAR_{CfoI}$ did not

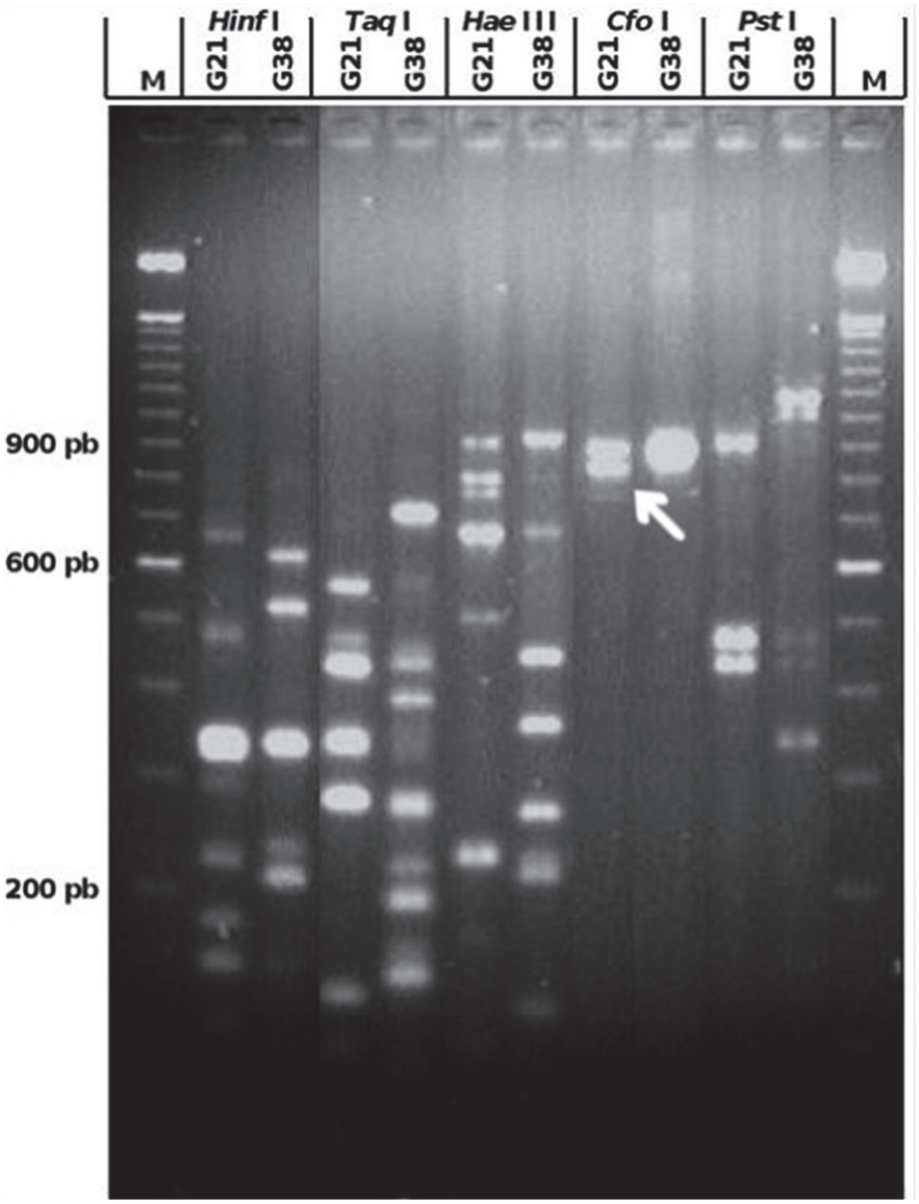

Figure 2. Digestion patterns from PCR products generated by the SCAR primers AT99151L and AT9915914R. M = 100 bp DNA Ladder; G21, the resistant genotype, G38, susceptible genotype. bp = base pairs. Arrow inficates polymorphic band between G21 and G38 genotypes.

correlate with the phenotypes of resistance or susceptibility (Table 2). In the first case (plant 196) the results lead to the assumption that there had been an error in the classification of resistance phenotypic as the resistant phenotype S1 can be confused with the S2 susceptible phenotype.

Moreover, the distance between *Ppr1* and the marker AV10/765 is 0.9 cm, but the distance between the marker AC8/1180 and gene *Ppr1* is 3.4 cM. Thus, genetic recombination between *Ppr1* and the marker AC8/1180 is easier than recombination events between *Ppr1* and the marker AV10/765. As for plant 414 that was properly characterized as the resistance phenotype and genotype, three recombination events would be required to occur: one between the RAPD marker AC8/1180 and *Ppr1*, another between *Ppr1* and RAPD marker AT9/917 and the third recombination event between SCAR marker $SCAR_{CfoI}$ and RAPD marker AV10/765. Although this is possible, the probability is very low. Therefore, this case is more likely to be an error of classification of the resistance phenotype. The third recombination event between *Ppr1* and the marker $SCAR_{CfoI}$ was detected in

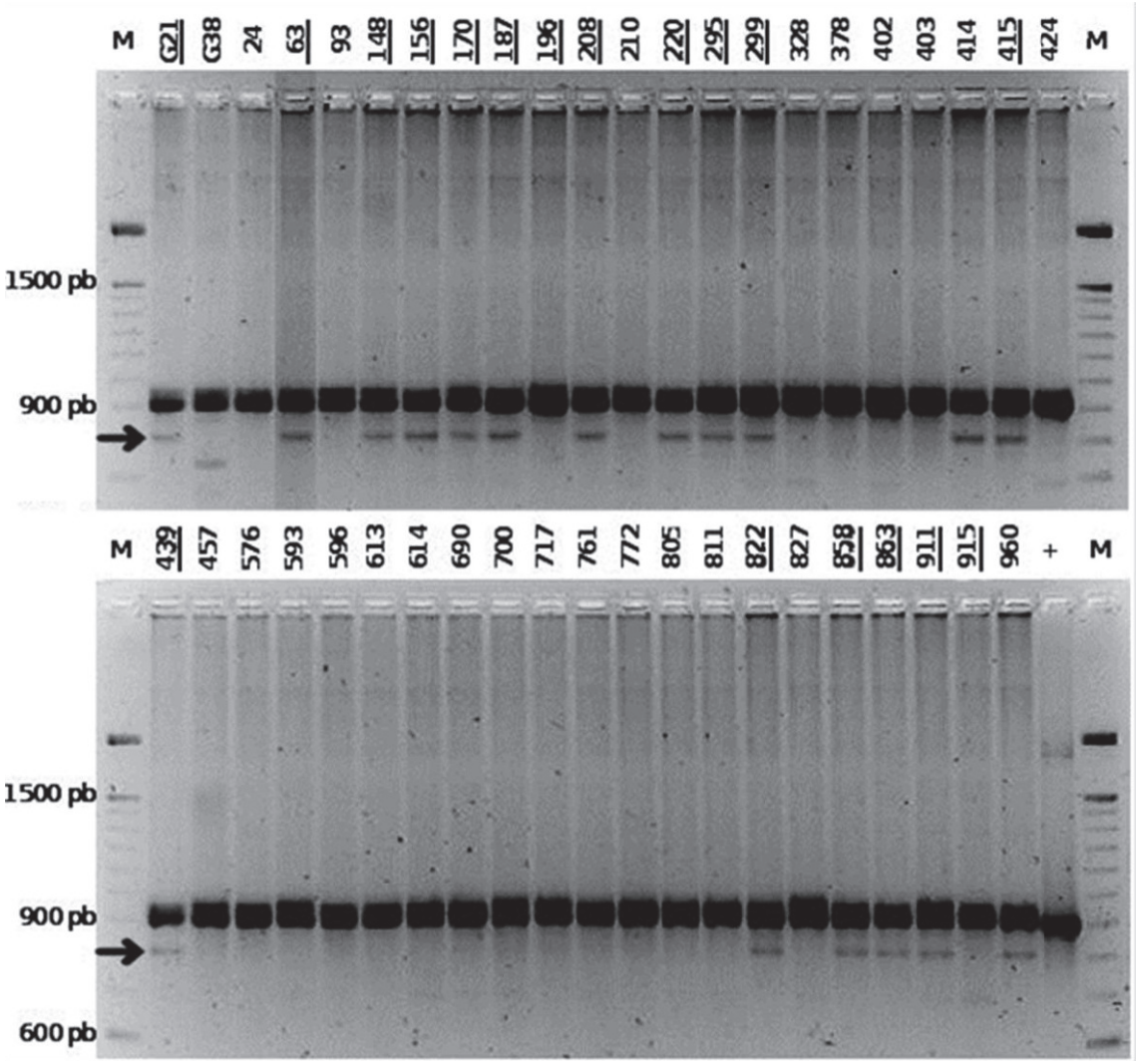

Figure 3. Co-segregation analysis of Ppr1 and $SCAR_{CfoI}$ marker in F1 *E. grandis* progeny, with recombination events near Ppr1. The PCR products generated by SCAR primers pair AT99151L and AT9915914R were digested with restriction enzyme CfoI. The digestion pattern was compared between the two parental, resistant (G21) and susceptible (G38), and F1 progeny. bp = base pairs. M = 100 bp DNA ladder. Underline = rust resistant genotype. Not underscore = eucalyptus susceptible to rust. "+" = Positive control (plasmid DNA containing the 917 bp fragment).

plant 915. In this case, there was a possible recombination between the RAPD marker AT9/917 and $SCAR_{CfoI}$. This allows us to assume that the RAPD marker AT9/917 is between the gene *Ppr1* and marker $SCAR_{CfoI}$. While the results obtained by Junghans et al. (2003) suggested that RAPD marker AT9/917 was linked to the gene *Ppr1*, they are unable to locate AT9/917. The last case of possible recombination between the marker $SCAR_{CfoI}$ and *Ppr1* occurred in plant 960. As in plant 196, these results may be due to an error in phenotypical characterization of disease resistance, since S1, which is considered resistant, can be confused with S2, which is considered susceptible, or vice versa. In addition, as the distance between the gene *Ppr1* and the marker AV10/765 is 0.9 cm, which is beyond the markers AT9/917 and $SCAR_{CfoI}$, the distance between the marker AC8/1180 and the gene *Ppr1* is 3.4 cM, indicating that recombination between *Ppr1* and AC8/1180 is easier than recombination between gene *Ppr1* is and the marker AV10/765.

Despite not having a linkage test, it can be assumed that the RAPD marker AT9/917 and SCAR marker, $SCAR_{CfoI}$, are very close to each other, and AT9/917 is between gene *Ppr1* and $SCAR_{CfoI}$. This can be very useful in positional cloning of the gene *Ppr1* is, because the $SCAR_{CfoI}$ marker can give the direction of traversal chromosomal targeting for cloning *Ppr1*. Moreover, the RAPD AT9/917 was unable to differentiate resistant from

Table 2. Co-segregation analysis of SCAR marker $SCAR_{CfoI}$ and *Ppr1* gene (Junghans et al., 2003) in F1 *E. grandis* progeny. The color breaking indicates a probable recombination.

Plant	K1	AE9	AC8	*Ppr*1		AT9/917	$SCAR_{CfoI}$	AV10	AM6
G21	+	+	+	R	(S0)	+	+	+	+
G38	-	-	-	S	(S3)	-	-	-	-
24	-	-	-	S	(S2)	-	-	+	+
63	-	-	-	R	(S0)	+	+	+	+
93	+	+	+	S	(S2)	-	-	-	-
148	+	+	+	R	(S0)	+	+	-	-
156	+	+	+	R	(S1)	+	+	-	-
170	-	-	-	R	(S0)	+	+	+	+
187	-	-	-	R	(S0)	+	+	+	+
196	+	+	+	R	(S1)	-	-		+
208	+	+	+	R	(S1)	+	+	-	-
210	-	-	-	S	(S3)	-	-	+	+
220	+	+	+	R	(S1)	+	+	-	-
295	-	-	-	R	(S0)	+	+	+	+
299	+	+	+	R	(S0)	+	+	-	-
328	+	+	+	S	(S3)	-	-	-	-
378	-	-	-	S	(S3)	-	-	+	+
402	-	-	-	S	(S3)	-	-	+	+
403	-	-	-	S	(S3)	-	-	+	+
414	+	+	+	S	(S3)	+	+	-	-
415	+	+	+	R	(S0)	+	+	-	-
424	+	+	+	S	(S3)	-	-	-	-
439	+	+	+	R	(S1)	+	+	-	-
457	-	-	-	S	(S3)	-	-	+	+
576	+	+	+	S	(S3)	-	-	-	-
593	-	-	-	S	(S2)	-	-	+	-
596	-	-	-	S	(S3)	-	-	-	-
613	-	-	-	S	(S2)	-	-	+	+
614	-	-	-	S	(S2)	-	-	+	+
690	+	+	+	S	(S3)	-	-	-	-
700	-	-	-	S	(S3)	-	-	+	+
717	-	-	-	S	(S3)	-	-	+	+
761	-	-	-	S	(S3)	-	-	+	+
772	+	+	+	S	(S3)	-	-	-	-
805	-	-	-	S	(S3)	-	-	+	+
811	+	+	+	S	(S2)	-	-	-	-
822	+	+	+	R	(S0)	+	+	-	-
827	-	-	-	S	(S2)	-	-	+	+
858	+	+	+	R	(S0)	+	+	-	-
863	+	+	+	R	(S0)	+	+	-	-
911	-	-	-	R	(S0)	+	+	+	+
915	+	+	+	R	(S0)	+	-	-	-
960	-	-	-	S	(S2)	+	+	+	+

1. R = resistant genotype, S = susceptible genotype; S0 or S1 = resistant individual, S2 or S3 = susceptible individual. 2. "+" = presence; "-" = absence. 3. Green color = genomic region inherited from genotype G21 (resistant to rust). 4. Red color = Genotypes recombinant to $SCAR_{CfoI}$ marker.

susceptible individuals. Therefore, $SCAR_{CfoI}$ is useful in selection of resistant individuals, or those with increased chance of being resistant to *P. psidii*.

Conflict of Interest

The authors declared that they have no conflict of interest.

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Full Length Research Paper

Ichthyofaunal diversity of mountain streams in the Tongboshan Nature Reserve, China

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Tongboshan Nature Reserve (between 28°03′30″ - 28°10′33″N and 118°12′00″ - 118°21′36″E) is located in the northeast of the Wuyi Mountain Range in the eastern Jiangxi Province. The fish fauna of mountain streams in the nature reserve was investigated seasonally during 2012. A total of 442 samples were collected and classified into four orders, eight families and 22 species. None of them collected in the nature reserve was exotic species. Among them, *Zacco platypus* was the most abundant fish species collected, followed by *Onychostoma barbatulu* and *Acrossocheilus parallens*. A total of 10 species were found to be endemic to China. Current threats to conservation of fishes in the nature reserve were identified and management solutions are suggested.

Key words: Tongboshan Nature Reserve, Mountain streams, ichthyofauna, diversity, conservation.

