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Phenotypic Characteristics of Weedy Rice Variants of Central Mindanao

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The presence of different weedy rice (WR) have already been reported in other areas of the Philippines. However, reports documenting its presence and phenotypic characteristics in Central Mindanao are not yet available. This study investigated the incidence, biology, and phenotypic characteristics of WR in Central Mindanao. Survey and collection were conducted in rice field areas of South Cotabato, North Cotabato, Sultan Kudarat, and Maguindanao from 2016–2017. Eight WR variants with distinct grain characteristics were identified and designated in 2016 DS (dry season); 24 variants in 2016 WS (wet season); 31 variants in 2017 DS; and 24 WR variants in 2017 WS. The most prevalent variants were WR-SuK3 (2016 WS), WR-SuK2 (2016 DS), WR-Min15 (2017DS), and WR-SuK3 (2017 WS). Germination test and characterization were conducted at the Philippine Rice Research Institute, Maligaya, Science City of Muñoz, Nueva Ecija. The collected WR variants had variable grain characteristics that affect grain quality and germinated earlier than cultivated rice, which makes WR more competitive. Under screenhouse conditions, all variants matured earlier and had better agronomic characteristics than cultivated rice (NSIC Rc 222). Identified agronomic characters of WR collected from Central Mindanao will be useful for advising control strategies to farmers.

Keywords: biotype, Central Mindanao, phenotype, weedy rice

INTRODUCTION

WR (*Oryza sativa* L.) is a weed problem in rice fields worldwide. It is believed to be the product of a natural cross between wild and cultivated species of rice (Londo *et al.* 2006). Kanapeckas *et al.* (2016) study show that California WR has phenotypes like medium-grain or gourmet cultivars, colored pericarp, seed shattering, and awns like wild relatives, suggesting that reversion to non-domestic or wild-like traits can occur following domestication. Moreover, Huang *et al.* (2018) mentioned that the presence of a domestication related allele in South Asian WR at the seed shattering locus (*sh4*) in WR populations with cultivated ancestry supports a de-domestication origin.

The emergence of WR has become a serious threat to production for rice-growing countries because it competes with cultivated rice. In Asian countries where the DSR system is very common, WR infestation is increasingly important as it is more adaptable than cultivated rice varieties (Singh *et al.* 2013). WR plants have been reported to disperse about 970 kg/ha of seeds in rice fields in one season, which is a great harvest loss, besides increasing the weed seed bank (Azmi and Karim 2008). The distribution of its species is continuously increasing because of its strong characterized seed shatterings and dormancies (Delouche *et al.* 2007). Baki *et al.* (2000) have reported that seed shattering in WR varies from 20–95% in different seasons and variants. Under moderate infestation of WR (21–30 panicles/m^2), yield loss is 70–80%. WR competes efficiently with cultivated rice for limited resources,

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is known to be well-adapted to different environments and adverse conditions, and is more stress-tolerant than cultivated rice (Azmi and Karim 2008). Under heavy infestation (more than 31 panicles/m^2), the lodging of WR plants may occur and cause total yield loss under tropical climatic conditions (Azmi *et al.* 2004). In Vietnam, rice yield begins to decrease when WR infestation exceeds 10 seeds/m^2. Azmi *et al.* (2005) have estimated the costs of WR control as an indirect cost through land preparation to be 17–28%; and as a direct cost through manual weeding or roguing of WR plants to be 3–5% of the total cost (amounting to USD 636–850/ha).

In the Philippines, WR was first documented by Second in 1991 in Occidental Mindoro. More studies about the extent of its infestation and distribution have been done in other areas. However, no morphological and agronomical characterization of WR has been conducted, particularly in South and North Cotabato, Sultan Kudarat, and Maguindanao (Central Mindanao). This study was conducted to determine the morpho-agronomic characteristics of WR collected in the area to provide information on how WR is closely related to the cultivated variety and how they become more adaptable to adverse environmental conditions. This information will anchor an effective and successful strategy in controlling WR.

MATERIALS AND METHODS

Survey and Collection

In 2016 and 2017, rice fields of South and North Cotabato, Sultan Kudarat, and Maguindanao (Central Mindanao) were surveyed during the reproductive stage for possible incidence of WR. The areas surveyed were irrigated lowland with transplanted and direct-seeded methods of planting. Collection sites were presented in Table 1.

During collection, WR was identified and classified based on differences in grain color/length/width/discoloration, presence/length of the awn, and whether the panicle was open or closed. WR was found to be commonly taller than the cultivated variety. One hill for each variant was collected, with a total of 229 samples gathered from all sites. The entire collection was brought to the Weed Science Laboratory of the PhilRice Central Experiment Station in Nueva Ecija for a germination test and further characterization.

Agronomic characterization. A screenhouse trial was conducted to characterize the weedy and cultivated rice. Two trials were conducted from the 2016 DS and WS collections with five replications for each variant. Seeds of weedy and cultivated rice were pre-germinated in Petri dishes under laboratory conditions. Pre-germinated seeds were sown in an 8-in pail at 1 seed/pail previously filled with 3.5 kg of soil (Maligaya clay loam: very fine, montmorillonitic, isohyperthermic Ustic Epiaquerts, pH 6.9, organic matter 0.93%, and CEC 37.9/100 soil meq). Fertilizer was applied at the rate of 90-30-30 kg nitrogen-phosphorus-potassium ha^{-1} at 15, 30, and 45 d after sowing, and water was supplied as needed. In each pail, agro-morphological characters were derived (Appendix Table I) using Descriptors for Wild and Cultivated Rice (*Oryza spp.*) (Biodiversity International). Plant height, leaf area index (LAI), and stem color was observed at the vegetative stage, culm number per plant, culm length, culm width, panicle number per plant, and panicle length was observed at maturity. The LAI was calculated following the formula used by Diarra *et al.* (1985).

Before harvest, net bags were put in each panicle of ten randomly selected WR variants because of their early shattering characteristics. After harvest, each plant $pail^{-1}$ was cut from its base and brought to the laboratory to determine other agronomic parameters. Grain length and width, and awn length were recorded by measuring 50 grains of both weedy and cultivated rice using a digital caliper.

Seed characterization and germination test. Ten seeds from each WR sample were randomly selected and characterized by their grain color, length, and width; and awn length and color. Seed color was characterized using the Royal Horticultural Society Color Chart in the Descriptors for Wild and Cultivated Rice (RHS 1986), while the size was measured using a digital caliper.

Seeds of WR were oven-dried for 1 h at 40 °C to break its dormancy. The seeds were then sown in a Petri dish lined with moistened filter paper to test germination, replicated three times. Seeds were considered germinated when the coleoptile emerged at least 5 mm in length. Ten seeds of the cultivated rice variety NSIC Rc 222 were also sown to serve as the control treatment. This was selected as check variety for being the most commonly used variety in the area, based on interviews with farmers. Each seed was incubated for 4 d under alternating light and dark conditions at 25 ºC. The number of seeds germinated per day was recorded, and percentages were compared by dividing the number of seeds that germinated over the total number of seeds sown.

Data Analysis

Laboratory setups and screenhouse experiments were arranged in a completely randomized design with four replications. The data gathered were variance-analyzed (ANOVA) while the means were separated by standard deviation or Fisher's least significant difference test at a 5% level of significance using the SAS 9.1.3. Cluster analysis was based on similarity in growth and development, yield components, and grain characteristics. A similarity matrix was generated based on the simple Euclidean distance across all WR variants and check variety using STAR (Statistical Tool for Agricultural Research) 2.0.0 by IRRI.

RESULTS

Field Surveys and Site Characterization

Field survey data are shown in Appendix Table II. In 2016 DS eight variants were observed and collected from the survey sites in North Cotabato and Sultan Kudarat, and were coded based on their grain characteristics. WR-SuK2 were the most prevalent in the sampling sites observed in five of eight sites. Five different variants were observed and collected in one sampling site at Tugal, Midsayap, which had the most diverse population of WR. In 2016 WS, 24 WR variants were collected in North and South Cotabato and Maguindanao, among which WR-SuK3 was the most prevalent in nine sites. Eight variants were found in Bialong, Mlang, North Cotabato alone.

