Field Crops Research 114 (2009) 411–418

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Weed competitiveness of the lowland rice varieties of NERICA in the southern Guinea Savanna

Jonne Rodenburg [a,*], Kazuki Saito [b], Romain Glele Kakaï [c], Amadou Touré [b], Mariame Mariko [b], Paul Kiepe [b]

[a] Africa Rice Center (AfricaRice), East and Southern Africa, P.O. Box 33581, Dar es Salaam, Tanzania
[b] Africa Rice Center (AfricaRice), 01 BP 2031, Cotonou, Benin
[c] Faculté des Sciences Agronomiques, Université d'Abomey Calavi, 01 BP 526, Cotonou, Benin

ARTICLE INFO

Article history:
Received 15 March 2009
Received in revised form 18 September 2009
Accepted 22 September 2009

Keywords:
Oryza sativa
Oryza glaberrima
Weed competition
Yield loss
Weed suppressive ability (WSA)
West Africa

ABSTRACT

Weed competition is a major constraint to lowland rice production in West Africa. Interspecific rice varieties named New Rice for Africa (NERICA) may have superior weed competitiveness and could as such play an important role in integrated weed management. The NERICA varieties were developed from the wide cross between high-yielding *Oryza sativa* (L.) and weed competitive and disease resilient *Oryza glaberrima* (Steud.). In this study weed competitiveness of all 60 lowland varieties of NERICA (NERICA-L) was compared with their most frequently used parents [IR64 (*O. sativa*) and TOG5681 (*O. glaberrima*)], the weed competitive variety Jaya (*O. sativa*) and the *O. glaberrima* upland NERICA parent CG14. During the 2006 and 2007 rainy seasons these varieties were grown under weed-free and weedy conditions in a lowland farmers' field with partially controlled irrigation in south-east Benin. Weedy plots included single hand weeding at 28 days after sowing, whereas weed-free plots were weekly weeded.

Most important weed species encountered in this study were *Basilicum polystachyon*, *Alternanthera sessilis*, *Echinochloa colona*, *Sorghum arundinaceum*, *Cyperus halpan* and *Cyperus rotundus*. Average weed-inflicted yield loss across varieties was 39% in 2006 and 8% in 2007. In both years varieties differed significantly in grain yields under weed-free and weedy conditions and in the growth of weed biomass they permitted under weedy conditions, as observed at harvest. None of the lowland varieties of NERICA consistently had stronger weed suppressive ability than TOG5681 across 2 years. Nine varieties of NERICA-L (-6, -32, -35, -37, -42, -53, -55, -58 and -60) were identified with high yields under both weed-free and weedy conditions. These nine NERICA-L varieties, together with Jaya, out-yielded the other 51 NERICA-L varieties as well as IR64 and the two *O. glaberrima* varieties. Weed-free yield, crop growth duration, and weed biomass at harvest significantly correlated with weedy yield in both years.

Interspecific breeding using *O. glaberrima* appears to be an effective approach for improving yield potential and weed competitiveness of semi-dwarf *O. sativa* and as such for widening the range of useful varieties for lowland rice farmers in Africa.

1. Introduction

In West Africa rice is the most rapidly increasing cereal commodity, in terms of production area and consumption (FAO, 2009). The crop is grown in different agro-ecological zones (Sahel, Sudan and Guinea Savanna and Equatorial Forest) and a range of agro-ecosystems (rain-fed upland, rain-fed and irrigated lowland and deepwater and mangrove swamps) (e.g. Balasubramanian et al., 2007). Of the total area under rice in sub-Saharan Africa roughly 52% is lowland (19% irrigated and 33% rain-fed) (Balasubramanian et al., 2007, updated with data from FAO, 2009).

Rain-fed and irrigated lowlands carry a large potential for rice production in West Africa. However, weed competition with the crop is usually high. Weeds are among the most important biological constraints to rice production in West Africa (e.g. Balasubramanian et al., 2007) with relative yield losses ranging from 28 to 54% in transplanted and 28–89% in direct-seeded lowland rice (Akobundu, 1980; Becker et al., 2003; Johnson et al., 2004). High weed-inflicted yield losses in rice in West Africa are mainly due to the low inherent competitive ability of the crop (van Heemst, 1985) and the limited number of effective and affordable weed control options available to farmers (e.g. Rodenburg and Johnson, 2009). Rice farmers in West Africa mainly rely on hand weeding and, to a lesser extent, on herbicides (e.g. Adesina et al., 1994). Hand weeding is time consuming and depends on the availability of labor (e.g. Ruthenberg, 1980), while herbicides

* Corresponding author. Tel.: +255 222780768; fax: +255 222780768.
E-mail address: j.rodenburg@cgiar.org (J. Rodenburg).

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doi:10.1016/j.fcr.2009.09.014

Table 1
Monthly and cumulative rainfall during the rice growing season in 2006 and 2007 in Deve (mm) compared to the 1991–2008 average and range.

	June	July	August	September	October	November	Cumulative
2006 (experiment)	81 (78)	28	33	49	139 (46)	36 (–)	367 (234)
2007 (experiment)	112 (–)	137 (117)	79	127	62	26 (19)	543 (403)
Average 1991–2008	141	122	62	94	108	26	554
Max.	251	365	157	169	252	78	1272
Min.	67	22	8	23	37	0	158

As sowing and harvest dates of the experiments did not coincide with the first and last day of the month, where this differs from the monthly totals the actual amounts of rainfall received during the experiments (2006: 6 June to 11 October; 2007: 19 July to 27 November) are shown between brackets.

require good application timing and methods in order to be effective and to prevent harmful side-effects to the crop, environment and human health (Gitsopoulos and Froud-Williams, 2004; Johnson et al., 2004). Preconditions for safe and effective herbicide use, like availability of the right product, functional application and protection equipment, and know-how on application procedures, are often not met in West Africa. Alternative weed management technologies are therefore much needed (Rodenburg and Johnson, 2009).