INTRODUCTION

Jiangxi Province (between 24°29′14″ - 30°04′41″N and 113°34′36″ - 118°28′36″E) is located in southern China, to the south of the middle and lower reaches of the Yangtze River. Poyang Lake, the largest freshwater body in China, is located in the north of Jiangxi Province. The area immediately surrounding Poyang Lake consists of low-lying alluvial plains prone to flooding. Mountains close to the boundaries of Jiangxi Province surround this region and all the five major rivers in the province (Ganjiang, Xinjiang, Fuhe, Raohe and Xiuhe Rivers) flow into the Poyang Lake. The drainage to Poyang Lake is a narrow outlet named Hukou, which flows into the Yangtze River and marks the northern border of the province. The sources of the rivers in Jiangxi Province are located in the surrounding mountains. Of a total of 220 recorded freshwater fish species throughout Jiangxi Province, about 131 species (59.5%) are believed to be endemic, many present in the mountainous regions (Huang et al., 2011). Protected areas such as nature reserves could play an important role in conservation of freshwater fishes within Jiangxi Province, but there is a need to better identify the conservation value of these areas in relation to biogeographical diversity of fishes and the factors impacting on fish communities.

Worldwide, freshwater fishes are the most diverse of all vertebrate groups, but are also the most threatened group of vertebrates after amphibians (Moyle and Leidy, 1992; Bruton, 1995; Duncan and Lockwood, 2001). Most

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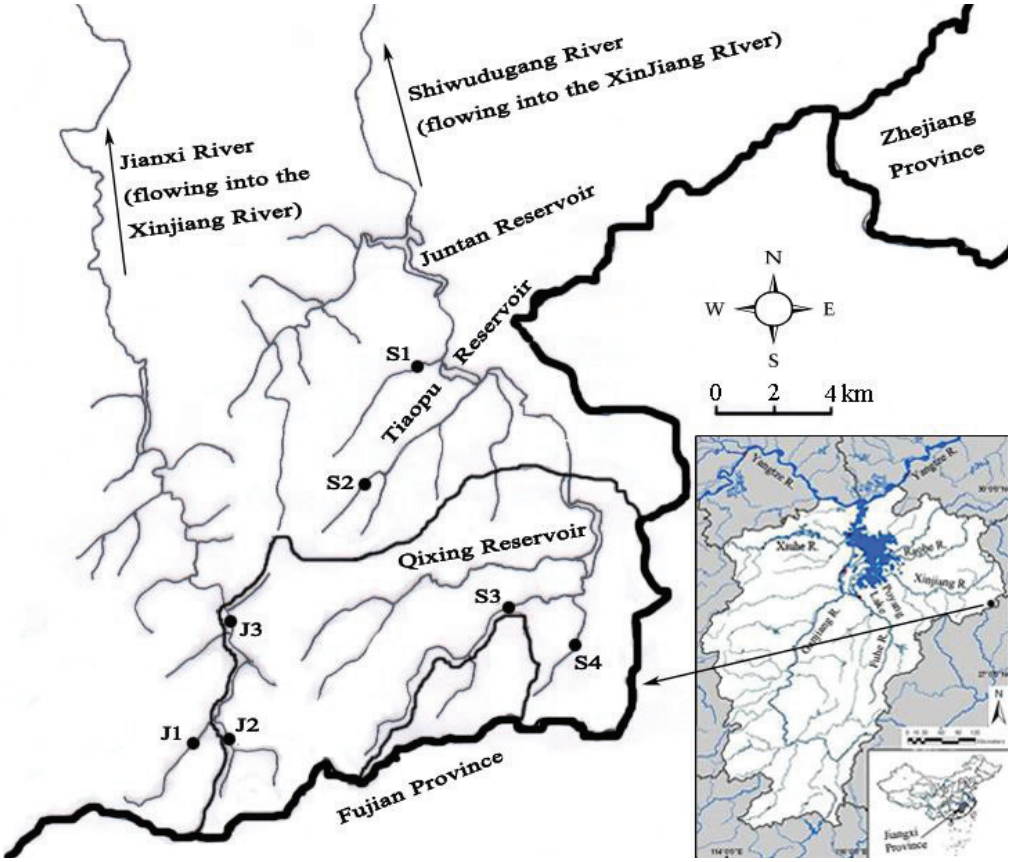

Figure 1. Map showing location of the TNR and sampling sites in the TNR.

mountain streams in the Tongboshan Nature Reserve (TNR) are shallow and the hydrology of most headwater streams has been modified by farming and irrigation of surrounding land. Recently, numerous anthropogenic disturbances, such as clear-cuts, small dams, road construction, fires and mining, have triggered physico-chemical alterations in the mountain streams (Tu et al., 2009; 2012).

At present, there have been several notable surveys of the flora and fauna within the nature reserve (Tu et al., 2009; 2012). However, until this work there have been no studies on the distribution and abundance of fish species in the nature reserve. The aims of the present study are:
(1) To characterize the species composition of the fish fauna and their distribution in the nature reserve;
(2) To review the main threats over fish biodiversity, and
(3) To establish some recommendations to the conservation of the fish fauna.

MATERIALS AND METHODS

Study area

The TNR (total area: 108 km^2, altitude: 1535 m, between 28°03′30″ - 28°10′33″N and 118°12′00″ - 118°21′36″E) is located in the northeast of the Wuyi Mountain Range in the eastern Jiangxi Province (Figure 1). The nature reserve presents humid subtropical climate and belongs to the forest ecological nature reserve for the conservation of evergreen broad-leaved forest ecological system and biodiversity. The annual precipitation is 1626.9 mm, annual temperature is 17.9°C, and forest coverage rate is up to 98% (Tu et al., 2009; 2012). Most mountain streams in the TNR flow into the Jianxi and Shiwudugang River which drain into the Xinjiang River (Figure 1).

Study site

Seven sampling sites were established on Jianxi and Shiwudugang River within the TNR (Figure 1). Sampling site selections were based on the representative habitat types present and accessibility during the study period. At each sampling site, the GPS position and altitude were recorded using a Garmin GPS map 76Cx. And water temperature, dissolved oxygen were measured with a hand-held YSI multi-meter. In addition, stream width and water depth were measured at each site.

Fish survey

Seasonally, samples were made at seven sites in the TNR during 2012. At each site, samples were collected using an electrofishing device consisting of two copper electrodes on wooden handles, powered by a 500-watt portable AC generator. Stunned fish were

Table 1. Characteristics of sampling sites within Jianxi River and Shiwudugang River, TNR, China.

Sampling sites		Altitude (m)	Depth (m)	Width (m)	Water temperature (°C)	Dissolved oxygen (mg/L)	Habitat description
Jianxi River	J1	715	0.2-1.5	1-4	9.6-17.2	9.6-10.8	Fast flowing and clear water, gravel and pebble substrate, shaded by forest canopy
	J2	796	0.1-1.2	1-3	9.0-16.8	9.8-11.2	Fast flowing and clear water, rocky and boulder substrate, shaded by forest canopy
	J3	670	0.2-2.0	2-5	10.2-17.6	9.5-10.6	Fast flowing and clear water, rocky and gravel substrate, river shaded by forest canopy
Shiwudugang River	S1	267	0.3-2.0	3-10	12.9-18.8	7.9-9.9	Slow flowing and slightly turbid water, gravel and sandy substrate, shaded by riparian vegetation
	S2	375	0.2-1.5	3-8	11.9-18.3	8.2-10.5	Slow flowing and clear water, gravel and sandy substrate, shaded by riparian vegetation
	S3	460	0.1-1.0	2-6	12.2-19.0	7.8-10.2	Slow flowing and clear water, gravel and boulder substrate, shaded by riparian vegetation
	S4	330	0.5-3.5	3-15	12.6-19.8	8.9-10.3	Slow flowing and slightly turbid water, gravel and sandy substrate, shaded by riparian vegetation

collected using dip nets or caught by hand. A cast net (mesh 5×5 mm; $\pi \times 0.6^2$ m = 1.13 m^2) was also used within shallow pools of the stream system to collect fish. Approximately 100 m of stream segment, typically comprising pool, run and riffle habitats, was sampled at each site. Collected specimens that could not be identified in the field were fixed in 10% formalin solution for accurate taxonomic verification. All specimens were identified according to Zhu (1995), Chen (1998), Chu et al. (1999) and Yue (2000).

Data analysis

The relative abundance of each species was estimated by:

$P_j = N_j / N$

where N_j = the number of species j collected in the TNR; N = the total number of all fish collected in the TNR. The Margalef index (D) and Shannon-Wiener index (H) were used to calculate fish species richness for each site (Peet, 1974; Magurran, 1988):

$D = (S - 1) / \ln N$ and $H_k = -\sum P_j \ln P_j$,

Where S = the total number of species collected in the TNR.

RESULTS

Stream characteristics and physicochemical parameters

The physical characteristics of each site are described in Table 1. Physico-chemical characteristics were similar among all studied sites in the TNR. Most of surveyed sampling sites were composed of sandy, gravel and pebbles substrates and the banks were lined by boulders and rocks. Shallow pools and riffles alternated in the segments studied. Generally, most mountain streams had clear water and were shaded by riparian vegetation or forest canopy. This appearance is typical of undisturbed forest stream at higher altitudes. All sampling sites were fully saturated with dissolved oxygen (mean ± SE, 9.6 ± 1.2 $mg \cdot L^{-1}$). And water temperature ranged from 9.0 to 19.8°C. The high dissolved oxygen could be attributed to low water temperature and high water speed.

Fish fauna

A total of 442 specimens were collected and classified into 22 species and eight families in the TNR (Table 2). Cyprinidae (11 species, 50.00% of the total number of fish species collected) was the dominant family followed by Homalopteridae (three species, 13.64%), Bagridae and Gobiidae (two species respectively) while Cobitidae, Siluridae, Amblycipitidae and Synbranchidae were represented by only one specie respectively. The dominancy of fish species in the TNR was *Zacco platypus* (102 specimens, 23.08% of the total specimens collected), followed by *Onychostoma barbatulu* (17.87%) and *Acrossocheilus parallens* (11.99%).

Table 2. Composition and distribution of fish species in the TNR, Jiangxi, China.

Family/species	*Jianxi River*			*Shiwudugang River*			
	J1	**J2**	**J3**	**S1**	**S2**	**S3**	**S4**
Cyprinidae							
Acrossocheilus parallens (Nichols, 1931)*				11	41		1
Onychostoma barbatulum (Pellegrin, 1908)*			1	2	43		33
Opsariichthys bidens Günther, 1873							16
Zacco platypus (Temminck and Schlegel, 1846)	35	31	32			2	2
Gnathopogon imberbis (Sauvage and Dabry de Thiersant, 1874)*							30
Chanodichthys erythropterus (Basilewsky, 1855)							1
Culter alburnus (Basilewsky, 1855)							3
Hemiculter leucisculus (Basilewsky, 1855)							5
Megalobrama amblycephala (Yih, 1955)							2
Sinibrama macrops (Günther, 1868)*							2
Rhynchocypris oxycephalus (Sauvage and Dabry de Thiersant, 1874)	10	11					
Cobitidae							
Misgurnus anguillicaudatus (Cantor, 1842)						2	21
Homalopteridae							
Formosania davidi (Sauvage, 1878)*					3		
Pseudogastromyzon changtingensis tungpeiensis (Chen and Liang, 1949)*		1		17	8		12
Vanmanenia stenosoma (Boulenger, 1901)*	1			1			
Siluridae							
Silurus asotus Linnaeus, 1758							2
Bagridae							
Pseudobagrus taiwanensis (Oshima, 1919)*	15	9	15				
Pseudobagrus medianalis (Regan, 1904)*						1	
Amblycipitidae							
Liobagrus anguillicauda (Nichols, 1926)*	1	1		1			
Gobiidae							
Rhinogobius cliffordpopei (Nichols, 1925)				3			3
Rhinogobius giurinus (Rutter, 1897)			1	6			1
Synbranchidae							
Monopterus albus (Zuiew, 1793)				1		1	1

*Endemic to China (Huang et al., 2011, FishBase: www.fishbase.org).

Overall, 10 species (45.45% of the total number of fish species collected) were found to be endemic to China in the TNR. Endemic fishes were classified into four families. The dominant family of endemic fishes was Cyprinidae (four species) and the subdominant families were Homalopteridae (three species), Bagridae (two species) and Amblycipitidae (one specie). The most common endemic species to China was *Onychostoma barbatulum* (79 specimens, 17.87% of the total specimens collected), followed in order of abundance by *Acrossocheilus parallens* (53 specimens, 11.99%), *Pseudobagrus taiwanensis* (39 specimens, 8.82%), *Pseudogastromyzon changtingensis tungpeiensis* (38 specimens, 8.60%), *Gnathopogon imberbis* (30 specimens, 6.79%), *Formosania davidi* and *Liobagrus anguillicauda* (3 specimens, 0.68% respectively), *Sinibrama macrops* and *Vanmanenia stenosoma* (2 specimens, 0.45% respectively), *Pseudobagrus medianalis* (1 specimen, 0.23%) in the TNR.

General distribution of fish species collected from the seven sampling sites in the TNR was shown in Table 2. Meanwhile, the ecological indices for two rivers in the TNR, Shiwudugang River compared to Jianxi River may be because the fish habitats in the Shiwudugang River have comparatively higher species richness and diversity (Table 3).

DISCUSSION

Factors favoring diversity and endemism

The results of the present field studies on the TNR showed that a total of 22 native species (10.00% of all

Table 3. Comparison of fish species diversity between Jianxi River and Shiwudugang River, TNR, China.

Mountain stream	Total number of species (S)	Total number of individuals (N)	*Margalef diversity index (D)*	*Shannon-Wiener diversity index (H)*
Jianxi River	8	164	1.37	1.57
Shiwudugang River	20	278	3.38	3.17

Jiangxi Province freshwater species) were collected or found to be distributed in mountain streams. For example, *Zacco platypus* (23.08% of the total specimens collected), *Onychostoma barbatulu* (17.87%), *Acrossocheilus parallens* (11.99%), *Pseudobagrus taiwanensis* (8.82%), *Pseudogastromyzon changtingensis tungpeiensis* (8.60%), *Rhinogobius giurinus* (1.81%), *Rhinogobius cliffordpopei* (1.36%) and *Liobagrus anguillicauda* (0.68%) are anatomically well adapted to live in fast flowing current with clear water and relatively higher dissolved oxygen concentration. Generally, they feed on algae growing on the rock as well as detritus and insects. Overall, ten endemic species (250 specimens, 56.56% of the total specimens collected) in the TNR represented 7.63% of total endemic species in Jiangxi Province (131 endemic species; Huang et al., 2011).

This study suggests that mountain streams in the TNR are very important for freshwater fish diversity and conservation in Jiangxi Province, especially for the endemic species. The more abundant or endemic species collected in the TNR may be partially due to habitat stability and lack of disturbances, such as introduction of exotic species. The riparian zones of streams in the TNR are well forested so that stream temperatures rarely reached 20°C even during the summer and dissolved oxygen levels were high at all sites, providing suitable environmental conditions for these fishes. Such as *Rhynchocypris oxycephalus* (21 specimens, 4.75% of the total specimens collected), a representative cold water species of the Holarctic Region in China, tend to be distributed in the north of China. The alternating Quaternary glacial and interglacial periods had the effect of moving *Rhynchocypris oxycephalus* south, where it survived in the small mountain streams where the water is cold (Zhang and Chen, 1997).