In addition, 31 WR variants were collected in North and South Cotabato and Sultan Kudarat during the 2017 DS (Appendix Table II). WR-Min 15, found in 12 collection sites, was the most prevalent variant. Seven WR variants were found in Centrala, Surallah, South Cotabato alone, whereas only one biotype was found in eight collection sites in Midsayap and Libungan, North Cotabato. In 2017 WS, 24 WR variants were collected in Maguindanao and South Cotabato. Of these, WR-SuK3 was found most prevalent in five collection sites.

WR infestation does not only lower the quality and quantity of rice yield but also increases production costs. Rice yield losses under moderate infestation could reach 50–60% (15–20 WR panicles per m^2), and 70–80% under high infestation (21–30 panicles per m^2). Heavy infestation (35 panicles/m^2) can result in total yield loss if it occurs due to the lodging of WR plants (Chauhan 2013).

Ziska *et al*. (2015) reported that the presence of 35–40 WR plants per m^2 could result in a 60% yield loss on tall rice cultivars and 90% on short cultivars. This report indicates that WR infestation causes even greater loss than other grass weeds. Moreover, their morphological variability, particularly growth behavior and high biological affinity with cultivated rice varieties, make it more difficult to control WR plants (Ferrero 2001).

During the 2016 and 2017 surveys, farmers practiced mostly direct seeding that favors WR infestation. According to Rao *et al*. (2007), there is no flooding at the time of crop emergence when direct seeding is practiced; therefore, both the WR variants and the cultivated rice varieties emerge simultaneously and cannot be differentiated. Also, the farmers planted mostly "good seeds" from the previous harvest. Moody *et al*. (1997) found a similar setting when they surveyed farmers in Iloilo, where 89% of 300 farmers planted their own rice seeds; only 10% used other seed materials. Their own or exchanged seeds could have been contaminated with seeds of WR.

WR seeds remain in the field because farmers normally neglect WR infestation. Heavy and early shattering of WR seeds (Azmi and Karim 2008) was also observed (Figure 1). Such seeds left in the field grow and compete with cultivated rice in the next cropping season.

Figure 1. High and early shattering of grains of WR.

Agronomic Characterization

All WR variants from North Cotabato and Sultan Kudarat (2016 DS, 1st trial) matured earlier than variety NSIC Rc 222 (Appendix Table III), with WR-SuK2 and SuK5 maturing earliest. The variants had longer culms than Rc 222 except for WR-Cot2 (75 cm). WR-SuK1 had the longest culm at 121.4 cm while SuK5 had the widest culm at 5.8 mm and LAI at 65.6 mm^2. Rc 222 had the widest flag leaf area (FLA) at 60 mm^2. Only the stems of WR-Cot2, WR-SuK1, SuK2, and SuK3 had anthocyanin coloration (AC). Flag leaves of the variants were characterized according to projection. WR-SuK2, SuK4, SuK5, and WR-Cot3 had erect flag leaves; those of WR-SuK1 and WR-Cot2 were semi-erect (intermediated); and those of WR-SuK3 and WR-Cot1 were descending (Figure 2).

Data from the second trial of the 2016 DS collection are also in Appendix Table III. The variants matured earlier and were taller than NSIC Rc 222 except for WR-SuK5. WR-Cot1 was the tallest (133.7cm), while SuK5 was the shortest (59.0cm). WR-Cot1 also had the longest (89.1cm) and biggest (4.9mm) culm. WR-SuK1 had the widest LAI at 80.1 mm^2; WR-Cot2 had the widest FLA at 72.2 mm^2.

All variants in the 2016 WS collection that were grown in the screenhouse matured earlier than NSIC Rc 222 (Appendix Table III). WR-Cot2 and WR-Min4 matured earliest at 78 d. The variants were taller than Rc 222 except WR-Min12 (97.6 cm) and Min14 (96.8 cm). Except for Min12 (48.2 cm), the variants had longer culms than Rc 222. WR-Min18 had the biggest culm diameter at 7.3 mm; Min4, the smallest, at 2.7 mm. Min1 had the highest LAI at 97.7 mm^2 and FLA at 97.07 mm^2; while Min13 had the least at 22.5 and 27.0 mm^2, respectively. WR-Min2, Min3, Min7, Min9, SuK5, Min14, Min15, Min16, and Min17 had purple stem coloration.

Another screenhouse trial was conducted to determine the biology and agronomic characteristics of the variants collected from South Cotabato and Maguindanao during the 2016 WS. In the second trial, NSIC Rc 222 still had the longest days of maturity compared to the WR variants, as shown in Appendix Table III. WR-Min13 was the tallest (137.8 cm) and Min19 had the most number of tillers that averaged 33.4. WR-Cot2 and Min6 had the widest LAI and FLA with averages of 81.5 and 180.6 mm^2. Nine variants had purple stem coloration, while 12 variants and the cultivated variety had no purple stem.

The variants from South Cotabato and Maguindanao had variable flag leaf attitudes (Figure 3). WR-Cot3 had erect flag leaves; those of Min1, Cot2, Min8, and Min16 were semi-erect; those of Min9, SuK5, and Min14 were horizontal; and those of WR-Min3, Min4, Min6, SuK4, Min10, Min11, Min12, and Min15 were descending.

The results of this study are similar to those of Martin *et al.* (2014). In their screenhouse trials, the variants collected from Nueva Ecija were taller, had early maturity, and had heavier plant biomass but shorter panicles than varieties PSB Rc 82 and IR 64.

Yield Component Characterization

Appendix Table IV shows the yield components of WR variants and NSIC Rc 222 under screenhouse conditions. WR had a higher number of panicles than Rc 222, variants with the most number of panicles were SuK5 (50.8), Suk2 (26.8), SuK3 (25.5), Cot1 (23.0), and Cot2 (22.0). The variants had longer panicles than Rc 222; Cot1 (258.5mm), SuK2 (255.5mm), SuK3 (243.3mm), SuK5 (238.3mm), and SuK1 (235.0mm) are the longest. However, check variety Rc 222 had the most number of grains, which were also biggest at 3.0 mm and the longest at 9.5 mm. Among WR variants Cot1 (107.5), Cot3 (87.5), SuK2 (81.8), SuK1 (77.5), and SuK5 (75.0) had the most number of grains. Cot2 (8.9 mm), Cot3 (8.5 mm), SuK2 (8.4 mm), SuK3 (8.0 mm), and Cot1 (7.8 mm) had the longest grains and Cot1 (2.6 mm), Cot2 (2.5 mm), Cot3 (2.4 mm), SuK2 (2.3), and SuK3 (2.2 mm) are the widest. Awns were longest in WR-SuK2 (44.3 mm), followed by SuK1 (15.5 mm), SuK3 (5.2 mm), and Cot3 (4.9 mm) (2016 DS 1st trial).

For the second trial, Rc 222 had the most number of panicles hill^{-1} (15.8), among the variants Suk5 (14.3), SuK2 (12.0), Cot2 (9.0), Cot1 (8.8), Cot3 (8.8), SuK3 (8.8), and SuK4 (7.8) had the highest number. WR variants with longer panicles than Rc 222 (209mm) were SuK2 (236), Cot2 (235), SuK4 (234), Cot1 (219), and SuK1 (218). Rc 222 had the most number of grains panicle^{-1} at an average of 151.5. WR-Cot1 had the longest (9.3 mm) and biggest grains (2.5 mm), and had awns during the second trial, unlike in the first trial.

Rc 222 had the most number of panicles hill^{-1} (23.3); compared with other WR variants, Min17 (15.8), Min18 (15.3), Min19 (14.5), Min16 (14), and Min3 (13.8) had a higher number of grains. WR-Min1 had the longest panicles at 28.7 mm, followed by Cot3 (26.7 mm), Min8 (25.5 mm), SuK3 (24.6 mm), Min2 (24.2 mm), and Min6 (24.2 mm), Rc 222 had an average of 24.2-mm panicle length. WR-Min9 had the most number of grains panicle^{-1} at 185.6; Min6 (157.6), Min8 (151.4), Cot3 (151.1), and SuK3 (150.0) had also high number of panicles. WR-Min1 had the longest grains (10.0 mm), while Min7 had the shortest (6.8 mm). The biggest grains were those of Min19 (2.8 mm), while the smallest belonged to SuK5 at 1.9 mm. Some variants had awns ranging from 5.0–22.6 mm. Min18 seeds were not harvested due to the death of the plant.

