Diversity of Red Rice in Arkansas

V.K. Shivrain, N.R. Burgos, K.A.K. Moldenhauer, and D.R. Gealy

ABSTRACT

Red rice is a troublesome weed in rice-growing areas of the southern U.S. Red rice in Arkansas may be diverse enough to warrant some adjustments in weed control programs. A study was conducted at the Rice Research and Extension Center (RREC), Stuttgart, Ark., in 2003 to determine the phenotypic diversity of red rice in Arkansas. One hundred thirty-six red rice accessions were collected from 26 rice-growing counties of Arkansas in summer 2002. Red rice seedlings were transplanted to the field on 12 May 2003. Data were collected on various morphological variables of red rice. Besides the two major hull colors, straw and black, other hull colors were also observed including brown and orange. There was no difference in plant height (overall mean = 53 in.) and tiller number (overall mean = 93) among strawhull accessions. Seed yield decreased with decreasing latitude in strawhull types. Among blackhull accessions, those from the east-central part of the state produced the most tillers (116) but were the shortest (52.5 in.) plants. Blackhull accessions from central Arkansas had the highest seed yield (196 g/plant). Phenotypic diversity was documented in red rice accessions from different regions based on hull color, presence of awns, height, tillering capacity, flowering, and seed yield.

INTRODUCTION

Red rice is a troublesome weed in the southern U.S. Red rice and cultivated white rice belong to the same genus and species. Due to similarity in their biology and physiology, red rice is difficult to control with traditional rice herbicides. For instance, both red rice and cultivated rice produce an enzyme, aryl acylamidase, that metabolizes propanil, which is one of the most commonly used herbicides in rice (Hoagland, 1978).
Red rice has been documented as the worst weed in rice production since the beginning of the 20th century and still is a problematic weed mainly due to its competitiveness and red seed color, which contaminates commercial white rice (Nelson, 1907, 1908; Vincenheller, 1906). Red rice grains shatter easily, even before complete maturity, and remain viable in the soil for several years (Smith et al., 1977). Red rice has been designated by various scientific names (Dodson, 1900; Smith, 1981), but now most scientists believe that red rice belongs to the same genus (*Oryza*) and species (*sativa*) as commercial white rice (Craigmiles, 1978; Hoagland and Paul, 1978). Based on hull color, Constantin (1960) reported three types of red rice in Louisiana: strawhull, blackhull, and an intermediate type grayhull. Strawhull red rice is more common than blackhull (Hu, 1978; Smith, 1981). Vaughan et al. (2001) reported that different kinds of red rice are intermingled across the southern U.S. rice belt and even within single production fields.

Herbicide-resistant crops provide growers with new and easy methods of weed management in commercial crops including rice. However, with the advancement of technology comes the issue of herbicide-resistant gene flow from herbicide-resistant rice to red rice and subsequent development of herbicide resistance in red rice due to herbicide selection pressure. Red rice diversity in different regions further complicates this situation. This study was conducted to determine the phenotypic diversity of red rice accessions from different rice-growing areas of Arkansas.

**PROCEDURES**

In summer 2002, one hundred thirty-six red rice accessions were collected from 26 rice-growing counties of Arkansas. Each accession was composed of one plant. Individual red rice plants were collected at least five miles apart. Whenever there were two kinds of red rice in the same field, a representative of each type was collected. Coordinates were recorded at the sample collection site with a GPS unit. Plant height, tiller number, culm angle, panicle length, and flag leaf characteristics (angle, length, width, color, and texture) were recorded. Seeds from collected plants were characterized on the basis of hull color, seed color, presence/absence of hairs, seed size, and awn length. In the following year (2003), three seeds from each accession were planted in the greenhouse on 28 April and later thinned to one seedling per accession. Red rice seedlings were transplanted later in the field at the RREC, Stuttgart, Ark. The field was tilled (6 in. deep) using a roto-tiller, and shallow flood was maintained for ease of transplanting. Seedlings were transplanted at two- to three-leaf stage on 12 May in a 3-ft by 3-ft grid pattern. The experiment was laid out in a randomized complete block design with 10 replications. The flood was raised to 5 in. 1 d after transplanting and the field was kept weed free during the whole season by hand weeding. Nitrogen (Urea, 46%N) was applied at a rate of 100 lb N/acre in a split application: first at 1 week after transplanting and second at 4 weeks after transplanting. Initiation of flowering was recorded when at least four tillers/plant had flowered. Morphological traits of plants: height, tiller number, culm angle, stem color, leaf color, shattering, and flag leaf characteristics (length, width, angle) were also recorded. Plants were bagged using delnet
bags to collect seeds. Panicles were harvested at maturity, threshed, and cleaned. Seed yield from each plant was recorded and seeds were characterized on the basis of hull color, seed color, pubescence, seed size, and awn length. For data analysis, the state was divided into four regions: northeast (NE), centraleast (CE), central (C), and southeast (SE) as shown in Fig. 1. Only hull color, seed yield, tiller number, plant height, and flowering will be discussed in this report. All data were subjected to analysis of variance, with means separated at the 0.05 level of significance using Fisher’s Protected Least Significant Difference (LSD).