It is interesting to note that the fish diversity was comparatively higher in Shiwudugang River than in Jianxi River. The habitats such as water depth and current, shoreline slopes and bottom substrates were relatively different. The substrate in Shiwudugang River was formed mainly of sandy-gravel, whereas in Jianxi River the substrate consisted mainly of rocky-pebbles which are very unstable. According to Zakaria et al. (1999) this condition could be a more suitable habitat for higher species diversity and richness. And most fishes were recorded in a channel stream part of a wide river where the water is deeper and slower. Some species such as *Chanodichthys erythropterus*, *Culter alburnus*, *Hemiculter leucisculus*, *Megalobrama amblycephala*, *Sinibrama macrops* and *Silurus asotus* were only collected at site S4.

Current threats and conservation

During recent decades, streams and rivers in China have been drastically modified because of agricultural activities, drinking water supplies and the construction of multi-purpose dams, artificial reservoirs, levees, and weirs. These physical alterations and other human influences, such as road construction and deforestation have accelerated eutrophication (Fu et al., 2003). For example, Juntan Reservoir (closed on April 1985), Tiaopu Reservoir (completed in the 1980's) and Qixing Reservoir (closed on December, 1991) were built on Shiwudugang River. These factors strongly diminished effective migration for those species moving between different stream habitats. Small and fast-flowing streams have often been changed to large, slow-flowing streams. This change would cause that the organisms become restricted to mountainous areas and to be replaced by other beings adapted to slow-flowing streams (Hu et al., 2009).

In addition, some people go fishing as a source of food in the mountain streams of the TNR using rotenone and other poisons which usually are used to exterminate snails. This kind of fishing not only contributes to reduce fish biodiversity but is also harmful to human health.

Therefore, the primary objective for successful conservation of the freshwater ichthyofaunal diversity in the TNR must be to develop effective controls and management practices that enable life cycle success, dispersal and population maintenance within stream systems. It is necessary to improve effective fish passage facilities in order to enhance the connectivity of streams for fish dispersal and migration. Fishing activities in the TNR, especially using rotenone and other poisons must be strictly prohibited. The present work agrees with the statement that "long-term management and conservation of the fish fauna of nature reserves and other protected areas in Jiangxi Province will require good bench-mark sites and a long-term monitoring protocol" (Jang et al., 2003).

Conflict of Interest

The authors declared that they have no conflict of interest.

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Full Length Research Paper

Evaluation of aerobic hybrid analysis of combining ability in three line hybrids in Rice (*oryza sativa* l.) under aerobic conditions

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Information on the availability of genetic variability and mode of gene action are critically important for choosing effective breeding methods that result in appreciable improvement in performance under drought stress. An investigation in rice (*Oryza sativa* L.) was carried out subjecting six 'lines' and 15 'testers' crossed in a Line x Tester mating design and the 90 hybrids along with 21 parents were tested for gene action, combining ability for 19 traits under aerobic condition. Three 'lines' *viz*., IR79128A (L_1), IR79156A (L_2) and IR70369A (L_4) and three 'testers' *viz*., IR7925A-428-2-1-1R (T_{11}), KMP -148 (T_{12}) and BI-33 (T_{15}) were identified as the best general combiners. The genotype IR70369A is suggested for conversion to cytoplasmic male sterility with suitable male sterile source. The parents MAS -26, IR 7925A-428-2-1-1R and KMP-105 are recommended for testing their restorability with suitable cytoplasmic male sterile source.

Key words: Additive genetic variance (σ^2A), dominance genetic variance (σ^2D), general combining ability variance/effects, specific combining ability variance/effects, aerobic rice.

INTRODUCTION

Rice is the staple food for over 70% of Asians, the majority of whom are living below the poverty line. More than 90% of the world's rice is produced and consumed in Asia (Barker et al., 1999) and rice production must be increased by an estimated 56% over the next 30 years to keep up with population growth and income-induced demand for food in most Asian countries where about 75% of total rice production comes from irrigated lowlands (Maclean et al., 2002).

Almost 25% of the world's rice is grown under rainfed lowlands and frequently affected by uneven rainfall distribution. Another 13% of the rice area under cultivation is always subjected to water stress during the growing season (Bouman et al., 2007). Food security in Asia and the increasing scarcity of fresh water resources for agriculture in many areas are stimulating the development of aerobic rice production system (Tuong et al., 2005).

Aerobic rice is high-yielding rice grown under non-flooded conditions in non-puddled and unsaturated (aerobic) soil. It is responsive to high inputs, can be rainfed or irrigated and tolerates occasional flooding (Maclean et al., 2002). The water use of aerobic rice was about 60% less than that of flooded rice and total water

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productivity was 1.6 to 1.9 times higher (Vijayakumar et al., 2006).

To formulate an efficient breeding program for developing drought tolerant varieties, it is essential to understand the mode of inheritance, the magnitude of gene effects and their mode of action (Farshadfar et al., 2008). Due to their quantitative nature, drought related traits cannot be studied in a simpler way. Specialized biometrical techniques are required to work out the type of genetic variability associated with the traits. These biometrical techniques are dependent on different mating designs such as diallel, line x tester, North Carolina design and generation mean analysis for the estimation of type of genetic variability.

In breeding high yielding varieties of crop plants, the breeders are often faced with the problems of selecting parents and crosses. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis. The Line x Tester analysis provides information about general combining ability (*gca*) of parents and specific combining ability (*sca*) effects of crosses and is helpful in estimating various types of gene actions. Zhang et al. (2002) studied the heterosis and combining ability of hybrid rice. The genetic improvement of rice for aerobic environments has not been understood well and major efforts in this front are lacking.

Significant yield advantage gained through the adoption and spread of hybrid rice technology had helped China to add about 350 million tonnes of extra rice to its food basket during 1976-1998 and enabled it to divert some of their rice areas to other commercial crops. Hybrid rice technology had also shown increased yield, farmer profitability and better adaptability to stress environments such as water scarce and aerobic conditions. Considering all these issues the main objective of this study is to develop rice hybrids with high yield potential for aerobic conditions to overcome the existing water crisis in India. For this breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability is the foremost.

MATERIALS AND METHODS

Site description

The present investigation was carried out in the Research farm of the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai, Tamil Nadu, India during 2009-2011.

A set of 21 parents comprising of six 'A' lines and corresponding 'B' lines, eight 'R' lines and seven aerobic varieties were used for the study. The commercially cultivated hybrid IR 6888 was used as the check. The details of the selected parents are furnished in Table 1. The seed materials were collected from Paddy Breeding Station, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore and Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu.

Hybridization programme

The 21 parental seed materials [six Lines and 15 Testers (Testers = eight R lines and seven aerobic rice varieties)] were sown in a raised nursery bed during the month of June, 2009. The source materials of A, B and R lines were sown adopting line sowing in raised beds of one meter width and convenient length in a fertile well leveled plot. Thin sowing in the nursery was followed by good water and nutrient management to obtain healthy seedlings with three to four tillers at the time of planting.

Seedlings of A, B, R lines which attained the age of 29 days were transplanted in three meter length row with the spacing of 30 cm between rows and 15 cm between plants of each genotype in four rows. R lines were planted separately with an isolation of 300 meter. The row ratio obtained for planting the A and B lines was 8:2. Recommended package of practices and need based plant protection measures were adopted. Crosses were effected in a 'Line x Tester' mating design (Kempthorne, 1957).

The spikelets which were likely to open in the same day were selected during early hours between 6.30 and 8.30 A.M. in the female parents. Wet cloth method of emasculation as suggested by Chaisang et al. (1967) was followed to emasculate the selected spikelets. In this method, Panicles of the A lines on the 3rd or 4th day of its blooming were selected. The immature already opened top and lower spikelets were removed leaving only the middle spikelets. The panicle was covered with wet cloth and hot air was blown through the mouth. Due to increase in temperature and humidity inside the wet cloth, the spikelets were forced to open in the pre-anthesis time. All the six stamens that protruded out of the opened spikelets were removed one by one carefully by using a pointed forceps without damaging the style and stigma. The unopened spikelets were clipped off. At the time of anthesis, the matured anthers from the male parents were collected and dusted on the stigma of the emasculated spikelets of the female parents. The crossed panicles were labeled and covered with red colored butter paper covers. The butter paper covers were removed three days after pollination. Crossing was repeated till sufficient number of crossed seeds were obtained in each of the cross combinations. Selfing of parents was also done by putting white colored butter paper covers on the panicles before the opening of spikelets.

Thus, hybrid seeds of 90 cross combinations and selfed seeds from all the 21 parents were collected after maturity. The seeds were dried at 12 %moisture and preserved at room temperature (28±1°C).

Evaluation of F_1 hybrids and parents for yield traits under aerobic condition

Ninety hybrids along with six lines, 15 testers and one check were raised in a Randomized Block Design (RBD) with three replications under non-puddled and non flooded aerobic soil, during Rabi, 2010. Each treatment was accommodated in two rows of one metre length with a spacing of 30 x 15 cm in each replication. A uniform population of 20 hills per treatment with single seedling was maintained in each replication. Recommended doses of fertilizer and cultural practices were adopted. The hybrids along with their parents were maintained under irrigated condition upto 55 days. From the 56th day onwards the treatment plot was maintained under aerobic condition. For every irrigation thereafter, soil sampling was carried out before and after irrigation to assess the soil moisture content. Irrigation was given only when hair line crack was noticed in the treatment plot and the control plot was maintained under normal flooded condition till maturity. The rainfall received during the entire crop period was recorded. Five plants were selected at random and tagged. Data were recorded at panicle initiation(75 – 80 days), flowering and maturity stages for physiological and quantitative traits. Observations of B lines were recorded for the

Table 1. Details of parents.

S/ No	Symbol	Genotypes	Source
		Lines	
1	L_1	IR 79128A	IRRI, Phillipines
2	L_2	IR79156A	IRRI, Phillipines
3	L_3	IR73328A	IRRI, Phillipines
4	L_4	IR70369A	IRRI, Phillipines
5	L_5	CO MS- 14A	TNAU, Coimbatore
6	L_6	CO MS 24A	TNAU, Coimbatore
		Testers	
1	T_1	IR 69726-29-1-2-2R	IRRI, Phillipines
2	T_2	IR 81178-2T-2-2-3R	IRRI, Phillipines
3	T_3	IR 80286-22-3-6-1R	IRRI, Phillipines
4	T_4	IR 7925A-428-2-1-1R	IRRI, Phillipines
5	T_5	IR 79582-21-2-2-1R	IRRI, Phillipines
6	T_6	IR 79200-45-2-2-1R	IRRI, Phillipines
7	T_7	IR 80402-88-3-1-3R	IRRI, Phillipines
8	T_8	IR05 N496R	IRRI, Phillipines
9	T_9	MAS- 946-1	UAS, Bangalore
10	T_{10}	MAS -26	UAS, Bangalore
11	T_{11}	KMP-105	UAS, Bangalore
12	T_{12}	KMP -148	UAS, Bangalore
13	T_{13}	KMP -149	UAS, Bangalore
14	T_{14}	BR -2655	UAS, Bangalore
15	T_{15}	BI-33	UAS, Bangalore

corresponding A lines.

Characters studied

Observations were recorded for the drought tolerant, yield and its component traits *viz*., Days to 50 %flowering (DF), Plant height (PH), Number of Productive tillers per plant (PT), Number of panicles per plant (PP), Panicle length (PL), Filled grains per panicle (FG), Spikelet fertility (SF), Hundred grain weight (HGW), Proline content (PC), SPAD chlorophyll meter reading (SCMR), Chlorophyll stability index (CSI), Relative water content (RWC), Biomass yield (BMY), Dry shoot weight (DSW), Dry root weight (DRW), Root / shoot ratio (RS), Root length (RL), Harvest index (HI), Single plant yield (YLD) under water stress and fully irrigated (control) conditions as per the Standard Evaluation System (1996). Proline content was estimated as suggested by Bates *et al*. (1973). The relative water content was calculated using the formula suggested by Weatherley (1950).

$$\text{RWC (\%)} = \frac{\text{(Fresh Weight – Dry Weight)}}{\text{(Turgid Weight - Dry Weight)}} \times 100$$

Statistical analysis

The mean values of all the above observations recorded on five randomly selected plants were utilized for statistical analysis. Lines, testers and hybrids were tested for their significance based on their respective means.

Line x Tester analysis

Analysis of variance

The analysis of variance of RBD and their significance for all the characters were worked out as suggested by Panse and Sukhatme (1964) as shown in Table 2.

The test of significance was worked out as suggested by Snedecor and Cochran (1967).

Test of significance for mean values

$$\text{SEd of lines} = \sqrt{\left(\frac{1}{r}+\frac{1}{rt}\right)EMS}$$

$$\text{SEd of testers} = \sqrt{\left(\frac{1}{r}+\frac{1}{rl}\right)EMS}$$

$$\text{SEd of hybrids} = \sqrt{\left(\frac{1}{r}+\frac{1}{rlt}\right)EMS}$$

Where, SEd=Standard error difference; EMS=Error mean square.

To calculate the CD value, SEd values were multiplied with table 't' value at error degrees of freedom.

Table 2. Analysis of variance of RBD and their significance

Sources of variation	Degrees of freedom	Mean squares	Expectations of mean squares
Replication	r-1		
Genotype	t-1	M_1	$\sigma^2e + r\sigma^2g$
Error	(r-1) (t-1)	M_2	σ^2e
Total	rt-1		

Where, r=Number of replications; t=Number of genotypes;M1=Mean squares for genotypes;M2=Mean squares for error

Phenotypic and genotypic variances

These were estimated according to the formulae given by Lush Jay (1940).

$$\text{Genotypic variance} \quad (\sigma^2_g) = \frac{M_1 - M_2}{r}$$

$$\text{Phenotypic variance} \quad (\sigma^2_p) = \sigma^2_g + \sigma^2_e$$

Phenotypic and genotypic co-efficient of variability (PCV and GCV)

For each character, PCV and GCV were computed based on the methods given by Burton (1952).

$$\text{PCV} = \frac{\sqrt{Phenotypic\ \text{var}iance}}{Grand mean} \times 100$$

$$\text{GCV} = \frac{\sqrt{Genotypic\ \text{var}iance}}{Grand mean} \times 100$$

Heritability

In general sense, heritability specifies the proportion of the total variability that is due to genetic causes or the ratio of genotypic variance to the total variance. It is a good index of the transmission of the characters from parents to their offspring (Falconer, 1967). Heritability (h^2) in the broad sense was calculated according to Lush Jay (1940).

$$h^2\ (\text{B.S.}) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,
σ^2_g = Genotypic variance and
σ^2_p = Phenotypic variance

The range of heritability was categorized as suggested by Johnson et al. (1955a):

Range: Frequency

0-30%: Low
31- 60%: Moderate
More than 60%: High

Genetic advance

It is a measure of genetic gain under selection. Genetic advance is defined as the difference between the mean genotypic value of the selected lines and the mean genotypic value of the parental population. It was derived according to the method of Johnson *et al.* (1955 a) for each character under study.

$$\text{Genetic advance (GA)} = \frac{\sigma^2_g}{\sigma_p} \times k$$

Where,
σ^2_g = Genotypic variance,
σ_p = Phenotypic standard deviation and
k = Selection differential at a particular level of selection intensity, which takes into account the mean phenotypic value of the selected families (Falconer, 1967).

Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson et al. (1955a).

$$\text{Genetic advance as percentage of mean} = \frac{Genetic\ advance}{Grand mean} \times 100$$

The range and frequency is as follows:

Less than 10: Low
10 to 20: Moderate
More than 20: High

Analysis of combining ability and gene action

Line x tester analysis was carried out to test parents and hybrids with respect to their general and specific combining ability respectively. The line x tester analysis of combining ability gives useful information regarding the choice of parents and elucidates the nature and magnitude of various types of gene action for the expression of yield and yield attributing characters.

The data on the hybrids and parents were subjected to L×T analysis.

The assumption of null hypothesis was tested for differences among the genotypes as detailed by Panse and Sukhatme (1964). The general combining ability effects of the parents and specific combining ability effects of the crosses were worked out as suggested by Kempthorne (1957). The mean squares due to different sources of variation as well as their genetic expectations

Table 3. ANOVA for combining ability.

Source of variation	Degrees of freedom	Mean squares	Expectations of mean squares
Lines	(l-1)	M_1	EMS + r(COV.F.S – 2.COV.H.S) + rt (COV.H.S)
Testers	(t-1)	M_2	EMS + r(COV.F.S – 2.COV.H.S) + rl (COV.H.S)
Line x Tester interaction	(l-1) (t-1)	M_3	EMS + r (COV.F.S – 2.COV.H.S)
Error	(r-1) (lt-1)	M_4	EMS
Total	(ltr -1)		

Where, r=number of replications; l=number of lines; t=number of testers.

were estimated as follows (Table 3).
From the genetic expectations, the covariance of full sib (COV.F.S) and half sibs (COV.H.S) were estimated as follows:

$$\text{COV.H.S.} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r(l+t)}$$

$$\text{COV.F.S.} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3r} - \frac{r(l+t)\,\text{COV.H.S}}{3r}$$

From the covariances of full and half sibs, variances due to general combining ability (σ^2GCA) and specific combining ability (σ^2SCA) were computed as follows:

Variance due to general combining ability (σ2GCA)=COV.H.S.
Variance due to specific combining ability (σ2SCA)=COV.F.S - 2.COV.H.S.

From the variances of GCA and SCA, the gene action was calculated as follows:

Additive genetic variance (σ2A) = 2 σ2GCA (Inbreeding co-efficient, F=1)
Non additive genetic variance (σ2D) = σ2SCA (Inbreeding co-efficient, F=1)

Estimation of combining ability effects

General combining ability effects (*gca*) of parents and specific combining ability effects (*sca*) of hybrids of ijkth observation were arrived at using the mathematical model given below

$$X_{ijk} = \mu + \hat{g}_i + \hat{g}_j + \hat{s}_{ij} + \hat{e}_{ijk}$$

Where,

X_{ijk}= value of ijkth observation
μ= population mean
$\hat{g}_i$ = *gca* of ith line
$\hat{g}_j$ = *gca* of jth tester
$\hat{s}_{ij}$ = *sca* of ijth hybrid
$\hat{e}_{ijk}$ = error associated with ijkth observation
i= number of lines
j= number of testers
k= number of replications

$$\text{Mean}(\mu) = \frac{X...}{rlt}$$

Where, X…=total of all hybrids; r=number of replications; l=number of lines; t=number of testers

General combining ability effects

The individual *gca* effects were estimated as follows:

$$gca \text{ effect of lines } (g_i) = \frac{X_{i..}}{rt} - \frac{X...}{rlt}$$

$$gca \text{ effect of testers } (g_j) = \frac{X_{.j.}}{rl} - \frac{X...}{rlt}$$

Where, Xi..=Total of ith line over 't' testers and 'r' replications
X.j.=Total of jth tester over 'l' lines and 'r' replications.
X…=Total of all hybrids.

Specific combining ability effects

The individual *sca* effects were estimated as follows:

$$sca \text{ effects of hybrid } (s_{ij}) = \frac{X_{ij.}}{r} - \frac{X_{i..}}{rt} - \frac{X_{.j.}}{rl} + \frac{X...}{rlt}$$

Where, Xij.=Total of the hybrid between ith line and jth tester over 'r' replications.

Test of significance of combining ability effects

The standard error pertaining to *gca* effects of lines and testers and *sca* effects of hybrids were calculated as follows:

i. $$\text{S.E. of } gca \text{ of lines} = \sqrt{\frac{EMS}{rt}}$$

ii. $$\text{S.E. of } gca \text{ of testers} = \sqrt{\frac{EMS}{rl}}$$

iii. $$\text{S.E. of } sca \text{ of hybrids} = \sqrt{\frac{EMS}{r}}$$

Where, S.E.= Standard error; EMS=Error mean square; 't'= $\frac{\text{Parameter}}{\text{S.E.}}$

The calculated 't' value was compared with table't' value at error degrees of freedom to test the significance. The significance of *gca* effect of lines, *gca* effect of testers and *sca* effects of hybrids was tested against twice the standard error at five %level and one %level. The ratio of $\sigma^2A/\ \sigma^2D$ was worked out for each character to find out predominance of additive or non-additive gene action, assuming the simple additive dominance model.

Estimation of heterosis

The term heterosis was coined by Shull in 1914. It refers to the superiority of F_1 hybrid over its parents. In other words, heterosis refers to increase in fitness and vigour of F_1 over the parental values. While heterosis refers to the phenomenon (cause), hybrid vigour is the phenotypic expression (effect) of the genetical phenomenon.

The mean values of hybrids and their respective parents were used for estimation of heterosis %under three categories. The magnitude of heterosis in hybrids was expressed as percentage of increase or decrease of a character over mid parent (d_i), better parent (d_{ii}) and standard hybrid (d_{iii}) and was estimated following the formula of Fonseca and Patterson (1968).

Heterobeltiosis (d_{ii})

The superiority of F_1 over better parent was estimated as follows:

$$d_{ii} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where, $\overline{F}_1$ = Mean value of hybrid; $\overline{BP}$ = Mean value of better parent

Standard heterosis (d_{iii})

The superiority of F_1 hybrid over the standard commercial variety or hybrid is known as standard heterosis. The term useful heterosis was used by Meredith and Bridge (1972). It is also called as economical heterosis. This type of heterosis is of direct practical value in plant breeding. It is estimated as follows:

$$d_{iii} = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

Where,

$\overline{F}_1$ = Mean value of hybrid, $\overline{SV}$ = Mean value of standard variety

The variety IR 6888 was used as standard variety for yield components and drought tolerant traits in the present study.

Test of significance

The significance of magnitude of heterobeltiosis and standard heterosis was tested at error degrees of freedom by the formula as suggested by Turner (1953).

$$\text{'t' for heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\sqrt{\frac{2EMS}{r}}}$$

$$\text{'t' for standard heterosis} = \frac{\overline{F_1} - \overline{SV}}{\sqrt{\frac{2EMS}{r}}}$$

Where, EMS=Error Mean Square; r=Number of replications

RESULTS AND DISCUSSION

Variability studies

Progress in any crop improvement venture depends mainly on the variability existing in the metric traits of the base population. Genetic variability studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop. The variability for 19 traits was estimated on the basis of phenotypic and genotypic co-efficient of variations. The PCV value was found to be higher in all the 19 characters studied than the GCV. The differences between PCV and GCV for the 19 characters were very less indicating less environmental influence on those characters (Table 4). Similar findings were reported by Muhammad et al. (2007).

Selection of biometrical techniques

The analysis of variance for combining ability indicated that the lines and testers differed significantly among themselves for all the traits under aerobic condition. Further, the analysis of GCA/SCA variances indicated that the nature of gene action was non additive due to dominance with non fixable genetic variation for all the characters studied. The results are in accordance with the earlier reports of Babu et al. (2001).

The presence of greater magnitude of non additive gene action offers scope for exploiting hybrid vigour through heterosis breeding and hence, these parents can be exploited for production of commercial hybrids. Similar results were also reported by Banumathy (2001). The proportional contribution to total genetic variance by the lines was found to be higher for 100 grain weight. For other characters contribution from line x tester interaction was higher. These results indicate the predominance of non additive gene action. This is in accordance with the earlier reports of Muhammad et al. (2010) and Malathi (2010).

Table 4. Variability parameters for different traits.

Characters	PCV (%)	GCV (%)	Heritability (%)	Genetic advance as %of mean
Days to 50 %flowering	6.71	4.73	50.00	6.88
Plant height	7.52	7.36	96.00	14.83
Productive tillers per plant	13.49	13.09	94.00	26.16
Panicles per plant	20.61	20.39	98.00	41.57
Panicle length	5.37	3.33	38.00	4.25
Spikelet fertility	8.74	8.62	97.00	17.49
Filled grains per panicle	13.91	13.78	98.00	28.13
100 grain weight	12.10	7.34	37.00	9.18
Harvest index	16.96	16.81	98.00	34.33
Single plant yield	7.65	7.62	99.00	15.61
Proline content	11.55	11.43	98.00	23.31
SPAD Chlorophyll meter reading	35.58	35.51	65.00	73.02
Chlorophyll stability index	10.96	10.85	98.00	22.10
Relative water content	6.75	6.30	87.00	12.13
Biomass yield	30.81	23.33	57.00	36.39
Dry root weight	23.21	18.62	64.00	30.77
Dry shoot weight	32.50	18.03	18.03	20.60
Root : Shoot ratio	20.64	20.50	99.00	41.93
Root length	14.35	14.29	99.00	29.32

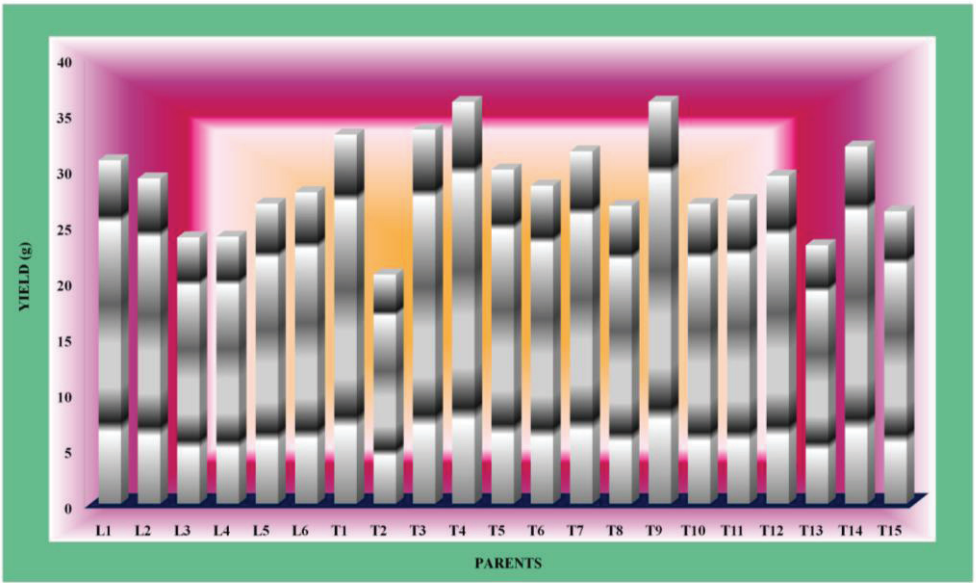


Figure 1. Mean performance of parents for single plant.

Evaluation of parents based on mean performance

As said by Gilbert, 1958 and Nadarajan, 1986 that the parents with high mean performance would result in good performing offspring, the lines IR79128A (L_1), IR79156A (L_2), COMS14A (L_5) and COMS24A (L_6) and the testers, IR 80286-22-3-6-1R (T_3), IR7925A-428-2-1-1R (T_4) and KMP -148 (T_{12}) were adjudged as the best parents as it had significantly desirable mean values for drought and yield traits (Figure 1).

Evaluation of parents based on general combining ability

Since the Combining ability effect is one of the most important parameters commonly used by plant breeders to evaluate the genetic potential of the materials handled,

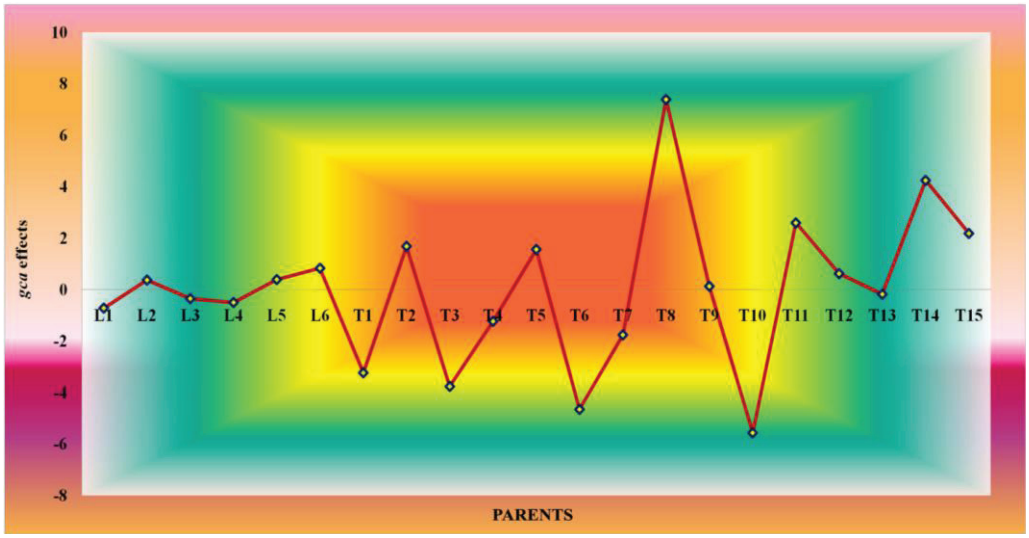


Figure 2. General combining ability of parents for single plant yield.

IR79128A (L_1), IR70369A (L_4) and IR79156A (L_2) among lines and BI-33 (T_{15}), IR79582-21-2-2-1R (T_5), KMP-105 (T_{11}), T_1 (IR 69726-29-1-2-2R) and MAS- 946-1 (T_9) (Figure 2) among testers were found to be the best general combiners as earlier reported by Simmonds (1979) emphasizing that *gca* effect gives the intrinsic genetic value of the parent for a trait. High *gca* effectsshow presence of favorable genes with additive type of gene action. Therefore, a multiple crossing programme involving good general combiners isolated in the present study is recommended to identify superior genotypes as suggested by Nadarajan and Gunasekaran (2005).

Evaluation of parents based on *per se* performance and *gca* effects

Evaluation of parents based on *per se* performance and *gca* effects separately might lead to contradiction in selection of promising parents since *per se* performance of parents was not always associated with high *gca* effects. IR79128A (L_1), IR79156A (L_2) and IR70369A (L_4) among lines and IR7925A-428-2-1-1R (T_{11}), KMP -148 (T_{12}) and BI-33 (T_{15}) among testers were the best parents for most of the traits since they had high *per se* performance and *gca* effects. Earlier studies also indicated that the parallelism between *per se* performance and *gca* effects did not always exist (Selvaraj et al., 2006).