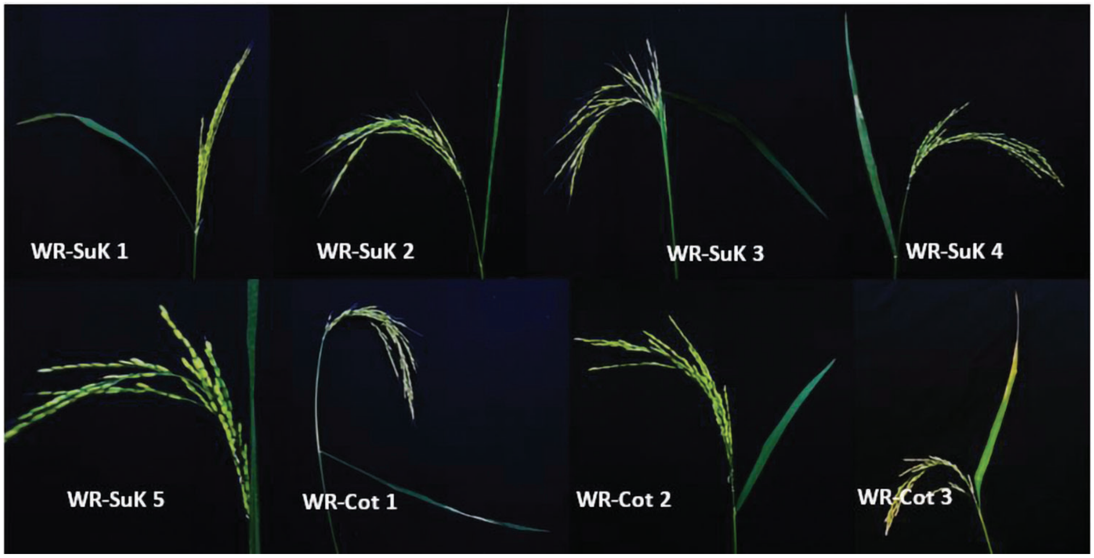


Figure 2. Flag leaf attitude of different WR variants of North Cotabato and Sultan Kudarat (2016 DS).

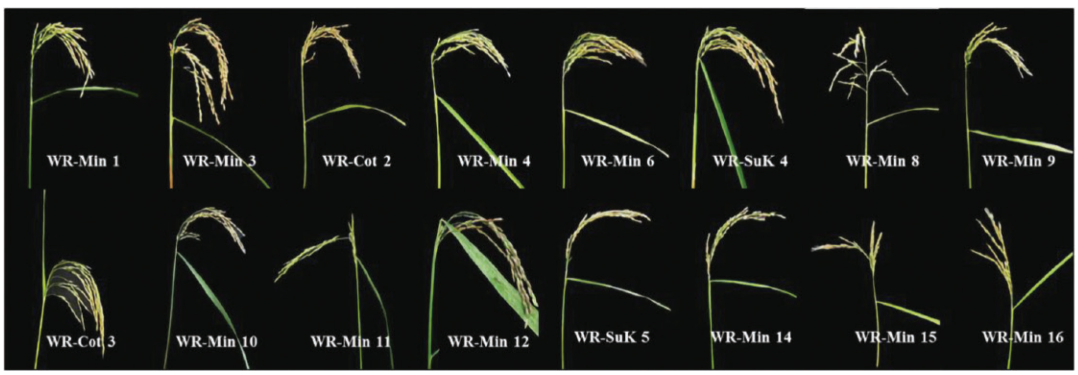


Figure 3. Flag leaf attitude of different WR variants of North Cotabato, South Cotabato, and Maguindanao (2016 WS).

During the second trial of the 2016 WS collection from North Cotabato, South Cotabato, and Maguindanao, the cultivated rice Rc 222 had the longest panicles with an average of 26.8 mm as compared with WR variants with long panicles such as SuK4 (25.6 mm), Min9 (25.3 mm), Min7 (25.0 mm), Min14 (23.7 mm), and Min1 (22.8 mm). Rc 222 had also the most number of grains panicle^{-1} (161.0) followed by WR variants Min9 (144.3), Min7 (141.3), Min19 (112.3), Cot2 (106.7), and Min14 (102.0). WR-SuK4 had the longest grains (9.7 mm), while those of Min9 and Min2 averaged 2.5 mm grain width only. Min6 had the longest awns with an average of 27.2 mm.

Ratnasekera *et al.* (2014) and Abeysekara *et al.* (2013) observed the same high degree of variability among the seeds of WR. The presence and absence of awn, color and length of awn, pericarp – as well as the size and shape of grains – were also recorded.

A study conducted by Martin *et al.* (2014) on WR variants collected from Nueva Ecija also found taller and had fewer panicles plant^{-1} than cultivated rice variety PSB Rc82 and IR64. Moreover, WR variants from Iloilo had also taller, matured earlier, and had fewer panicles plant^{-1} as compared to cultivated variety PSB Rc14 and PSB Rc82 (Donayre *et al.* 2016).

Burgos *et al.* (2011) reported that every individual WR variant is responsible for a mean decrease of 270 kg ha^{-1} in cultivated rice with 20 WR plants m^{-2} in a rice field. Chauhan (2013) also reported that five and 20 WR plants m^{-2} caused yield losses of 40% and 60%, respectively. The presence of WR in the rice field can cause significant yield loss and lower the quality of those produced.

Grain Characteristics and Germination

The WR variants collected from Central Mindanao had variable seed characteristics. All variants had straw-colored grains and light brown to brown pericarps (Appendix Table V). In the first trial, only WR-Cot3, SuK1, SuK2, and SuK3 had awns. The grains of Cot2, SuK1, and SuK5 had purple tips, while those of the other five variants had none.

Four variants had straw- to-yellow-colored awns (WR-Cot3, SuK1, SuK2, and SuK3) while the other four were awnless. In the second trial, only SuK1 and SuK5 had purple tips. Unlike in the first trial, Cot2 did not have purple tips.

In the 2016 WS collection, each of the 21 WR variants also had variable grain characteristics. Seeds had straw-to-yellow grain color. Some grains had pericarps that were whitish to yellowish-green in color, while others had light brown to brown pericarps. WR-Min11 and Min12 had black-colored pericarps as shown in Appendix Table V. Awns were present in 11 variants – namely, WR-Min3, Min6, Min8, Min7, Cot3, Min13, SuK5, Min15, Min16, Min17, and Min19. Their variable grain characteristics greatly helped in classifying them. Sudianto *et al.* (2016) stated that the absence and presence of awns, as well as the hull color, were useful traits to distinguish the different WR variants in Malaysia.

WR-Min21, Min22, Min24, Min28, Min29, Min30, Min33, and Min34 belong to one group, with yellow, blackish brown, brown (tawny), and light gold grain color; white, light brown, brown, light gold, and black pericarp color; and straw- and yellow-colored awns. The other group – composed of WR-Cot2, Cot3, SuK3, SuK4, SuK5, Min1, Min4, Min5, Min6, Min7, Min9, Min10, Min13, Min15, Min16, Min20, Min23, Min25, Min26, Min27, Min31, Min32, Min35, and the check variety – had straw, whitish, and yellow grain color; whitish, brown, yellowish-green, light brown, and brown pericarp color; and straw- and yellow-colored awns. Min5, Min16, Min20, Min23, Min25, Min28, Min29, Min30, and Min33 had a purple tip coloration (Appendix Table V).

The WR variants collected from Maguindanao and South Cotabato (2017 WS) were shown in Appendix Table V, Min38, Min39, Min40, Min44, and Min45 had straw-colored grains, straw and light brown to brown pericarp color, and straw-colored awns. WR-Cot2, Cot3, SuK3, SuK4, SuK5, Min1, Min4, Min5, Min6, Min7, Min9, Min10, Min13, Min27, Min36, Min37, Min41, Min42, Min43, and check variety had straw-and yellow-colored grains; whitish, brown, yellowish-green, and light brown pericarp color; and straw-colored awns. WR-Min5, Min36, Min39, Min42, Min43, Min44, and Min45 had purple tips.

Figure 8 shows the seed germination rate – Rc 222 had 93.33% germination after 2 d of incubation (DAI), Cot1 (93.33%) emerged ahead of the other WR variants. At 4 DAI, all seeds were fully germinated except Rc 222, which had 96.67% germination.