Although rice is generally perceived a weak competitor, genetic variation in weed competitive ability has been reported (e.g. Fofana and Rauber, 2000; Haefele et al., 2004; Zhao et al., 2006a). Following Jannink et al. (2000) and Zhao et al. (2006c), weed competitiveness (WC) is composed of weed tolerance, which is the ability to maintain high yields under weed competition, and weed suppressive ability (WSA), the ability to suppress weed growth. Genetic variation in WC offers a great potential for resource-poor farmers in West Africa as rice varieties with enhanced weed competitive abilities could play a key role in an integrated weed management strategy (e.g. Johnson et al., 1998; Fofana and Rauber, 2000; Gibson et al., 2003; Haefele et al., 2004). However, to date only very few rice varieties with superior WC are known and used by African farmers. For lowland conditions only *Oryza sativa* variety Jaya (Haefele et al., 2004) can be mentioned. The recently developed varieties of NERICA (New Rice for Africa) may have the potential to complement the limited set of available weed competitive germplasm for lowland conditions. NERICA varieties, developed by the Africa Rice Center (AfricaRice) and partners, are interspecifics between the two cultivated rice species, the Asian *O. sativa* (L.) and the African *Oryza glaberrima* (Steud.) (Jones et al., 1997) and currently consist of 18 upland and 60 lowland varieties (Rodenburg et al., 2006).

The most important breeding objectives for the lowland varieties of NERICA were yield potential, grain quality, high environmental adaptation and tolerance against Rice Yellow Mottle Virus and African Gall Midge (M. Sié, personal communication). The latter two should be inherited from the *O. glaberrima* parent (TOG5681, TOG5674 or TOG5675). In addition, the main *O. glaberrima* parent TOG5681 has potentially favorable growth traits for weed suppression, including broad and droopy leaves, high straw biomass production, tallness and high LAI (Heuer et al., 2003). The use of TOG5681 in the interspecific crosses (57 out of 60 NERICA-L varieties) is therefore expected to benefit the WC of the offspring. The *O. sativa* parent, in turn, would provide the interspecific varieties with high yield potential. Empirical evidence of the superior performance of NERICA, in particular the ability to better cope with weeds, is still awaited (e.g. Dingkuhn et al., 2006; Orr et al., 2008; Wopereis et al., 2008).

The objectives of this study are to evaluate the weed competitiveness and yield potential of all the currently available lowland varieties of NERICA and to identify superior varieties that are potentially suitable for use in integrated weed management strategies in farmers' fields. This is the first study presenting a comprehensive assessment of the weed competitive ability of the lowland varieties of NERICA.

2. Materials and methods

2.1. Experimental site

A screening trial was conducted during the 2006 rainy season and repeated in 2007. Both trials were carried out in a farmers' field of the *Périmètre Agricole Irrigué de Deve*, in Deve, located at 15 km north-east of Lokossa in the Department of Mono, south-east Benin (latitude: 6°45′N and 1°37′E; altitude: around 19 m a.s.l.). The 2006 field was adjacent to the 2007 field. This site is located in the southern Guinea Savanna zone (Windmeijer and Andriesse, 1993). Prior to these trials, the 2006 and 2007 fields have both been under rice production (single cropping, one crop per year) for more than 10 years. The fields are characterized as partially controlled irrigated lowlands; they are irrigated but water cannot be drained. Such limited water control conditions are frequently observed in lowland rice production systems in the sub-region (e.g. Balasubramanian et al., 2007).

Rainfall during the 2006 season was relatively low but within the medium-term (1991–2008) range, while rainfall in 2007 was close to the medium-term average (Table 1). The soils are characterized as a vertic-Eutric Gleysol according to the FAO systematic classification (FAO, 1998) with 29:30:41 (%) of sand:silt:clay composition (0–20 cm) according to the hydrometer method (IITA, 1982), moderate acid, and moderate soil organic carbon and total nitrogen (Table 2). The two fields had similar soil fertility properties.

2.2. Germplasm

In both years, 64 rice varieties were evaluated. This selection included all the 60 lowland NERICA varieties (NERICA-L) of which 56 varieties were derived from interspecific crosses between TOG5681 (*O. glaberrima*) and IR64 (*O. sativa*). Four varieties had either other *O. sativa* parents (NERICA-L-21 had IR1529-680-3-2 as *O. sativa* parent) or both other *O. sativa* and *O. glaberrima* parents (IR31785-58-1-2-3-3 and TOG5674 were parents of NERICA-L-43

Table 2
Soil properties in the experimental fields in 2006 and 2007 (0–20 cm).

Soil property	2006	2007
pH (H_2O; 1:1)	6.0	5.9
Organic carbon (g kg^{-1})[a]	14	16
Total nitrogen (g kg^{-1})[b]	1.5	1.6
Extractable P (mg kg^{-1})[c]	11	13

[a] Chromic acid digestion (Heanes, 1984).
[b] Kjeldahl digestion and colorimetric determination (Bremner and Mulvaney, 1982) on Technicon Auto-Analyzer II (Technicon Instrument Corporation).
[c] Mehlich three extraction (Mehlich, 1984) followed by colorimetric P determination using the Technicon Auto-Analyzer II (Technicon Instrument Corporation).