Evaluation of hybrids

Hybridization is the most important method of crop improvement. The basic idea of hybridization is to combine favourable genes present in different parents into a single genotype.

Evaluation of hybrids based on mean performance

The hybrids IR79156A / KMP-105 (L_2 x T_{11}), IR70369A / MAS -26 (L_4 x T_{10}), IR79156A / IR05 N496 (L_2 x T_8), IR79156A / BI-33 (L_2 x T_{15}) and CO MS- 14A / BR -2655 (L_5 x T_{14}) exhibited significantly desirable mean performance for most of the characters which included drought tolerant, yield and yield components under aerobic condition. These results are in conformity with the earlier findings of Sabesan et al. (2009) and Saravanan et al. (2006).

Evaluation of hybrids based on *sca* effects

The second important criterion for the evaluation of hybrids is the specific combining ability effects which could be related with hybrid vigour. The *sca* effects signify the role of non-additive gene action in character expression (Sprague and Tatum, 1942). The hybrids IR70369A / IR 7925A-428-2-1-1R (L_4 x T_4), IR 79128A / BR -2655 (L_1 x T_{14}) and IR70369A / KMP-105 (L_4 x T_{11}) expressed superior *sca* effects for majority of drought tolerant and yield attributing characters including single plant yield.

Evaluation of hybrids based on heterosis

Significant standard heterosis over check IR6888 was observed in IR79156A / IR 79582-21-2-2-1R (L_2 x T_5) for 16 traits except plant height, 100 grain weight and root:

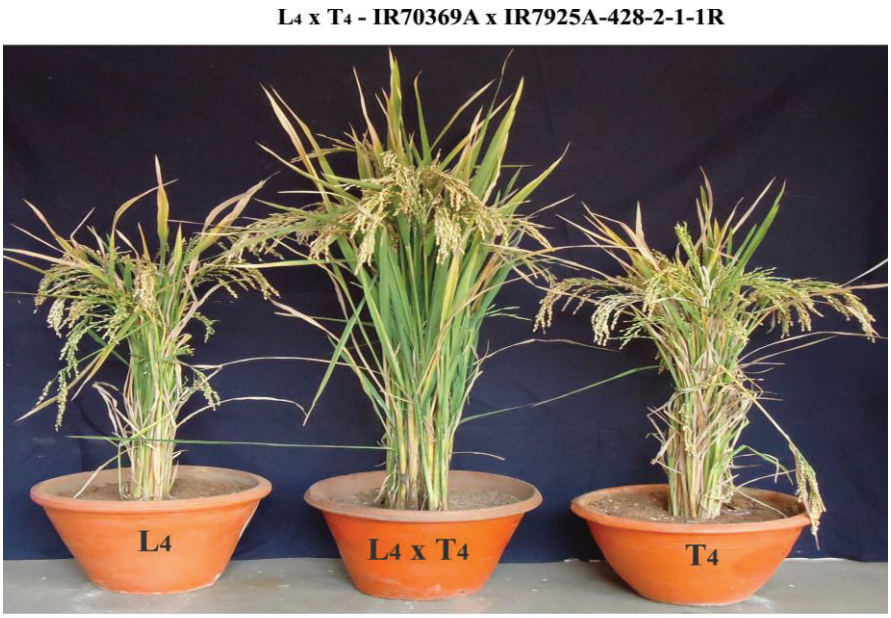
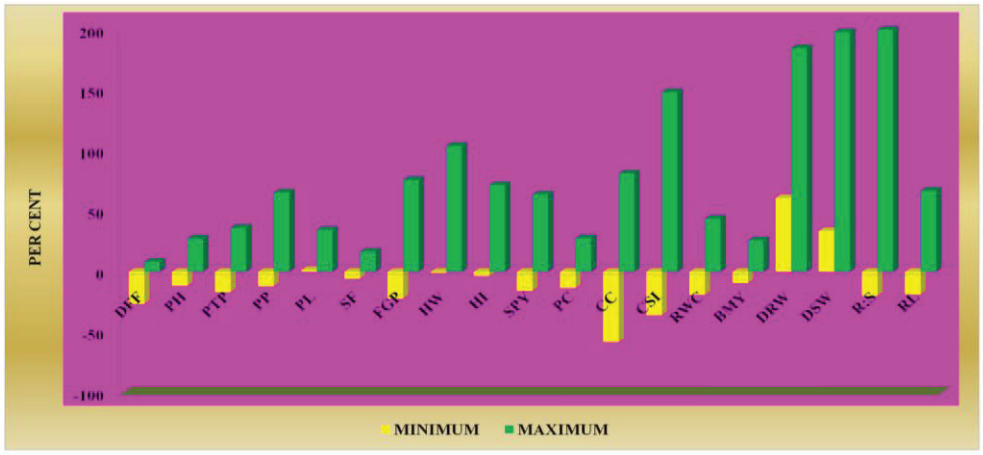


Plate 1. Hybrid recommended for heterosis breeding.



DFF - Days to 50 per cent flowering
PH - Plant height
PTP – Productive tillers per plant
PP – Panicles per plant
PL – Panicle length
SF – Spikelet fertility
FGP – Filled grains per panicle
HW – Hundred grain weight
HI – Harvest index
SPY – Single plant yield
PC – Proline content
CC – SPAD chlorophyll meter reading
CSI – Chlorophyll stability index
RWC – Relative water content
BMY – Biomass yield
DRW – Dry root weight
DSW – Dry shoot weight
R : S - Root : Shoot
RL - Root length

Figure 3. Range of standard heterosis for different traits.

shoot ratio. Similar results have been reported by Khoyumthem et al. (2005) and Soni et al. (2005).

Selection of best Parents and hybrids for utilization in plant breeding programme

The utilization of hybrids directly for commercial seed production mainly depends on the genetic constitution of hybrids. The genetic constitution from the parameter like mean performance, *sca* effects and extent of heterosis. The hybrids IR70369A / IR 7925A-428-2-1-1R (L_4 x T_4) and IR70369A / KMP-105 is suitable for heterosis breeding (Plate 1) under aerobic condition (Figure 3). This is in accordance with the reports of Malarvizhi et al. (2010).

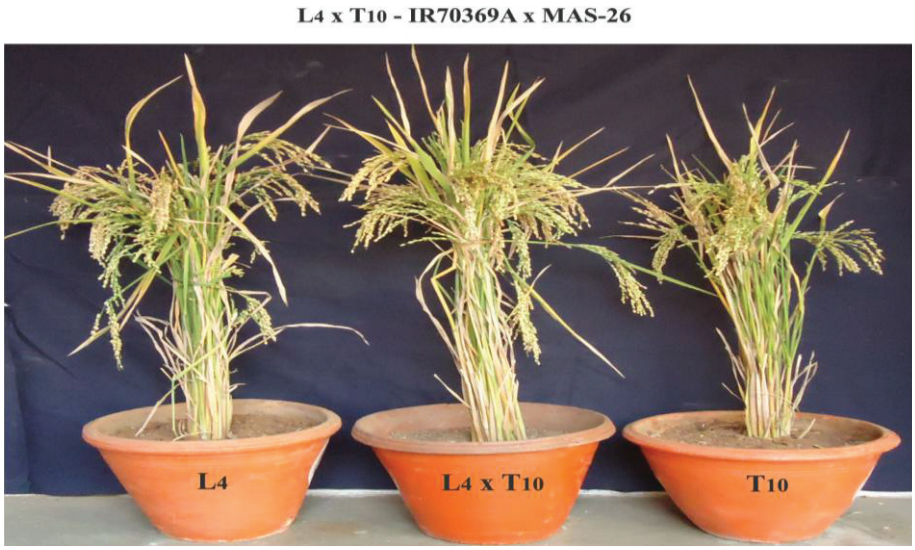


Plate 2. Hybrid recommended for recombination breeding.

Considering the hybrids showing non- significant *sca* effects with significantly favourable *gca* effects of parents for more than one character, the hybrid IR70369A / MAS -26 (L_4 x T_{10}) is suitable for recombination breeding to get desirable segregants in early segregating generations for drought tolerant and yield attributes (Plate 2). These results are supported by the findings of Utharasu (2007) and Sheeba et al. (2010).

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Impact of cooperative society on fish farming comercialization in Lagos State, Nigeria

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This study was carried out to determine the impact of cooperative society among the fish farmers in Lagos State. A multi stage purposive sampling techniques was used to select five Local Government areas notable for fish farming business. 30 fish farmers were selected from each of the Local Government areas for cooperative society and 30 farmers from non cooperative society having a total of 150 respondents each. A well structured questionnaire was used to obtain information and 130 questionnaires were retrieved each from cooperative and non-cooperative members. Analytical techniques used include descriptive statistics and Tobit regression Analyses. The results show that the mean age of the farmers is 56 and 57 for cooperative and non-cooperative fish farmers, respectively. Majority (83%) and (93%) of the cooperative and non-cooperative fish farmers respectively were males. It was discovered that both farmers have an average of 8 household members. It was revealed that larger percentage of the cooperative fish farmers (50%) used amount ₦100,000 to ₦500,000 as the initial investment while (56%) of the non cooperative used the same amount as capital investment. The result of the Tobit regression analysis indicates that gender of farmers is significant at 5%, years of formal education; membership of cooperative and the cost of inputs were significant at 1%. Since majority were producing for profit making, it is suggested in the paper that government should increase the supply of credit to cooperative farmers and embark on enlightenment campaign to increase the participation of rural farmers in cooperative activities.

Key words: Impact, cooperative society, fish farming, commercialisation, Lagos State.

INTRODUCTION

In developing countries in which Nigeria is one, agriculture dominates the economy of the nation. It has been established that about 70% of Nigeria population is engaged in agriculture while 90% of Nigeria total food production comes from small farms and 60% of the country population earn their living from these small farms. The fall in agricultural production could be attributed to inadequate infrastructure, under mechanization and inadequate finance (Oluwatayo et al., 2008). One of the major problems of agricultural development in Nigeria is that of developing appropriate organization and institution to mobilize and induce members of the rural sector to a greater productive effort (ICA, 2010). As such rural farmers who are characterized

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by low income, low resource utilization, small farm holdings and scattered nature of farmland, finds it difficult to pool their resources together in order to raise their farm income and substantially improve their living conditions (Ibitoye, 2012).

Inadequate finance has remained the most limiting problem of agricultural production. This is because capital is the most important input in agricultural production and its availability has remain a major problem to small scale farmers who account for the bulk of agricultural produce of the nation. In Nigeria, credit has long been identified as a major factor in the development of agricultural sector (Ndifon et al., 2012). Cooperative societies in Nigeria perform multipurpose functions. They are engaged in the production, processing, marketing, distribution and financing of agricultural products. It is an established fact that many household in the country today, live below the poverty line, in fact, investigation has shown that the highest percentage of Nigeria's workforce work in the public sector and earn their monthly salary of below one dollar per day (Awotide et al., 2012). The rural community, whose main occupation is agriculture, produces the food consumed in the country, but which is hardly sufficient to feed the people, because farmers still use crude farming implements to till the land. The federal government, in a bid to fight the menace of poverty therefore, has set up some agencies essentially to provide financial assistance particularly to youths and women involved in small scale businesses. So recently, Cooperate Societies, a concept that was given birth from the traditional thrift collection, began to spread like wild fire in virtually every part of Nigeria. There is hardly any workplace in Nigeria today particularly government establishments, where a cooperative society is not operational. It is quite effective because transactions of money are carried out in conjunction with employers of labour on behalf of their staff (Godwin, 2011).

Agricultural commercialization is the share of agricultural produce that is marketed. Commercialization is the process through which increased amount of small farm resources (land, labour e.t.c) is transferred from self consumption production to market oriented production. As such commercialization can be measured along a continuum from zero (total subsistence oriented production) to unity (100% production is sold). Commercialization of agriculture involves a transition from subsistence oriented to increasingly market – oriented patterns of production and input use (Nweze, 2003).

In spite of the importance of loan in agricultural production, its acquisition is fraught with a number of problems. The small scale farmers are forced to source for capital from relations, money-lenders and contribution clubs. All of these are known to be ineffective in providing capital for substantial increase in agricultural production. The last hope for the small scale farmers then lies with the cooperative societies, the cooperative has been identified to be better channel of credit delivery to farmers the NGO's in term of its ability to sustain the loan delivery function (Alufohai, 2006).

Adekunle and Henson (2007) studied the effect of cooperative thrift and credit societies on personal agency belief: A study of entrepreneurs in Osun State, Nigeria. He opined that little or no attention has been paid to the role of entrepreneurship and the capacity of institutions like Cooperative Thrift and Credit societies to promote entrepreneurship. Cooperatives are defined as "an autonomous association of persons who unite voluntarily to meet their common economy and social needs and aspiration through a jointly owned and democratically controlled enterprise. Cooperatives are established by like-minded persons to pursue mutually beneficial economic interest. Researchers are of the opinion that under normal circumstance cooperative play significant role in the provision of services that enhance agricultural development (Ndifon et al., 2012).

Regular and optimal performance of these roles will accelerate the transformation and sustainability of not only the cooperatives but the enhancement of agricultural and rural economic development. Cooperative embraces all type of farmers and a well organized and supportive cooperative is a pillar of strength for agriculture in Nigeria. Previous studies have shown that cooperative carryout the function of credit delivery to farmers but there is ample evidence that farmers face difficulties in obtaining credit and the problem of sourcing for capital still lingers on. Therefore, any cooperative society to be effective and successful, it must continuously achieve two inter-related goals: enhance viability and improve ability to service its members; and remain an economically viable, innovative and competitive enterprise (Dogarawa, 2005).

Fish farmers in Lagos State are generally involves in one form of self help group or cooperative organization to carry out their production activities such as improvement on fish farming practices (that is, adoption of new technology) income growth and stability, business growth, purchase of inputs like fingerlings, feed and other basic needs such as clothing, food and shelter. One of the ways to improve the lots of these fish farmers' welfare and productivities is cooperative society membership and participation. Without an iota of doubt, the cooperative society will help the farmers a lot to improve their productivities as well as their welfare. Through cooperative, fish farmers will be able to access more fund for their fish production hence engage in fish farming commercialization.

Nigeria being a coastal country has about 1,280 km marine areas and about 124,878 km of inland waterways. Lagos State with a general area of 3,577 km representing 0.4% of Nigeria territorial land mass is one of the maritime states of Nigeria and as such share a potion of the Atlantic Coast of the Gulf of Guinea which is rich in fisheries resources. In spite of this potential, domestic

fish production is grossly inadequate to meet even domestic demand (FAO, 1990). Fish is the cheapest sources of protein and because of its low cholesterol level which makes it medically acceptable to young and old people. The demand for fish protein according to Federal Department of Fisheries (FDF) was 2.6 million tonnes in 2007 while domestic production was 634,370 tonnes. The deficit was partly augmented by massive importation of frozen fish of about 740,000 tonnes valued at 94.- a big draw – down on scarce foreign exchange. This leaves a huge deficit of 1.3 million tonnes and hence the concerted efforts to ensure self sufficiency in fish production through fish farming (aquaculture). Aquaculture has been estimated to have a potential of producing 2.5 milloin ones annually which is fully harnessed can almost satisfy the demand for fish in Nigeria alone. The estimated total law available for aquaculture production is 1.7 million hectares excluding marine brackish water bodies. Unfortunately, aquaculture production was only 85,087 tonnes in 2007 despite its potential and its enormous water resources in contrast with the state fish production capacity of about 157,000 tonnes (Kareem et al., 2012).