The seedlings were also observed at seven days after germination for the presence of AC on their coleoptiles. Each seedling was rated according to the following: 0 – no AC; 1 – very weak AC; and 3 – weak AC. The seedlings of four variants (WR-SuK2, SuK3, SuK5, and Cot1) had no AC; SuK4 and Cot2 had very weak AC; and SuK1 and Cot3 had weak AC.

The seeds of variants collected from North/South Cotabato and Maguindanao (2016 WS collection) and the check variety were also sown to test their germination (Figure 9). Rc 222 seeds were the earliest to germinate (93.33%) after 2 DAI, followed by SuK3 and SuK4 with 76.67%, Min5 (73.33%), Min2 and Min8 66.67%, Min6 (60%), and Min20 (53.33%). WR-Min5 and Min10 attained 100% germination at 3 DAI; SuK1, Cot2, Min7, SuK4, Min8, and Min9 at 4 DAI. Meanwhile, NSIC Rc 222 remained with 96.67% germination at 4 DAI.

Donayre *et al.* (2016) saw similar results on the percent germination of WR variants of Iloilo. At 4 DAI, all seeds except for WR-ILO7 and ILO8 had 100% germination compared to varieties PSB Rc 14 and Rc 82. In this present study, the seeds of the variants had longer roots than those of NSIC Rc 222. Similar results were found by Donayre *et al.* (2016). Xia *et al.* (2011) also found that WR variants had earlier germination and root development than cultivated rice varieties. This trend was observed after incubating weedy and cultivated rice seeds at 25 or 30 ºC for 1 wk.

Seed dormancy variability is a major factor that contributes to the successful adaptation and survival of WR in ecosystems (Ratnasekera *et al.* 2015). The rapid rate of seed germination of WR implies that these variants are great competitors of the cultivated rice varieties, whose seedlings cannot keep up with weeds (Rao *et al.* 2007).

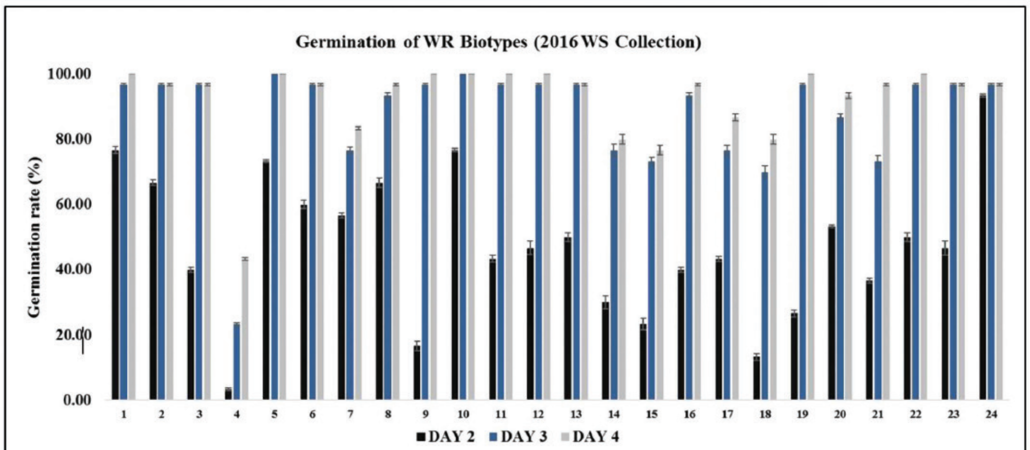
Cluster Analysis

Cluster analyses were done per batch of collection. For the 2016 DS collection, a dendrogram shows two major cluster groups (Figure 4). Rc 222 was separated from the group and all WR variants belong to one cluster. WR variants grouped further into three sub-clusters. Cot3 and SuK5 show similarity in pericarp color, LAI, FLA, culm width, panicle length, grains panicle^{-1}, grain length, and grain width; SuK1, Cot1, and Cot2 are one group with similarity in culm width, panicle hill^{-1}, panicle length, grains panicle^{-1}, and grain width; SuK4, SuK2, and SuK3 had the same grain color, maturity, FLA, culm width, and grain length.

Figure 5 shows the 2016 WS collection; the dendrogram indicated two major groups – cluster I comprised Rc 222 and Min1 while cluster II comprised 20 WR variants. Cluster II further grouped in two subclusters consisting Min10, Min15, Min13, and SuK5 subgroup; and Min14, Min7, Min16, Min12, Cot2, Min11, Min19, Min2, Min17, Min3, Min9, Min4, Min6, Cot3, SuK3, and Min8 subgroup.

The weedy and cultivated varieties were designated as: 1.WR-SuK1; 2.Suk2; 3.SuK3; 4.SuK4; 5.SuK5; 6.Cot1; 7.Cot2; 8.Cot3; and 9.NSIC Rc 222.

Figure 8. Seed germination of eight WR biotypes of North and South Cotabato and Sultan Kudarat, and cultivated rice variety (2016 WS). Vertical bars are SEs of the means.



The weedy and cultivated varieties were designated as: 1.WRSuK3; 2.Min1; 3.Min2; 4.Min3; 5.Cot2; 6.Min4; 7.Min5; 8.Min6; 9.Min7; 10.SuK4; 11.Min8; 12.Min9; 13.Cot3; 14.Min10; 15.Min11; 16.Min12; 17.Min13; 18.SuK5; 19.Min14; 20.Min15; 21.Min17; 22.Min18; 23.Min19; 24.NSIC Rc 222.

Figure 9. Seed germination of WR biotypes of North/South Cotabato and Maguindanao, and cultivated rice variety (2016 WS collection – 1st trial). Vertical bars are standard errors of the means.

The dendrogram for the 2017 DS collection (Figure 6) shows two clusters – cluster I is distant in traits like grain, pericarp, and awn color consist of Min33, Min24, and Min34. Cluster II consists of two subclusters – the Min15, Min21, Min22, Min9, SuK4, Cot2, SuK3, Min20, Min32, Min31, Min10, Min1, Min13, Min27, Min16, Min25, Min7, Min4, Min5, Min6, Cot3, SuK5, and Rc222 (22 WR variants and check variety) subgroup; and the Min23, Min26, Min35, Min30, Min28 and Min29 (6 WR variants) subgroup.

Collection from 2017 WS also has two clusters (Figure 7). Clusters I and II consist of two subclusters. Min38, Min40, Min44, Min39, and Min45 are subgroups from cluster I; Min5, Min41, Min10, Min1, Min9, SuK4, Cot2, SuK3, Min4, Min6, Cot3, SuK3, Min13, Min27, and Rc 222 are the other subgroups. Cluster II subgroups are Min43, Min36, and Min42; and Min7 and Min37.

WR collected from Central Mindanao had characteristics like early maturity and a high number of tillers that makes it more competitive to cultivated rice. There are also WR variants that had close similarity with check variety Rc222, which makes it more difficult to control. Chauhan (2013) asserted that weed management strategies – including thorough land preparation; appropriate time,

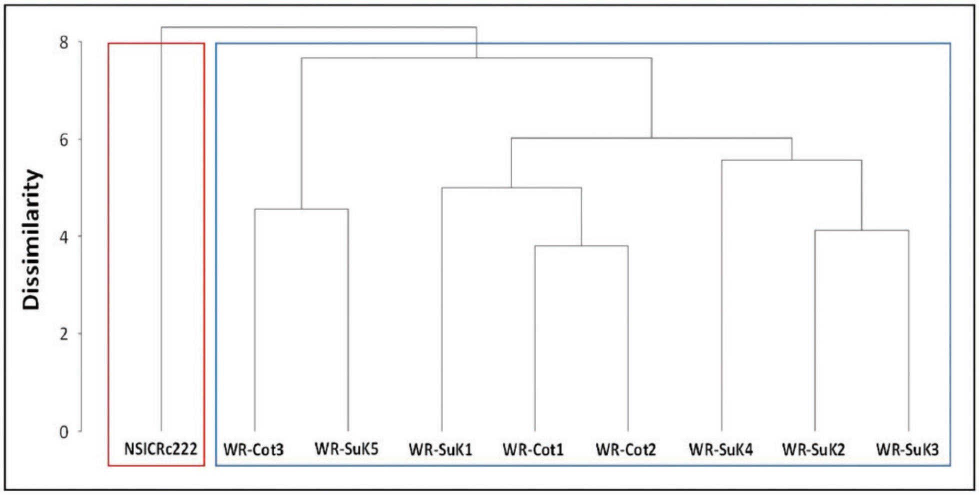


Figure 4. Dendrogram of the 2016 DS WR variants collected in North Cotabato and Sultan Kudarat under screenhouse conditions. NSIC Rc222 is the check variety.