**RESULTS AND DISCUSSION**

Red rice accessions fall into two major categories: strawhull and blackhull types. Besides the two major hull colors, straw and black, other hull colors were also observed including brown and orange. There was no statistical difference in plant height and tiller number among strawhull red rice accessions across regions. Strawhull accessions from NE Arkansas produced an average of 95 tillers per plant, whereas accessions from the SE produced 92 tillers (Fig. 2). Average height of strawhull accessions across regions was 53 in. (Fig. 4). Strawhull accessions from the NE part of the state produced the highest amount of seed per plant (190 g), whereas accessions from CE, C, and SE produced 174, 170, and 162 g seed, respectively (Fig. 3). Seed yield decreased with decreasing latitude in strawhull types, not because of reduced seed production potential, but due to increasing maturity periods. Accessions from SE did not reach full maturity at the RREC. These biotypes might mature at the RREC if planted earlier. Strawhull accessions from NE flowered earliest starting from 9 week after planting (WAP). Most of the NE accessions flowered during 12 WAP whereas accessions from SE flowered latest, the majority of which occurred during 15 WAP (Fig 5). Flowering period extended to 19 WAP for accessions from SE Arkansas. However, most accessions from C and CE part of the state flowered during 12 to 15 WAP (Fig 5). The date of flower initiation ranged from 11 July to 5 September. The period from planting to flower initiation increased with decreasing latitude. Among blackhull red rice, accessions from CE region produced the most tillers at 115/plant (Fig. 2) but were the shortest blackhull types with mean height of 53 in. (Fig 4). Blackhull accessions from SE had the least number of tillers (101/plant), although this was not statistically different from average tiller number of CE and C accessions (Fig. 2). Average height of blackhull accessions from C, SE, and NE were 60, 58, and 56 in., respectively (Fig 4). Blackhull accessions from C Arkansas yielded highest (mean=196 g), whereas NE accessions had the lowest seed yield at 154 g/plant (Fig 3). Seed yield of blackhull accessions did not change with latitude, which reflects no correlation between latitude of origin and flowering date of blackhull accessions. In general blackhull accessions from all regions of the state flowered later (15 WAP) than strawhulls (12 WAP). Blackhull accessions produced more tillers (108) and were taller (58 in.) than strawhull accessions. Phenotypic diversity of red rice was documented based on hull color, presence of awns, height, tillering capacity, flowering dates, and seed yield.
SIGNIFICANCE OF FINDING

This study demonstrated that there is great phenotypic diversity in red rice across different regions of the state. To manage red rice and gene flow effectively, we need to consider this diversity. The competitiveness of these biotypes varies, therefore there is a need for adjustment of management strategies based on red rice biotypes. Of greater significance is the spread in flowering period, which needs to be considered in mitigating gene flow from herbicide-resistant rice varieties. Based on phenotypic differences, we are also evaluating natural mutations in ALS gene sequences, which could lead to development of herbicide-resistant populations in response to selection pressure from ALS-inhibitor herbicides like Newpath.

ACKNOWLEDGMENTS

This study was supported by rice growers’ checkoff funds through the Arkansas Rice Research and Promotion Board. We would also like to express our gratitude to Jared Holzhauer, Jason Grantham, Jimmy Branson, and Howard Black for their assistance in this study.

LITERATURE CITED


Fig. 1. Origin of red rice accessions used in the experiment. Northeast (NE), Centraleast (CE), Central (C), and Southeast (SE). Number of accessions per region is indicated in parentheses.
Fig. 2. Average number of red rice tillers/plant across regions in Arkansas. NE= Northeast, CE= Centraleast, C= Central, SE= Southeast. All accessions were planted at the Rice Research and Extension Center, Stuttgart, Ark., 2003.

Fig. 3. Average red rice seed yield of strawhull and blackhull accessions across regions in Arkansas. NE= Northeast, CE= Centraleast, C= Central, SE= Southeast. All accessions were planted at the Rice Research and Extension Center, Stuttgart, Ark., 2003.
Fig. 4. Average plant height of strawhull and blackhull red rice accessions across regions in Arkansas. NE= Northeast, CE= Centraleast, C= Central, SE= Southeast. All accessions were planted at the Rice Research and Extension Center, Stuttgart, Ark., 2003.

Fig. 5. Flowering of red rice accessions across regions in Arkansas. NE= Northeast, CE= Centraleast, C= Central, SE= Southeast. All accessions were planted at the Rice Research and Extension Center, Stuttgart, Ark., 2003.