In view of the above, this study therefore deals with the effect of cooperative society on fish farming commercialization, determined the problems faced by the artisan and identified the factors that affect participation in fish farming in Lagos State. This study is significant in the sense that the assessment of co-operative development will further serve as framework for formulating new and better policies for agricultural co-operative development in Nigeria.

MATERIALS AND METHODS

Area of study

The area of study is Lagos State which was created in 1967. Lagos State is located on the coast in the most South Western corner of Nigeria. It is the smallest but most densely populated state in the federation with land of 3,586 km^2 which is about 0.39% of the Nations 923,768 km^2 area.

Sampling procedure and sample frame

The sampling method adopted for the study was the multistage purposive random sampling; Lagos State comprises of twenty local government areas which was divided into five geographical zones namely, Ikeja, Ikorodu, Epe, Lagos Island and Badagry.

The research was carried out in five local government areas of Lagos State which represent geographical zones of the state and notable for fish farming in large production. The list of cooperative fish farmers in each local government were obtained from the Lagos State agricultural development project, Oko – Oba, Lagos since they coordinate the activities of the cooperative society.

A total of 150 cooperative fish farmers and 150 non – cooperative fish farmers were interviewed. That is, 30 cooperative fish farmers and 30 non – cooperative fish farmers from each local government. However, 130 questionnaires were retrieved each from cooperative farmers and non cooperative farmers for analyses making a total of 260 farmers.

Data collection and analytical procedures

The data used was obtained mainly from primary source through the use of structured questionnaires that was administered to fish farmers. The questionnaires contain both open and close ended questions covering the social and personal characteristics of the respondents and other related variables such as awareness and participation in cooperative activities, income and expenditure, pond size. The instrument for data collection is subjected to expert validation.

Data collected during the study was analysed using descriptive statistics and Tobit regression analysis. Descriptive Statistics – Tables was used to present frequency distribution, percentages and averages on demographic and non-demographic characteristics of the cooperative fish farmers. Tobit regression analysis – Tobit regression analysis was employed to examine the functional relationship among the variables.

The Tobit model is expressed as – $\Upsilon^* = \beta\chi + \mu$; Υ^* = Y = Income; β = Vector of parameter estimated; X = Set of explanatory Variables; μ = The disturbance term; X_1 = Age (years); X_2 = Gender; X_3 = Fish farming Experience (years); X_4 = Education; X_5 = Size of pond (m^2); X_6 = Marital Status; X_7 = Cooperative membership (Members = 1, Non member = 0); X_8 = Cost of input in naira and X_9 = Household Size.

RESULTS AND DISCUSSION

Table 1 shows the socio economic characteristics of the fish farmers. It reveals that 43% of the cooperative fish farmers were within the age of 56 years while 46% of the non-cooperative fish farmers were in the same age range. There is no significant difference between the mean ages of the cooperative and non-cooperative farmers. About 46% of the cooperative fish farmers and 47% of the non-cooperative fish farmer have secondary school education. Majority (83%) and 93% of the cooperative and non-cooperative fish farmers were males, respectively. It was also discovered that both cooperative fish farmers and non-cooperative has an average of 8 household members.

Table 2 showed the initial capital outlay and sources of fund for both cooperative and non-cooperative fish farmers in the study areas. The result shows that higher percentage (45%) sourced their fund through personal savings, 20% sourced fund through friends while about 36% sourced fund through cooperative society. It was revealed that larger percentage of the cooperative fish farmers (50%) used amount #100,000 to #500,000 as the initial investment while (56%) of the non cooperative used the same amount as capital investment. About 53% cooperative fish farmers and 14% non cooperative fish farmers were operating with over half a million (above #500,000.00) as initial capital investment in fish commercialisation. The results revealed that the involvement in cooperative society had made great impact in fish commercialisation and the fish farmers have been able to increase their initial capital investment

Table 1. Socio-economic characteristics of respondents (Co-operatives & Non cooperative Fish farmers).

Variables	Cooperative farmers	Frequency	Percentage	Variables non cooperatives farmers	Frequency	Percentage
Mean age (Yrs)	**56**	**56**	**43.08**	**57**	**60**	**46.15**
Sex	Male	108	83.08	Male	122	93.85
	Female	22	16.92	Female	8	6.15
Marital status	Single	6	4.62	Single	4	3.08
	Married	98	75. 38	Married	104	80.00
	widowed	26	20.00	widowed	22	16.92
Religion	Christianity	70	53	Christianity	62	47.69
	Islam	48	36.92	Islam	54	41.54
	Tradition	12	09.23	Tradition	14	10.77
Education	No formal edu.	8	6.15	No formal education	12	9.23
	Primary	20	15.38	Primary	24	18.46
	Secondary	60	46.15	Secondary	62	47.69
	Tertiary	42	32.31	Tertiary	32	24.62
Years of experience	1 - 5	72	55.38	1 - 5	64	49.23
	6 - 10	30	23.08	6 - 10	38	29.23
	11 - 15	18	13.85	11 - 15	22	16. 92
	Above 15	4	3.08	Above 15	6	4.62
H/H size	1 - 5	46	35.38	1 - 5	44	33.85
	6 - 10	62	47.69	6 - 10	58	44.62
	11 - 15	18	13.85	11 - 15	22	16.92
	Above 15	4	3.08	Above 15	6	4.62

Source: Field survey, 2014.

in the enterprise. The larger number of the side of the cooperative fish farmers might not be unconnected to the financial assistance obtained from the cooperative society for fish farming.

Table 3 shows the purpose for engaging in fish farming in the study area. The results show that about 88% of the cooperative farmers and 98% of the non-cooperative farmers were running the business for profit making; that is, they were fully commercialised while only 12% engaged in the fish farming for sustaining the family.

The problems encountered in the fish farming are inadequate capital, marketing problem and high cost of input (Figures 1 and 2). Tax from government was not posturing too much problem for both cooperative and non-cooperative fish farmers in the study areas.

Table 4 shows the factors that affect farmers' participation in fish farming commercialization using Tobit regression model. Nine explanatory variables were considered in the model. However,

Table 2. Sources of fund and Initial Capital Outlay.

Variable	cooperative farmers fish	Frequency	Percentage	Variables non-coperative farmers	Frequency	Percentage
Sources of Fund	Own Savings	58	44.62	Own Savings	114	87.69
	Friend	26	20.00	Friend	16	12.31
	Co-operatives	46	35.38	Cooperatives	-	
Initial Capital investment (#)	Less than 100,000	27	20.77	Less than 100,000	32	24.62
	100,001 - 500,000	50	38.46	100,001 - 500,000	56	43.08
	500,001 - 1,000,000	48	36.92	500,001 - 1,000,000	12	9. 23
	Above 1,000,000	5	3.85	Above 1,000,000	2	1.54
Income Group	Less than 100,000	12	9.23	Less than 100,00	25	19.23
	100,001 - 500,000	48	36.92	100,001 - 500,000	64	49.23
	500,001 - 1,000,000	66	50.77	500,001 - 1000,000	40	30.77
	Above 1,000,000	4	3.08	Above 1000,000	1	0.77

Source: Field survey, 2014.

Table 3. Purpose for engaging in fish farming in the study area.

Variable	cooperative fish farmers	Frequency	Percentage	Variables non-coperative farmers	Frequency	Percentage
Purpose of engaging in fish farming	Profit	114	87.69	Profit	98	75.38
	To maintain family	16	12.31	To maintain family	32	24.62

Source: Field survey, 2014.

only four were significant. They are sex of farmers, years of formal education, membership of cooperative and the cost of inputs. The log likelihood ratio of - 2006 and the P - Value of 0.0001 reveals that the model as a whole is statistically significant.

Education is significant ($P < 0.029$) and positively related to fish farming commercialization. This shows that at higher level of education, fish farming commercialization is high. This is due to the fact that formal education can improve technical know-how in fish production and marketing. Gender is significant ($P < 0.0449$) and negatively related to fish farming, this shows that female fish farmers tend to be involved more in fish farming commercialization. This may be as a result of the fact that women are producing mainly to sell and not to feed their household. Membership of cooperative is significant ($P < 0.0001$) and is positively related to fish farming commercialization. This may be as a result of the assistance obtained from the cooperative societies to promote fish farming commercialization.

The cost of input is significant ($P < 0.0001$) and positively related to fish farming commercialization because as the input cost increases more fish will be produced and fish farming commercialization will be promoted. This will also motivate the farmers to seek for assistance when the cost of

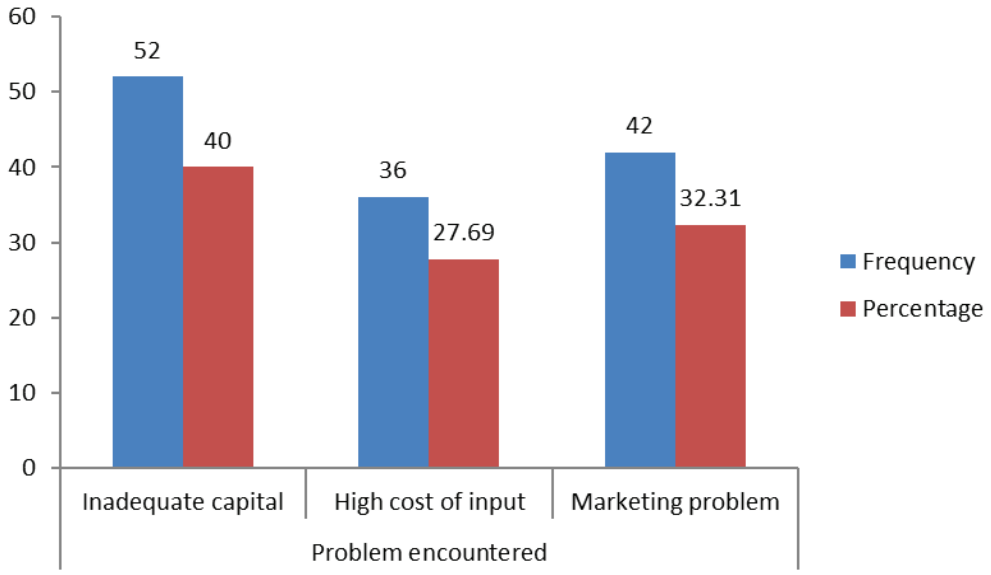

Figure 1. Problem encountered by cooperative farmers.

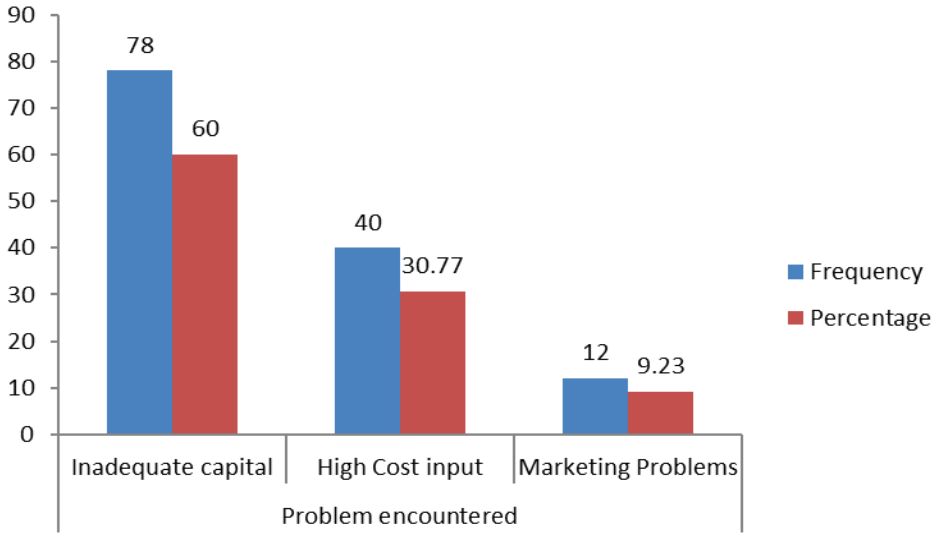

Figure 2. Problem encountered by non cooperative farmers.

production is high in which the cooperative society will be of advantage to them. The size of pond is negatively related to fish farming commercialization. This may be due to the fact that the size of pond does not determine pond stocking density and fish output. Fish output was determined by quantity of fish stocked and proper management practices.

CONCLUSION AND RECOMMENDATION

This study had shown that there is great prospect for fish farmers in Lagos State since fish farming commercialisation is profitable. Since the respondents confirmed that their income is always higher than the capital outlay in fish farming. it was concluded that co-operative societies have effect on member's welfare and the role of co-operative society in poverty reduction and capital formation cannot be overlooked in the development process of any country particularly the less developed countries like Nigeria.

However, the findings revealed the importance of cooperative societies arises from the fact that the rural poor (farmers) are not properly served by formal

Table 4. Tobit Regression Analysis for the identification of factors that affect participation in fish farming commercialization.

Variable	Coefficient	Std error	T	9 > (t)
Age	9.24	6.96	1.33	0.184
Gender	- 151.40*	75.49	- 2.01	0.044
Fishing experience	36.97	19.90	1.86	0.063
Formal education	22.66**	7.61	2.98	0.0021
Size of pond	-56.03	87.08	-0.64	0.52
Marital status	147.86	80.05	1.85	0.064
Cooperative membership	439.68***	88.08	4.99	0.0001
Cost of input	1.40***	0.08	17.21	0.0001
Household size	4.86	15.90	0.31	0. 760

Source: Field survey, 2014. Log likelihood - 2006; No of Observation 260; Schwarz Criterion 4073. *, **, *** significant at 10, 5, and 1% level respectively.

institution agencies (viz, commercial banks and other government owned financial institution). These institutions refrain advancing loan to the rural poor because of the bureaucratic procedures and high cost service involved in lending. Therefore, this study gives credence to the use of cooperative as machinery for rural transformation and agricultural development in Nigeria. The continued existence and operation of cooperative societies have to be encouraged by both individuals and government. They have been able to make impart in the area of membership enrolment, farm input procurement through loan disbursement and training of members.