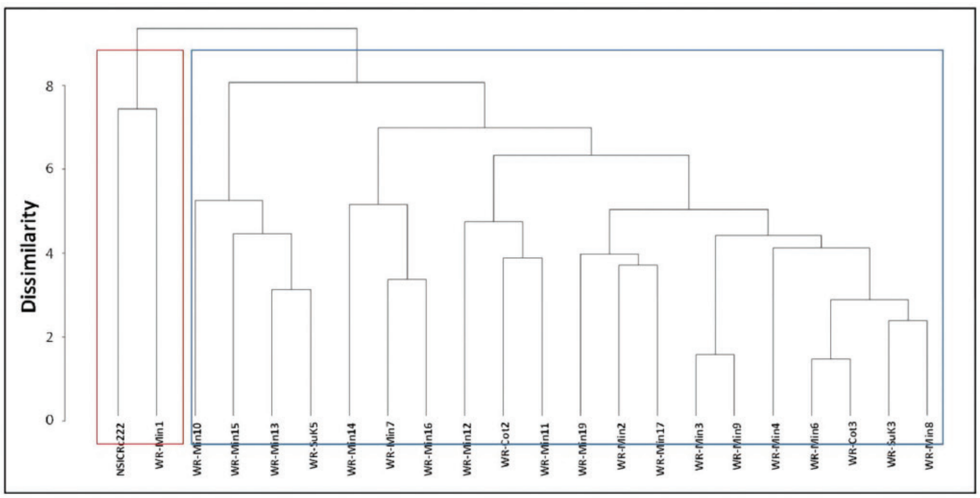


Figure 5. Dendrogram of the 2016 WS WR variants collected in North and South Cotabato and Maguindanao under screenhouse conditions. NSIC Rc222 is the check variety.

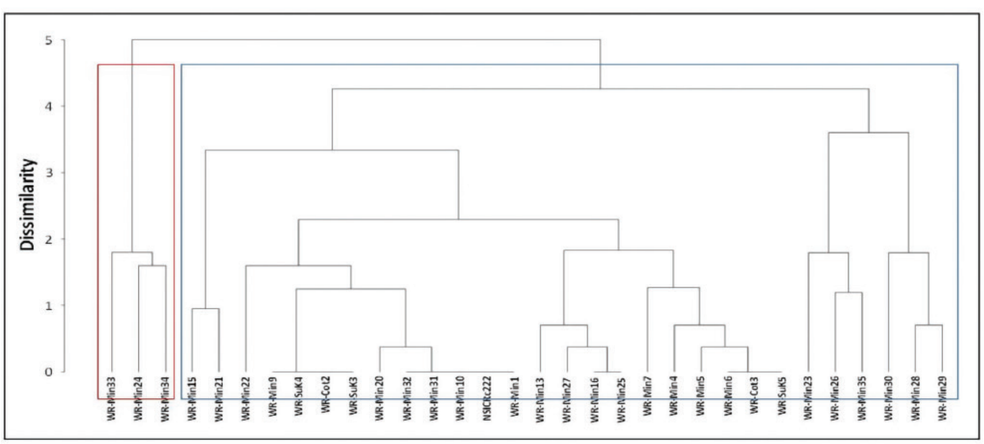


Figure 6. Dendrogram of the 2017 DS WR variants collected in South Cotabato and Maguindanao under screenhouse conditions. NSIC Rc222 is the check variety.

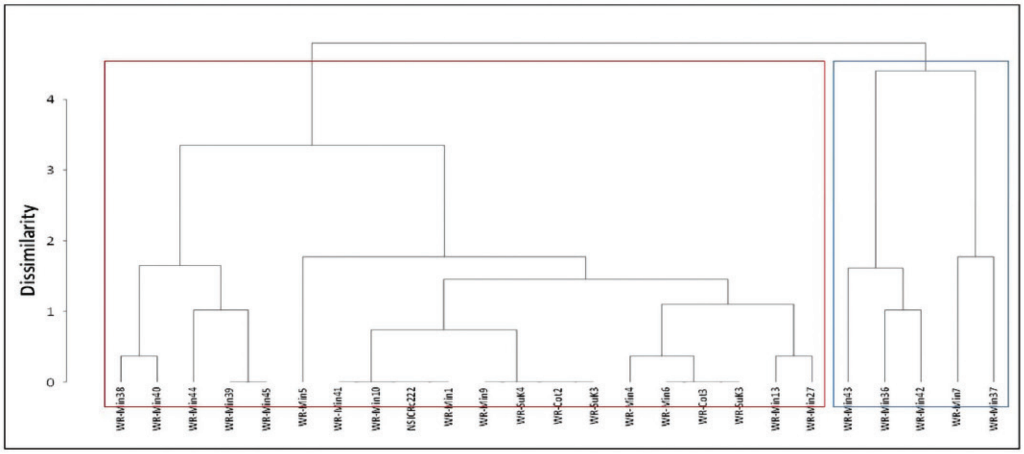


Figure 7. Dendrogram of the 2017 WS WR variants collected in South Cotabato and Maguindanao under screenhouse conditions. NSIC Rc222 is the check variety.

depths, and duration of flooding; the judicious use of herbicides; stale seedbed practice; and crop rotation – could alleviate the problem of WR.

CONCLUSION

Eight (2016 DS) and 24 (2016 WS); and 31 (2017 DS) and 24 (2017 WS) WR variants were collected in the rice field areas of South/North Cotabato, Sultan Kudarat, and Maguindanao (Central Mindanao). The most prevalent of these were WR-SuK3 (2016 WS), WR-SuK2 (2016 DS), WR-Min15 (2017 DS), and WR-SuK3 (2017 WS). These variants had agronomic and phenotypic characteristics comparable to cultivated rice.

The variants germinated rapidly and had shorter growth durations, making them very competitive with cultivated rice. This indicates that the increasing variants of WR truly threatens to reduce the quantity and quality of cultivated rice production in rice-growing countries like the Philippines.

Variability in the phenotypic and agronomic characteristics of WR populations was observed. In most cases, the growth and development of WR variants were superior to cultivated rice. Initial findings on the extent of distribution and infestation of WR are now on record. This information provides an understanding of the morphological characteristics of WR and their distribution in Central Mindanao. With this information, we can apply management strategies against WR in those specific areas. This study suggests that immediate attention be given to the different traits of WR that could reduce the yield of cultivated rice varieties. Its ability to survive from a period of dormancy, the timing of emergence, and the capabilities of its seedlings to emerge from soil or water depth in adverse environmental conditions must be tackled. Management strategies that could effectively inhibit the establishment of WR in rice fields should also be developed. The spread of WR in the Philippines must be stopped.

Farmers in the surveyed areas of North/South Cotabato and Sultan Kudarat must carry out a holistic approach to control the spread and infestation of WR in rice fields. Only clean seeds and machines must be used, and proper water management and weeding either mechanically or manually should also be practiced.

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APPENDICES

Appendix Table I. Procedure on gathering of WR variants and check variety.

Parameters	Description
Plant height (cm)	From the base of the plant to the highest culm.
Leaf area index (LAI) (mm^2)	Computed as follows: LAI = LAT x TT / PA, where LAT = leaf area per tiller, TT = total number of tillers, and PA = area of the pot
Flag leaf area (mm^2)	FLA = length x width
Culm number per plant	Total number of grain-bearing and non-bearing tillers
Culm length (cm)	Measured from ground level to the base of the panicle
Culm width (cm)	Measured as the outer diameter of basal portion of the main culm
Purple stem	Presence of purple color from anthocyanin, observed on the outer surface of the internodes on the culm
Panicle number per plant	Number of panicles per plant
Panicle length (mm)	Length of main axis of panicle measured from the panicle base to the tip
Ligule length (mm)	Measured from the base of collar to the tip of the ligule of the penultimate leaf, *i.e.* the leaf below the flag leaf
Number of grains per panicle	Total number of filled and unfilled grains per panicle
Number of grains per panicle	Total number of filled and unfilled grains per panicle
Panicle shattering	Extent to which grains have shattered from the panicle
Grain length (mm)	Measured the distance from the base of the lower most glume to the tip (apiculus) of the fertile lemma or pales, whichever is longer
Grain width (mm)	Measured the distance across the fertile lemma and pales at the widest point
Awn length (mm)	Measured the longest awn

Appendix Table II. Weedy rice survey and collection in rice fields of Central Mindanao (2016–2017).

Collection site			Weedy rice variants
Province	Municipality	Barangay	
2016 DS			
North Cotabato	Midsayap	Nes (site 1)	WR-Cot2
		Nes (site 2)	WR-Cot3, WR-Cot2, WR-Cot1
		Tugal (site 1)	WR-Cot2, WR-SuK5
		Tugal (site 2)	WR-Cot2, WR-Cot3, WR-SuK1, WR-SuK2, WR-SuK3
Sultan Kudarat	Isulan	Kulambo (site 1)	WR-SuK1, WR-SuK2, WR-SuK3
		Kulambo (site 2)	WR-SuK2, WR-Cot1
		Sampao (site 1)	WR-SuK1, WR-SuK2, WR-Cot3
		Sampao (site 2)	WR-SuK2, WR-SuK4, WR-SuK5
2016 WS			
North Cotabato	Kabacan	Kilasagan	WR-SuK3, WR-Min1
	M'lang	Bialong	WR-SuK3, WR-Min2, WR-Min3, WR-Cot2, WR-Min4, WR-Min5, WR-Min6, WR-Min7
		Malayan	WR-Min1, WR-Cot2, WR-Suk4
	Tulunan	Sibsib	WR-SuK3, WR-Min1, WR-Cot2, WR-Min4
		Bual	WR-SuK3, WR-Min1, WR-Min9, WR-Cot3
	Midsayap	Tugal	WR-Min1, WR-SuK4, WR-Cot3, WR-Min10
		Lower Glad	WR-SuK3, WR-Min1, WR-Min4, WR-Cot3, WR-Min12
Maguindanao	Datu Paglas	Damalusong	WR-SuK4, WR-Min8, WR-Min9, WR-Min10

Collection site			Weedy rice variants
Province	Municipality	Barangay	
		Katil	WR-Cot2, WR-SuK4, WR-Min11, WR-Min12
South Cotabato	Koronadal City	Esperanza	WR-SuK3, WR-Min5, WR-Min9, WR-Cot3
		Mabini	WR-SuK3, WR-Min5, WR-SuK5
		San Jose	WR-Min13, WR-SuK5
		Avanceña	WR-SuK3, WR-Min6, WR-Min7
	Norala	Poblacion	WR-SuK5, WR-Min14, WR-Min15, WR-Min16
	General Santos City	Alabel	WR-SuK3, WR-Min9, WR-Min17, WR-Min18, WR-Min19

Appendix Table III. Growth and development of weedy rice variants of Central Mindanao and variety NSIC Rc 222 under screenhouse conditions.

Variants/ cultivated rice	Maturity (d)	Plant height (cm)	Leaf area index (mm^2)	Flag leaf area (mm^2)	Culm plant^{-1}	Culm length (cm)	Culm width (mm)	Purple stem
2016 DS collection in North Cotabato and Sultan Kudarat (1st trial, May–September 2016)								
NSIC Rc 222	106.0 a	–	48.5 ab	60.0 a	23.0 b	90.1 c	5.4 bc	Absent
WR-Cot1	90.0 c	–	30.8 b	27.4 c	23.5 b	103.9 b	3.6 d	Absent
WR-Cot2	90.0 c	–	25.5 b	29.0 bc	22.3 b	75.0 d	9.4 a	Present
WR-Cot3	87.0 d	–	30.9 b	29.9 bc	19.3 b	113.8 ab	4.1 d	Absent
WR-SuK1	95.0 b	–	35.9 b	29.9 bc	20.5 b	121.4 a	5.4 bc	Present
WR-SuK2	82.0 e	–	33.2 b	29.7 bc	28.0 b	103.2 b	4.2 cd	Present
WR-SuK3	87.0 d	–	35.5 b	33.7 bc	27.3 b	105.6 b	5.6 b	Present
WR-SuK5	82.0 e	–	65.6 a	49.0 ab	38.8 a	106.2 b	5.8 b	Absent
2016 DS collection in North Cotabato and Sultan Kudarat (2nd trial, November 2016 – March 2017)								
NSIC Rc 222	106.0 a	80.0 d	45.2 de	38.4 c	–	58.4 e	4.2 ab	–
WR-Cot1	98.0 c	133.7 a	62.8 b	38.1 c	–	89.1 ab	4.9 a	–
WR-Cot2	98.0 c	116.1 b	57.2 bc	72.2 a	–	75.0 c	4.7 a	–
WR-Cot3	98.0 c	100.5 c	35.6 ef	27.8 cd	–	74.8 c	3.6 bc	–
WR-SuK1	90.0 d	114.0 b	80.1 a	55.4 b	–	84.9 b	4.9 a	–
WR-SuK2	90.0 d	94.5 c	51.2 cd	36.2 c	–	74.5 c	3.7 bc	–
WR-SuK3	90.0 d	92.5 c	42.3 def	28.8 cd	–	67.2 d	3.7 bc	–
WR-SuK4	90.0 d	114.9 b	39.3 ef	29.3 cd	–	91.1 a	3.0 c	–
WR-SuK5	100.0 b	59.0 e	32.8 f	18.8 d	–	41.5 f	3.3 c	–
2016 WS collection in North Cotabato, South Cotabato, and Maguindanao (1st trial, October 2016 – February 2017)								
NSIC Rc 222	106.0 a	102.8 kl	35.48 j	57.8 efg	–	65.9 m	4.3 bcde	Absent
WR-Cot2	78.0 l	105.8 kl	62.9 bcde	52.4 efghi	–	82.7 jkl	3.0 cde	Absent
WR-Cot3	94.0 d	155.8 abcd	61.9 cde	53.3 efghi	–	114.7 cd	4.0 bcde	Absent
WR-SuK3	89.0 f	146.3 bcde	59.9 cde	80.5 bc	–	108.7 de	5.0 bcd	Absent
WR-SuK5	102.0 b	114.8 jkl	32.2 jk	39.4 jkl	–	80.6 jk	3.7 cde	Present
WR-Min1	94.0 d	167.5 a	97.7 a	97.0 a	–	109.9 cde	6.1 ab	Absent
WR-Suk4	–	130.7 fgh	68.9 bcd	88.0 ab	–	90.2 hi	4.4 bcde	Absent
WR-Min2	83.0 i	146.3 bcde	60.1 cde	80.1 bc	–	108.7 de	4.9 bcd	Present
WR-Min3	89.0 f	158.6 abc	64.1 bcde	56.5 gef	–	117.7 bc	3.6 cd	Present
WR-Min4	78.0 l	138.7 efg	59.6 cde	48.8 ghij	–	133.5 a	2.7 e	Absent
WR-Min6	88.0 g	160.6 ab	58.4 def	52.3 ghij	–	123.9 b	5.1 bc	Absent
WR-Min7	84.0 h	137.7 efgh	56.4 ef	56.0 efgh	–	99.4 fg	3.6 cde	Present