Based on the findings, the following recommendations were made:

i. Fish farmers should be encouraged to join cooperative societies as this promotes fish farming commercialization.
ii. Women should be encouraged to go into fish farming.
iii. Fish farmer should be supported financially by the government and financial organization through provision of loans.
iv. Government should increase the supply of credit to cooperative farmers and embark on enlightenment campaign to increase the participation of rural farmers in cooperative activities vis a vis improve fish commercialization.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

An appraisal-analyze method for SWC function of forest in Simian Mountain, China

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Soil erosion is one of the biggest environmental problems. It is urgently needed to understand soil and water conservation capacity of different plantation types so that the best plantation type can be determined. In Qinjiagou watershed of Simian Mountain, Chongqing City, 18 indices were selected from canopy layer, litter layer, soil layer and topography to evaluate the soil and water conservation capacities of four common plantation types by ideal point method. Results indicated that the broadleaf plantation of robur (*Lithocrpus glabra*) and Chinese gugertree (*Schima superba*) (*LS*) has the biggest soil and water conservation capacity. The rank of three other plantation types from big to small is the mixed broadleaf plantation *of* sweetgum (*Liguidambar formosana*), Chinese gugertree and camphor tree (*Cinnamomum camphora*) (*LSC*), the mixed broadleaf-conifer plantation of Chinese fir (*Cunninghamia lanceolata*), Masson pine (*Pinus massoniana*) and Chinese gugertree (*CPS*), and the mixed Pine plantation of Chinese fir and Masson pine (*CP*). Under the same climate and topographical condition, the broadleaf plantation has better soil and water conservation capacity than the conifer plantation. Sensitivity analysis showed that the three most sensitive indices are soil non-capillary porosity, soil aggregation, and soil initial infiltration rate. The litter amount and soil properties are the most important indicators of soil and water conservation capacity of plantations. Therefore, suitable measurements such as deep tillage should be taken to improve the properties of soil under different plantations.

Key words: Ideal point method, soil erosion, soil and water conservation, soil properties, sensitivity analysis.

INTRODUCTION

Soil erosion is one of the biggest environmental problems in the Southwest region of China. Many measurements have been taken to protect soil and water resources. Researches indicated that various types of plantations are all able to reduce surface runoff and soil erosion effectively (Woodward and.,

Lee 1995; Jiang et al., 2007), and their function was affected by human and natural disturbances (Noske et al., 2010; Uzun et al., 2011). In the upper reaches of the Yangtze River, people have replanted most of farmlands with Chinese fir (*Cunninghamia lanceolata*), Masson pine (*Pinus massoniana*), robur (*Lithocrpus glabra*), sweetgum (*Liguidambar formosan*), camphor tree (*Cinnamomum camphora*) and other tree species. Are these plantation types suitable for reforestation, and are they helpful to protect soil and water? The information is urgently needed to understand soil and water conservation capacity of different plantation types.

The methods proposed to evaluate the soil and water conservation capacities of the forest are based on the use of "runoff plots", which is a labor-intensive and time-consuming process (Wang et al., 2006). The evaluation of soil and water conservation capacity is often based on the single index of coverage (Truman and Bradford, 1990; Deuchras et al., 1999). But the comprehensive assessment of forest's soil and water conservation affected by different factors is a multiple objective decision-making problem, in which a mathematical model needs to be established scientifically. Multiple criteria decision (MCD) method has been used to solve the assessment of forest function for a long time (Kangas and Kangas., 2005; Xevi and Khan, 2005; Lin et al., 2007). Ideal point method is a kind of outranking methods and it is also a good method for multiple objective decision-making. At first, ideal point method was mainly used in the economic and politics field (Henry et al., 1989; Hua and Liang, 1997; Hagemann, 2007). Now, it has been used in diversified fields. Zhang has used ideal point method to solve the fuzzy dynamic environment load dispatch (Zhang et al., 2006). Yang applied the ideal interval method of multi-objective decision-making to comprehensive assessment of water resources renewability (Yang et al., 2004). Qin applied ideal point method to forest harvest regulation (Qin et al., 1997). However, in most previous studies, the weighs of different indices were deemed to be even when they are, in fact, different. The objectives of this paper were: (1) to compare variation of the soil and water conservation capacity of four plantation types in Qinjiagou watershed of Simian Mountain by ideal point method; and (2) to discover the plantation type that has the best soil and water conservation capacity. It will provide a theoretical basis and decision-making reference for the planting and management.

MATERIALS AND METHODS

Study area

Simian Mountain, belongs to the Three Gorges Reservoir Area, is a typical case in terms of its complexity of natural environment and fragility of ecosystem in China. The soil erosion is posing a serious threat to the ecological security and regional sustainable development in upper reaches of Yangtze River. The study area, Qinjiagou watershed (28°31' N - 28°46N', 106°17' E -106°30' E), is situated in the middle part of Simian Mountain, Southwest of China (Figure 1). The forest land of Qinjiagou watershed belongs to the upstream of Yangtze River. The altitude is from 900 to 1500 m. Soils are mainly yellow loam and purple soil, which is infertile, with a depth ranging from 10 to 70 cm.

The representative types in Simian Mountain are mixed forest of Chinese fir and Masson pine (*Cunninghamia lanceolata* × *Pinus massoniana* (CP)), mixed broadleaf-conifer forest of Chinese fir × Masson pine × Chinese gugertree (Schima superba) (*CPS*), mixed broadleaf forest of robur (*Lithocrpus glabra*) × Chinese gugertree (*LS*), mixed broadleaf forest of sweetgum (*Liguidambar formosana*), Chinese gugertree and camphor tree (*Cinnamomum camphora*) (*LSC*). All the four plantation types were planted in 1999, with 1 ha of *LSC*, *CP*, *CPS*, and 0.8 hm^2 of *LS*. The previous shrubs were cut off before new plantations were planted, but the litter is kept. There was no management after the plantations were planted except irrigation in spring.

Samples collection and treatment

Ideal point method

Ideal point, a popular method for multiple objective decision-making, is objective thus avoiding large deviation due to subjective opinion (Henry et al., 1989; Zhang et al., 2006; Hagemann, 2007). That enables the user to resolve the task of multiple criteria decision. There into, the linear function method is the most suitable method for normalizing indices (Walczak et al., 1997; Rafael et al., 2006), did not need expert review (Henry et al., 1990; Hochman et al., 1991). And entropy method is a kind of objective method to determine indices' weights (Guo et al., 2008). That method could reduce the disturbance of subjectivity in the course of assessment, and reflect the contribution of each index to regional ecological safety more objectively (Jia et al. 2006). Therefore, normalizing indices and weighting determination was deal with the above methods (Figure 2).

Sensitivity analysis

Sensitivity analysis is necessary for evaluation (Chen 1987;

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Abbreviations: LS, Broadleaf plantation of robur (*Lithocrpus glabra*) and Chinese gugertree (*Schima superba*); **LSC,** Mixed broadleaf plantation of sweetgum (*Liguidambar formosana*), Chinese gugertree and camphor tree (*Cinnamomum camphora*); **CPS,** Mixed broadleaf-conifer plantation of Chinese fir (*Cunninghamia lanceolata*), Masson pine (*Pinus massoniana*) and Chinese gugertree; **CP,** Mixed Pine plantation of Chinese fir and Masson pine.

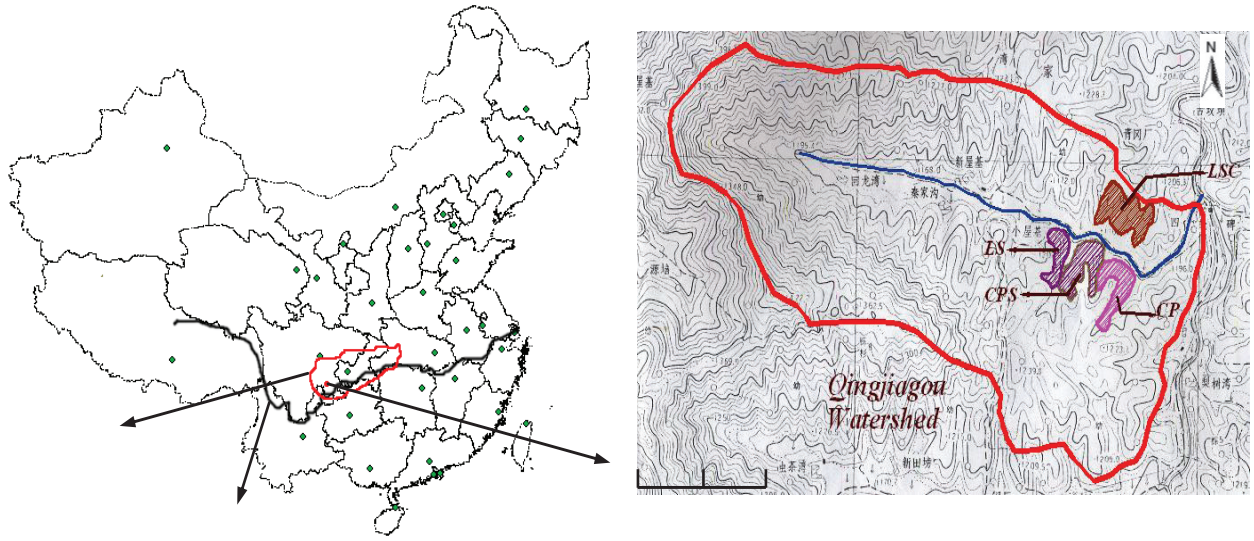

Figure 1. Location of field site.

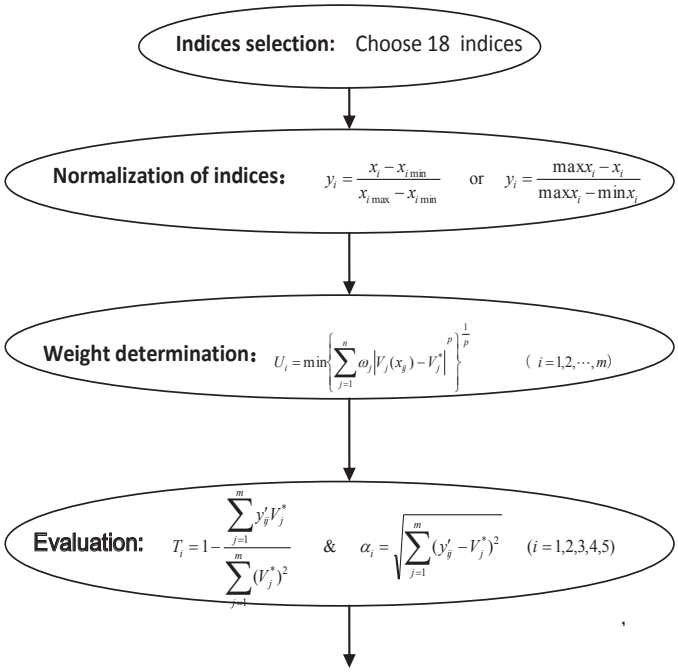

Figure 2. Four-step process of the ideal point method.

Fan et al., 2004). The analysis will determine the certainty of the rank of every two plantation types. Taking $\bar{y}_k$ as the possibly changed value of y'_{ij}, then:

$$\bar{T}_i = 1 - \frac{\sum_{j=1}^{m-1} y'_{ij} V_j^* + \bar{y}_k V_k^*}{\sum_{j=1}^{m} (V_j^*)^2} \quad (1)$$

$$\Delta = \bar{y}_k - y'_{ij} = \frac{(T_i - \bar{T}_i) * \sum_{j=1}^{m} (V_j^*)^2}{V_k^*} \quad (2)$$

when $\bar{y}_k \in \left[\min_i y'_{ij}, \max_i y'_{ij}\right]$, the change of $\bar{y}_k$ will not induce the change of V_k^*. When $\bar{y}_k$ is very close to y'_{ij}, the original rank is not steady. y'_{ij} is the sensitive index. If $\bar{y}_k$ is very close to y'_i when the Δ value belongs to $[0, 0.1]_j$, it means that y'_{ij} is sensitive. And the lower the value is, the more sensitivity indices are. If the numbers of sensitive indices between two plantation types are more than 3, the rank of them is uncertain.

RESULTS AND DISCUSSION

Plant investigation

In July 2009, three 20×20 m^2 plots were established at each plot of four plantation types in study area. The height of all trees was measured. The number of trees in each subplot was counted and recorded. In each 20×20 m^2 plot, four 5×5 m^2 subplots were established for investigation of shrub diversity. The number and names of the different shrubs were recorded. In each shrub plots, two 1×1 m^2 subplots were established for investigation of grass diversity and the names and amounts of the different grasses were recorded. According to measurement, the basic condition and characteristics of each plantation is show in Table 1.

Five 1×1 m^2 subplots were randomly chosen in each 20×20 m^2 plots and leaf litter fall was sampled. A total of 15 leaf litter fall samples were taken in each plot of every plantation type. The maximum water capacity of litter was measured by putting leaf litter fall in water 24 h.

Table 1. Basic condition and characteristics of each plantation.

Items	*CP*	*LSC*	*LS*	*CPS*
Mean tree height (m)	2.87	2.2	3.26	3.83
Coverage (%)	46	70	78	55
Number of shrub species	5	7	7	6
Number of grass species	12	10	9	9

Soil properties

In June 2009, soil samples for physical properties measurements were collected from each location of plantation types (Table 3). Five replicated soil cores for bulk soil density, total porosity and non-capillary porosity were taken in each 20×20 m^2 plot along a diagonal transect. Analyses of physical soil properties were conducted. Three composite surface soil samples were collected from the plots of each plantation. The soil samples were sieved to pass a 2 mm mesh and the percent of soil particles bigger than 2 mm equals the percent of gravel in the soil.

All the physical soil properties and chemical properties were determined by a method described by the Editorial Committee of Soil Physical and Chemical Analysis (Editorial Committee, 1996). Bulk soil density was measured by a core method. Soil particle size analysis was carried out by a hydrometer method. Total porosity was calculated according to the determined particle density. The infiltration rate (IR) of the soils was measured by using a double-ring infiltrometer with a 22 cm outer diameter, a 10.5 cm inner diameter and a height of 25 cm (Song et al., 2007). Organic matter of the soil was determined by an oil bath-$K_2Cr_2O_7$ titration method.

Implementing ideal point method

Values of all the indices

In this study, 18 indices were selected (Figure 3) for ideal point model. That is one is different from the previous research (Truman et al., 1990; Deuchras et al., 1999). There into, two indices, aspects and roots distribution, are qualitative indices obtained by the method of expert's gradation according to the studies about the relationship between indices and soil erosion. And the other 15 indices values are all obtained from field measurements. The scores of two qualitative indices were shown in Tables 2 and 3.

Normalization of indices

The evaluation system is composed of 4 programs (4 plantations) and 18 indices. Then, the original matrix of the evaluation system is $X=(x_{ij})_{4\times18}$,

$$X=\begin{bmatrix} 46 & 2.87 & 30 & 0.15 & 202.79 & 19.17 & 0.237 & 1.096 & 0.049 & 0.186 \\ 70 & 2.2 & 70 & 0.03 & 191.82 & 16.82 & 0.113 & 1.033 & 0.031 & 0.313 \\ 78 & 3.26 & 30 & 0.043 & 246.94 & 25.43 & 0.134 & 1.139 & 0.097 & 0.238 \\ 55 & 3.83 & 50 & 0.26 & 64.47 & 6.04 & 0.069 & 1.236 & 0.117 & 0.203 \end{bmatrix}$$

$$\begin{bmatrix} 0.397 & 0.085 & 4.53 & 0.18 & 10.75 & 36 & 90 & 1161 \\ 0.502 & 0.112 & 5.04 & 0.37 & 17.42 & 38.5 & 50 & 1160 \\ 0.484 & 0.127 & 5.24 & 0.35 & 37.92 & 36 & 90 & 1166 \\ 0.525 & 0.126 & 5.29 & 0.30 & 10.08 & 28.8 & 70 & 1170 \end{bmatrix}$$

The matrix after normalization is $Y=(y_{ij})_{4\times18}$,

$$Y=\begin{bmatrix} 0 & 0.411 & 0 & 0 & 0.758 & 0.677 & 1 & 0.690 & 0.209 & 0 \\ 0.75 & 0 & 1 & 0.556 & 0.698 & 0.556 & 0.262 & 1 & 0 & 1 \\ 1 & 0.650 & 0 & 1 & 1 & 1 & 0.387 & 0.478 & 0.767 & 0.409 \\ 0.281 & 1 & 0.5 & 0.407 & 0 & 0 & 0 & 0 & 1 & 0.134 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0.024 & 0.258 & 1 & 0.9 \\ 0.820 & 0.643 & 0.671 & 1 & 0.263 & 0 & 0 & 1 \\ 0.680 & 1 & 0.934 & 0.833 & 1 & 0.258 & 1 & 0.4 \\ 1 & 0976 & 1 & 0.833 & 0 & 1 & 0.5 & 0 \end{bmatrix}$$

According to entropy method, the weights of different indices were calculated and shown in Table 4.