Variants/ cultivated rice	Maturity (d)	Plant height (cm)	Leaf area index (mm²)	Flag leaf area (mm²)	Culm plant⁻¹	Culm length (cm)	Culm width (mm)	Purple stem
WR-Min8	88.0 g	142.0 def	53.7 efg	50.0 ghij	–	109.6 cde	4.0 bcde	Absent
WR-Min9	84.0 h	159.9 ab	70.7 bc	63.8 def	–	117.3 bc	2.8 e	Present
WR-Min10	88.0 g	108.5 kl	41.7 hij	30.0 kl	–	74.7 kl	7.1 bcde	Absent
WR-Min11	98.0 c	123.3 hij	38.1 ij	41.5 ijk	–	81.2 jk	2.9 de	Absent
WR-Min12	98.0 c	97.6 l	74.4 b	73.2 cd	–	48.2 n	3.6 cde	Absent
WR-Min13	102.0 b	108.9 jkl	22.5 k	27.0 l	–	66.5 lm	3.2 cde	Absent
WR-Min14	102.0 b	96.8 l	36.3 ij	43.1 ij	–	71.7 lm	4.0 bcde	Present
WR-Min15	80.0 k	125.4 gih	47.8 fghi	51.0 ghij	–	83.6 ij	4.1 bcde	Present
WR-Min16	92.0 e	140.8 ef	36.6 ij	45.8 ghij	–	86.9 hij	3.3 cde	Present
WR-Min17	81.0 j	123.2 hij	53.1 efg	43.5 hij	–	93.4 gh	4.1 becd	Present
WR-Min18	80.0 k	147.0 bcde	43.9 ghij	65. de	–	105.7 ef	7.3 a	Absent
WR-Min19	80.0 k	145.0 bcde	64.8 bcde	56.2 efgh	–	103.3 ef	3.9 bcde	Absent
2016 WS collection in North Cotabato, South Cotabato, and Maguindanao (2nd trial, July–November 2017)								
NSIC Rc 222	106 a	126.2 ab	62.8 b	49.0 cde	26.4 ab	34.0 hi	–	Absent
WR-Cot2	102 c	125.6 ab	81.5 a	62.1 bc	16.4 cd	80.6 d	–	Absent
WR-SuK3	102 c	136.5 ab	50.8 bcdef	43.5 de	13.2 def	96.8 a	–	Absent
WR-SuK4	102 c	133.2 ab	62.5 bc	52.8 bcd	12.2 def	39.4 fghi	–	Absent
WR-SuK5	104 b	134.4 ab	36.4 efgh	45.1 cde	16.8 cd	50.7 e	–	Present
WR-Min1	102 c	84.46 c	34.3 gh	36.5 def	21.2 bc	50.2 ef	–	Absent
WR-Min2	102 c	124.4 ab	24.2 h	38.6 def	15.8 cde	85.0 bcd	–	Present
WR-Min3	102 c	141.2 a	54.9 bcd	46.6 cde	15.6 cde	98.6 a	–	Present
WR-Min4	102 c	136.6 ab	62.3 bc	40.6 cdef	13.0 def	90.4 abcd	–	Absent
WR-Min5	102 c	134.2 ab	46.1 cdefg	48.3 cde	11.6 def	82.8 cd	–	Absent
WR-Min6	102 c	136.0 ab	52.2 bcde	180.6 a	10.6 def	100.4 a	–	Present
WR-Min7	102 c	125.8 ab	54.6 bcd	73.8 b	8.0 f	99.4 a	–	Absent
WR-Min8	102 c	130.2 ab	51.9 bcde	52.2 bcd	9.2 ef	46.0 efg	–	Absent
WR-Min9	102 c	118.4 ab	58.6 bcd	45.2 cde	16.4 cd	31.1 i	–	Present
WR-Min11	102 c	121.4 ab	53.3 bcd	42.3 cde	11.8 def	35.0 ghi	–	Absent
WR-Min13	102 c	137.8 ab	49.9 bcdefg	55.4 bcd	9.8 ddef	44.1 efgh	–	Absent
WR-Min14	104 b	117.4 b	47.9 bcdefg	49.0 cde	9.8 def	93.2 abc	–	Present
WR-Min15	91 d	114.6 b	24.5 h	19.4 f	11.8 def	95.4 a	–	Present
WR-Min16	91 d	118.8 ab	33.3 gh	28.3 ef	15 def	98.4 a	–	Present
WR-Min17	91 d	124.2 ab	51.9 bcde	44.4 cde	15.2 cde	90.8 abcd	–	Present
WR-Min19	91 d	123.2 ab	44.0 defg	35.9 def	33.4 a	84.4 bcd	–	Absent

Means in a column followed by the same letters are not significantly different at 0.5% level of significance by LSD.

Appendix Table IV. Yield components of weedy rice variants of Central Mindanao and variety NSIC Rc 222 under screenhouse conditions.

Variants/ cultivated rice	Panicle hill⁻¹	Panicles length (mm)	Grains panicle⁻¹ (mm)	Grain length (mm)	Grain width (mm)	Awn length (mm)
2016 DS collection in North Cotabato and Sultan Kudarat (1st trial, May–September 2016)						
NSIC Rc 222	18.8 bcd	188.0 b	110.0 a	9.5 a	3.0 a	0.0 d
WR-Cot1	23.0 bcd	258.5 a	107.5 ab	7.8 cd	2.6 ab	0.0 d
WR-Cot2	22.0 bcd	234.0 ab	63.8 b	8.9 ab	2.5 ab	0.0 d
WR-Cot3	14.3 d	224.5 ab	87.5 ab	8.5 ab	2.4 ab	4.9 cd

Variants/ cultivated rice	Panicle hill^{-1}	Panicles length (mm)	Grains panicle^{-1} (mm)	Grain length (mm)	Grain width (mm)	Awn length (mm)
WR-SuK1	17.5 cd	235.0 ab	77.5 ab	7.5 abd	2.0 b	15.5 b
WR-SuK2	26.8 b	255.5 a	81.8 ab	8.4 bc	2.3 ab	44.3 a
WR-SuK3	25.5 bc	243.3 ab	70.5 ab	8.0 cd	2.2 b	5.2 c
WR-SuK5	50.8 a	238.3 ab	75.0 ab	7.3 d	2.0 b	0.0 d
2016 DS collection in North Cotabato and Sultan Kudarat (2nd trial, November 2016 – March 2017)						
NSIC Rc 222	15.8 a	209.0 abc	151.5 a	9.2 a	2.3 b	0.0 e
WR-Cot1	8.8 cd	219.0 ab	88.4 bc	9.3 a	2.5 a	14.0 b
WR-Cot2	9.0 cd	235.0 a	87.7 bc	8.7 b	2.5 ab	0.0 e
WR-Cot3	8.8 cd	163.0 c	74.3 c	7.5 e	2.5 ab	7.7 c
WR-SuK1	5.3 d	218.0 ab	88.9 bc	7.9 cde	2.5 ab	22.0 a
WR-SuK2	12.0 bc	236.0 a	113.0 b	8.3 cb	2.2 c	14.5 b
WR-SuK3	8.8 cd	184.0 bc	65.7 c	7.9 cde	2.4 ab	2.9 d
WR-SuK4	7.8 d	234.0 ab	84.9 bc	7.6 de	2.5 a	0.0 e
WR-SuK5	14.3 b	189.0 abc	68.7 c	8.0 cd	2.5 a	0.0 e
2016 WS collection in North and South Cotabato and Maguindanao (1st trial, October 2016 – February 2017)						
NSIC Rc 222	23.3 a	242.0 bcde	144.0 bcde	9.5 b	2.3 hi	0.0 f
WR-Cot2	9.3 efghi	211.0 fghi	147.1 abcd	7.5 jk	2.2 fghi	0.0 f
WR-Cot3	9.5 efghi	267.0 ab	151.1 abc	8.5 ef	2.2 fghi	5.2 e
WR-SuK3	9.8 cdefgh	246.0 bcd	150.0 abc	8.3 fg	2.2 fgh	0.0 f
WR-SuK5	10.0 bcdefgh	–	–	7.0 lm	1.9 j	5.0 e
WR-Min1	12.8 bcdefg	287.0 a	147.6 abc	10.0 a	2.4 defg	0.0 f
WR-Min2	10.3 bcdefg	242.0 bcde	117.9 bcdef	7.4 kl	2.5 bcd	0.0 f
WR-Min3	13.8 bcdef	235.0 cdef	146.7 bcdef	7.9 hi	2.5 b	0.0 f
WR-Min4	10.3 bcdefgh	221.0 defgh	143.1 bcde	9.0 cd	2.1 hi	5.3 e
WR- Min6	11.3 bcdefg	242.0 bcde	157.6 ab	8.7 de	2.2 hi	22.6 a
WR-Min7	8.5 fghi	200.0 hi	87.9 fg	6.8 m	2.5 b	8.3 d
WR-Min8	10.3 bcdefgh	255.0 bc	151.4 abc	8.1 gh	2.3 efgh	0.0 f
WR-Min9	15.5 bc	236.0 cdef	185.6 a	7.9 hi	2.4 bcde	0.0 f
WR-Min10	7.5 ghij	–	–	7.6 ijk	2.2 ghi	0.0 f
WR-Min11	11.0 bcdefg	206.0 ghi	70.1 g	7.7 hij	2.1 ij	0.0 f
WR-Min12	10.0 bcdefgh	219.0 efgh	107.5 defg	9.7 b	2.5 b	0.0 f
WR-Min13	7.5 ghij	–	–	8.3 fg	2.1 ij	5.3 e
WR-Min14	13.3 bcdefg	187.0 i	68.3 g	8.7 ed	2.4 cdef	0.0 f
WR-Min15	5.0 hij	–	–	7.4 efg	2.3 fgh	17.6 b
WR-Min16	14.0 bcdef	191.0 i	74.1 g	6.9 m	2.5 bcd	13.5 c
WR-Min17	15.8 b	224.0 efgh	115.0 cdef	9.3 bc	2.5 bc	7.8 de
WR-Min18	15.3 bcd	226.0 defg	–	–	–	–
WR-Min19	14.5 bcde	240.0 cde	119.8 bcdef	7.6 ijk	2.8 a	12.6 c
2016 WS collection in North and South Cotabato and Maguindanao (2nd trial, July–November 2017)						
NSIC Rc222	–	26.8 a	161.0 a	8.9 bc	2.0 fgh	0.0 f
WR-Cot2	–	18.9 defg	106.7 cde	7.5 j	2.1 efg	8.3 e
WR-Suk3	–	14.0 gh	89.0 def	8.6 bcde	1.9 h	1.0 f
WR-SuK4	–	25.6ab	101.3 de	9.7 a	2.3 abcd	0.0 f