Evaluation results

After normalization and weights' determination, the final matrix *Y'* is as following,

$$Y'=(y'_{ij})_{4\times18}=Y*\omega_j \quad (1)$$

where $Y=(y_{ij})_{4\times18}$ is the matrix after normalization; ω_j means weights of different indices.

$$Y'=\begin{bmatrix} 0 & 0.016 & 0 & 0 & 0.043 & 0.048 & 0.065 & 0.032 & 0.009 \\ 0.034 & 0 & 0.06 & 0.031 & 0.040 & 0.040 & 0.017 & 0.047 & 0 \\ 0.045 & 0.025 & 0 & 0.056 & 0.058 & 0.072 & 0.025 & 0.022 & 0.035 \\ 0.013 & 0.039 & 0.03 & 0.023 & 0 & 0 & 0 & 0 & 0.046 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0.001 & 0.016 & 0.042 & 0.028 \\ 0.071 & 0.038 & 0.046 & 0.028 & 0.078 & 0.017 & 0 & 0 & 0.031 \\ 0.029 & 0.032 & 0.072 & 0.039 & 0.065 & 0.065 & 0.016 & 0.042 & 0.012 \\ 0.009 & 0.047 & 0.070 & 0.042 & 0.065 & 0 & 0.064 & 0.021 & 0 \end{bmatrix}$$

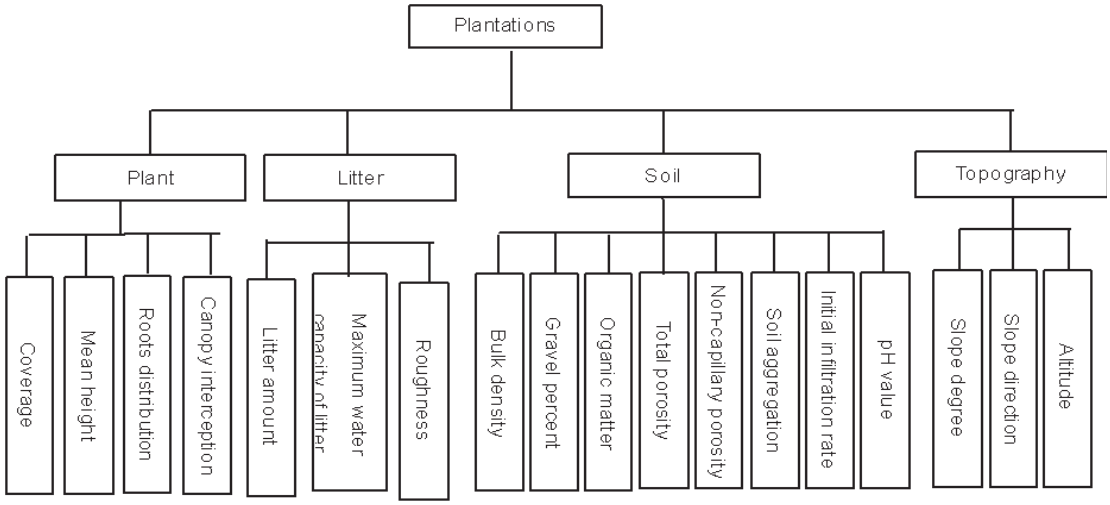

Figure 3. The indices of soil and water conservation capacity assessment.

Table 2. Original values of all the indices.

Indices \ Plant types	*CP*	*LSC*	*LS*	*CPS*
*X*1 Coverage (%)	46	70	78	55
*X*2 Mean height (m)	2.87	2.2	3.26	3.83
*X*3 Roots distribution	30	70	30	50
*X*4 Canopy interception (mm/mm)	0.15	0.03	0.043	0.26
*X*5 Litter amount (t/(ha yr))	202.79	191.82	246.94	64.47
*X*6 Maximum water capacity of litter (t/(ha 24 hrs))	19.17	16.82	25.43	6.04
*X*7 Roughness	0.237	0.113	0.134	0.069
*X*8 Bulk density (g/cm^3)	1.096	1.033	1.139	1.236
*X*9 Gravel percent (%)	0.049	0.031	0.097	0.117
*X*10 Non-capillary porosity	0.186	0.313	0.238	0.203
*X*11 Total porosity	0.397	0.502	0.484	0.525
*X*12 Organic matter (g/kg)	0.085	0.112	0.127	0.126
*X*13 PH	4.53	5.04	5.24	5.29
*X*14 Aggregation	0.18	0.37	0.35	0.30
*X*15 Initial infiltration rate (mm/h)	10.75	17.42	37.92	10.08
*X*16 Slope degree (^{o})	36	38.5	36	28.8
*X*17 Slope aspect	90	50	90	70
*X*18 Altitude (m)	1161	1160	1166	1170

After normalization, the value of 18 indices all belonged to interval [0, 1]. The maximum was the best. Therefore, the ideal program I_1^* should be composed of the maximum value of each index as follows,

$$I_1^* = (0.045 \quad 0.039 \quad 0.06 \quad 0.056 \quad 0.058 \quad 0.072 \quad 0.065 \quad 0.047 \quad 0.046 \quad 0.071 \quad 0.047 \quad 0.072 \quad 0.039 \quad 0.078 \quad 0.065 \quad 0.064 \quad 0.042 \quad 0.031)$$

$$T_i = (0.634 \quad 0.437 \quad 0.354 \quad 0.523)$$

$$\alpha_i = (0.202 \quad 0.156 \quad 0.121 \quad 0.170)$$

Therefore, the evaluation of soil and water conservation capacity of LS is the minimum, that of CP is the maximum. The second one is CPS, followed by LSC.

Sensitivity analyses

Sensitivity analysis showed us the certainty of the sequence between every two plantation types. It implied the sensitivity of indices to external factors and the

Table 3. Scores of qualitative indices.

Indices	Standard				
	Slight erosion	Moderate erosion	intensive erosion	Very intensive erosion	Severe erosion
Aspects	Northeast	Northwest	Southwest	—	—
Roots distribution	5-50	5-40	5-30	5-25, 10-30	—
Scores	90	70	50	30	10

Table 4. Weights of different indices.

Indices	*X*1 Coverage	*X*2 Mean height	*X*3 Roots distribution	*X*4 Canopy interception	*X*5 Litter amount	*X*6 Maximum water capacity of litter	*X*7 Roughness
Weights	0.045	0.039	0.060	0.056	0.058	0.072	0.065
Indices	*X*8 Bulk density	*X*9 Gravel percent	*X*10 Non-capillary porosity	*X*11 Total porosity	*X*12 Organic matter	*X*13 PH	*X*14 Aggregation
Weights	0.047	0.046	0.071	0.047	0.072	0.042	0.078
Indices	*X*15 Initial infiltration rate	*X*16 Slope degree	*X*17 Slope direction	*X*18 Altitude			
Weights	0.065	0.064	0.042	0.031			

possibility of improving soil and water conservation capacity. *CP* has the minimum T_i value, and has only 3 sensitive indices with other three plantation types. While *LS* has 9 sensitive indices with *LSC* and 6 sensitive indices with *CPS* respectively, which means the sequence of *LS* and *LSC* is uncertain, as well as *LS* and *CPS*. From Equation 12, the Δ value was calculated and shown in Table 5, where sensitive indices were shown by italics.

Table 5 showed that *CP* has three sensitive index with other three plantation types, and *LS* is respectively sensitive to *LSC* and *CPS,* more than three sensitive indices. And soil properties and vegetation characteristics of *LS* are much larger than those of others, especially the soil properties. Conversely, the *CP* has the worst soil and water conservation capacity because the soil properties there, such as bulk density, porosity and aggregation, are much more worse than other plantation types. Therefore, *LS* has the greatest soil and water conservation capacity.

Comparing those plantation types, it can be seen that under the same conditions hardwood forest has a larger soil and water conservation capacity than mixed forest of hardwood and softwood. And hardwood forest has much greater conservation capacity than pure conifer forest. This supports the earlier studies that suggested the hardwood forest has good soil and water conservation capacity in upper Yangtze basin (Shi et al., 2004; Sun et al., 2009). It also coincides with the conclusion that conifer forest has less effect on soil and water conservation than broad-leaved forest (Feng et al., 1998). The results confirm the others conclusions that broadleaf forest has the best soil and water conservation capacity by Wang et al. (2005), who studied on the soil and water conservation capacities of four kinds of forest types by the method of “runoff plots” in Jinyun Mountain, Chongqing city, southwest of China. It also coincides with a previous study which considered 10 indices by comprehensive coordinate method in Simian Mountain (Chen et al., 2009).

While *LS* and *LSC* have no obvious differences in the water capacity of their canopies, *LS* is better than *LSC* in the soil and water conservation capacity based on the amount of litter, water capacity of litter layer, soil organic matter and soil initial infiltration rate. Descroix et al. (2001) found that organic matter was negatively correlated with runoff and soil loss, which is confirmed by this study. There are eight sensitive indices between *LSC* and *LS*, and three of them are very sensitive (soil non-capillary porosity, soil aggregation and soil initial infiltration rate). It means that the soil structure should be optimized to improve the soil and water conservation capacity of *LSC*.

There are six sensitive indices between *LS* and *CPS*, and most of them are litter characteristics and soil properties. This indicates that soil and litter characteristics plays an important role in the forest capacity to conserve soil and water. While *CPS* is better than *LSC* in the water interception of canopy, its soil and water conservation capacity is much worse than that of *LSC*, mostly due to its less litter and poor function of soil.

Litter depth appeared to be an important ecological factor in determining the magnitude of soil loss. The litter layer can protect soil surface, prevent soil detachment, and provide surface roughness that minimizes soil particle movement down the slope and reduces runoff

Table 5. The Δ value of indices X1-X8 and X9-X17.

Plantations \ Indices		X1	X2	X3	X4	X5	X6	X7	X8	X9
						X1-X8				
CP	*LS*	0.2834	0.3271	0.2126	0.2278	0.2199	0.1772	0.1962	0.2714	0.2773
	LSC	0.4043	0.4665	0.3032	0.3249	0.3137	0.2527	0.2799	0.3871	0.3955
	CPS	0.1481	0.1709	0.1111	0.1190	0.1149	*0.0926*	0.1025	0.1418	0.1449
LS	*LSC*	0.1208	0.1394	*0.0906*	*0.0971*	*0.0938*	*0.0755*	*0.0837*	0.1157	0.1182
	CPS	-0.1344	-0.1551	-0.1008	-0.1080	-0.1043	*-0.0840*	*-0.0931*	-0.1287	-0.1315
LSC	*CPS*	-0.2562	-0.2956	-0.1922	-0.2059	-0.1988	-0.1601	-0.1774	-0.2453	-0.2507
						X9-X17				
Plantations \ Indices		X10	X11	X12	X13	X14	X15	X16	X17	X18
CP	*LS*	0.1796	0.2714	0.1772	0.3037	0.1635	0.1962	0.1993	0.3037	0.4115
	LSC	0.2563	0.3871	0.2527	0.4332	0.2333	0.2799	0.2843	0.4332	0.5869
	CPS	0.1039	0.1418	*0.0926*	0.1587	*0.0854*	0.1025	0.1041	0.1587	0.2150
LS	*LSC*	*0.0766*	0.1157	*0.0755*	0.1295	*0.0697*	*0.0837*	*0.0850*	0.1295	0.1754
	CPS	*-0.0852*	-0.1287	-0.0840	-0.1440	*-0.0776*	*-0.0931*	*-0.0945*	-0.1440	-0.1952
LSC	*CPS*	-0.1624	-0.2453	-0.1601	-0.2745	-0.1478	-0.1774	-0.1802	-0.2745	-0.3719

Italics means that the indices were sensitive.

velocity (Descroix et al., 2001; Hartanto et al., 2003; Casermeiro et al., 2004). Soil properties, including bulk density, porosity, and organic matter content, was considered as important indicators of soil erosion (Deuchras et al., 1999; Barthès and Roose., 2002). The results show that the most sensitive indices are from soil layer and litter layer. And plantations whose litter layer and soil layer have good soil and water capacities exhibited better effect of combating soil erosion. It confirms that litter and soil layer under forest play a very important role in protecting soil and water and their capacities reflect the soil and water conservation capacity of forest.

LS, *LSC* and *CPS* have more than three sensitive indices, which mean that their soil and water conservation capacities are very sensitive to external factors such as human disturbances and managing practices. It also means that the soil and water conservation capacity of each plantation types can be easily improved by proper management or reduced by improper management. On the contrary, that *CP* has only 3 sensitive indices means that it is few sensitive to external factors. Since *CP* has the worst soil and water conservation capacity and is not sensitive to external factors, it is hard to improve its soil and

water conservation function even if we apply proper managing practices.

CONCLUSION AND SUGGESTION

Soil and water conservation is one of the most important targets of eco-environment construction in Southern China. We found that under the same condition, soil and water conservation capacity of hardwood forest is better than that of mixed forest of hardwood and softwood, and much better than that of conifer forest.

According to the sensitivity analysis, it showed that hardwood *LS* has the best soil and water conservation capacity among the others. Therefore, the mixed broadleaf forest of robur and Chinese gugertree should be the first choice when we implement the 'returning farmland to forest' policy in the Three Gorges area.

It also showed that the soil and water conservation capacity of *CP* is difficult to improve over a short time from now. However, the soil and water conservation capacity of *LS*, *LSC*, and *CPS* can be improved by taking proper managing practices. Litter and soil layer under the forest play a very important role in protecting soil and water. Improving the soil properties should be taken to enhance the soil and water conservation capacity of these plantations. From above discussion, we believe that we have got the same results about the soil and water conservation capacity of different plantation types by ideal point method as by other methods. That proves that ideal point method is suitable for evaluating forest soil and water conservation capacity. Using the ideal point method to evaluate the capacity of soil and water conservation of different forest types can avoid long-time processing measurement, but with more objective and precise results. New research suggests that the ideal point method may be used in conjunction with various optimization techniques to facilitate the selection of optimal combinations of forest types, but little work has been carried out on this approach to date.

Conflict of Interest

The authors have not declared any conflict of interest.

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