Variants/ cultivated rice	Panicle hill^{-1}	Panicles length (mm)	Grains panicle^{-1} (mm)	Grain length (mm)	Grain width (mm)	Awn length (mm)
WR-SuK5	–	21.0 abcdef	98.0 de	8.4 cdefg	2.4 abcd	7.9 e
WR-Min1	–	22.8 abcdef	82.3 def	8.7 bcd	2.0 fgh	0.0 f
WR-Min2	–	19.1 cdefgh	87.4 def	7.6 hij	2.5 a	0.0 f
WR-Min3	–	13.0 h	85.0 def	7.3 j	2.3 abcd	0.0 f
WR-Min4	–	20.3 bcdef	56.0 f	8.4 cdefg	2.4 abcd	16.6 bcd
WR-Min5	–	18.7 efgh	60.7 f	8.4 cdefg	2.4 abcd	21.2 ab
WR-Min6	–	19.0 defgh	104.0 de	7.8 fghij	2.0 fgh	27.2 a
WR-Min7	–	25.0 abcd	141.3 abc	8.8 bcd	2.3 abcd	0.0 f
WR-Min8	–	20.3 bcdefg	73.0 ef	7.7 ghij	2.2 cdef	0.0 f
WR-Min9	–	25.3 abc	144.3 ab	9.2 ab	2.5 a	0.0 f
WR-Min11	–	16.8 fgh	76.7 def	8.0 efghi	2.3 abcd	22.2 ab
WR-Min13	–	20.4 bcdef	74.7 ef	7.5 ij	2.0 fgh	10.5 de
WR-Min14	–	23.7 abcde	102.0 de	7.9 fghij	2.2 cdef	11.1 cde
WR-Min15	–	18.1 efgh	80.7 def	8.2 defgh	2.0 fgh	27.6 a
WR-Min17	–	21.6 abcdef	71.67 ef	8.8 bcd	2.2 cdef	11.0 cde
WR-Min19	–	22.3 abcdef	112.3 bcd	7.9 fghij	2.0 fgh	18.5 bc

Means in a column followed by the same letters are not significantly different at 0.5% level of significance by LSD.

Appendix Table V. Grain characteristics of weedy rice variants of Central Mindanao and NSIC Rc 222.

Variants	Grain color	Pericarp color	Awn color
2016 DS collection in North Cotabato and Sultan Kudarat (1st trial, May–September 2016)			
NSIC Rc 222	Straw	Whitish	None
WR-Cot1	Straw	Light brown	None
WR-Cot2	Straw, purple tip	Brown	None
WR-Cot3	Straw	Light brown	Straw
WR- SuK1	Straw, purple tip	Brown	Yellow
WR- SuK2	Straw	Brown	Straw
WR- SuK3	Straw	Brown	Straw
WR- SuK4	Straw	Brown	None
WR- SuK5	Straw, purple tip	Light brown	None
2016 DS collection in North Cotabato and Sultan Kudarat (2nd trial, November 2016 – March 2017)			
NSIC Rc 222	Straw	Whitish	None
WR-Cot1	Straw	Light brown	None
WR-Cot2	Straw	Brown	None
WR-Cot3	Yellow	Brown	Straw
WR- SuK1	Straw, purple tip	Brown	Straw
WR- SuK2	Straw	Light brown	Straw
WR- SuK3	Straw	Brown	Straw
WR- SuK4	Straw	Brown	None
WR- SuK5	Straw, purple tip	Brown	None
2016 WS collection in North/South Cotabato and Maguindanao			
NSIC Rc 222	Straw	Whitish	None
WR-Cot2	Straw	Brown	None
WR-Cot3	Straw	Brown	Straw

Variants	Grain color	Pericarp color	Awn color
WR-SuK3	Straw	Brown	None
WR-SuK5	Straw	Brown	Straw
WR-Min1	Straw	Whitish	None
WR-Min2	Straw	Brown	Straw
WR-Min3	Straw	Brown	None
WR-Min4	Straw	Yellowish green	Straw
WR-Min6	Straw	Brown	Straw
WR-Min7	Whitish	Brown	Straw
WR-Min8	Straw	Brown	None
WR-Min9	Straw	Brown	None
WR-Min10	Straw	Whitish	None
WR-Min11	Straw	Black	None
WR-Min12	Straw	Black	None
WR-Min13	Straw	Light brown	Straw
WR-Min14	Yellow	Whitish	None
WR-Min15	Straw	Brown	Straw
WR-Min16	Yellow	Brown	Straw
WR-Min17	Straw	Brown	Straw
WR-Min19	Straw	Light brown	Straw
2017 DS collection in Maguindanao and South Cotabato			
NSIC Rc 222	Straw	Whitish	None
WR-Cot2	Straw	Brown	None
WR-Cot3	Straw	Brown	Straw
WR- SuK3	Straw	Brown	None
WR- SuK4	Straw	Brown	None
WR-SuK5	Straw	Brown	Straw
WR-Min1	Straw	Whitish	None
WR-Min4	Straw	Yellowish green	Straw
WR-Min5	Straw, purple tip	Brown	Straw
WR-Min6	Straw	Brown	Straw
WR-Min7	Whitish	Brown	Straw
WR-Min9	Straw	Brown	None
WR-Min10	Straw	Whitish	None
WR-Min13	Straw	Light brown	Straw
WR-Min15	Straw	Black	None
WR-Min16	Straw, purple tip	Whitish	Straw
WR-Min20	Straw, purple tip	Whitish	None
WR-Min21	Yellow	White	None
WR-Min22	Blackish brown	Light brown	None
WR-Min23	Straw, purple tip	Brown	Straw with purple pigmented tip
WR-Min24	Light brown	White	None
WR-Min25	Straw, purple tip	Whitish	Straw
WR-Min26	Yellow	Whitish	Yellow
WR-Min27	Straw	Whitish	Straw
WR-Min28	Yellow, purple tip	Light brown	Straw

Variants	Grain color	Pericarp color	Awn color
WR-Min29	Brown (tawny), purple tip	Whitish	Straw
WR-Min30	Yellow, purple tip	Brown	Yellow
WR-Min31	Straw	Whitish	None
WR-Min32	Straw	Whitish	None
WR-Min33	Light gold, purple tip	Light gold	Straw
WR-Min34	Brown (tawny)	Black	None
WR-Min35	Yellow	Brown	Yellow
2017 WS collection in Maguindanao and South Cotabato			
NSIC Rc 222	Straw	Whitish	None
WR-Cot2	Straw	Brown	None
WR-Cot3	Straw	Brown	Straw
WR- SuK3	Straw	Brown	None
WR- SuK4	Straw	Brown	None
WR-SuK5	Straw	Brown	Straw
WR-Min1	Straw	Whitish	None
WR-Min4	Straw	Yellowish green	Straw
WR-Min5	Straw, purple tip	Brown	Straw
WR-Min6	Straw	Brown	Straw
WR-Min7	Whitish	Brown	Straw
WR-Min9	Straw	Brown	None
WR-Min10	Straw	Whitish	None
WR-Min13	Straw	Light brown	Straw
WR-Min27	Straw	Whitish	Straw