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Comparative Analysis of Seed Morphological Traits in Egyptian Cultivated Rice and Weedy Rice

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Abstract

Weedy rice is a conspecific weed of cultivated rice that threatens the production of world rice. The present study aimed to differentiate Egyptian cultivated rice from weedy rice based on seed morphological traits. Seeds from eight cultivated rice varieties and twenty-five weedy rice plants were collected from different paddy fields. The morphological similarity between weedy and cultivated rice, coupled with weedy rice rapid growth, seed dormancy, and shattering, requires efforts to distinguish between them to effectively manage this problematic weed. The seed morphological traits were documented, such as hull, pericarp, and awn color; awn, palea, and lemma length, seed width and length; grain number; and grain weight. A cladistic analysis was performed using these traits. Notable variations in seed morphology were observed between cultivated and weedy rice. Cultivated rice seeds exhibit straw-colored hulls, white pericarps, and lack awns, whereas most weedy rice seeds have brown hulls, red-brown pericarps, and either short or long awns. The presence of awns and the high seed length-to-width ratio in most weedy rice can be considered adaptive mechanisms, facilitating seed dispersal. Cultivated rice generally has a higher grain weight than weedy rice, reflecting the better endosperm development, which results in greater grain mass. Understanding these morphological variations can used by farmers for early identification and removal to prevent seed dispersal and control weedy rice. The analysis of the cladogram, which focused on seed morphology, demonstrated a significant relationship between cultivated and weedy rice, suggesting a shared genetic basis and possibly originating from a common ancestry.

Keywords: Awnless; cladogram analysis; morphological traits; pericarps; weedy rice.

Introduction

Weedy rice (*Oryza spp*.), commonly referred to as red rice, is a member of the Poaceae family and the Oryzeae tribe. Weedy rice has appeared as one of the major global threats to rice production in direct-seeded rice fields (Ziska et al., 2015). Weedy rice is an annual grass that resembles cultivated rice (*Oryza sativa*). Weedy rice has the same growth pattern as cultivated rice, such as the vegetative phase, reproductive phase, and ripening phase (Abd Hamid et al., 2007). Weedy rice is classified as the same species as cultivated rice (*Oryza sativa*). Two scientific names are commonly used for weedy rice includes *Oryza sativa L.* and *Oryza sativa f. spontanea*. Genomic data have shown that *O. sativa L*. refers to weedy rice populations derived from cultivated *O.sativa*, while O. *sativa f. spontanea* refers only to specifically weedy types that derived from *O. rufipogon*. Neither of these names applies to African weedy rice, which is descended from African wild rice or *O. glaberrima* lineage. Therefore, when the lineage of the weedy population is unknown, the name for the weedy rice to use is the generalized name *Oryza spp* (Burgos et al., 2021). The studied weedy rice couldn't be wild rice because of the absence of wild rice in Egypt. Further genetic studies required to illustrate the origin of Egyptian weedy rice. Easy grain shattering, a lengthy seed dormancy period, and higher nitrogen efficiency for biomass production are the traits that differentiate weedy rice from cultivated rice (Rathore et al., 2017; Ghosh et al., 2017).

Compared to cultivated rice, weedy rice also has several of unfavorable characteristics, such as the ability to germinate more quickly and persist in the soil bed for up to ten years (Ferrero, 2003). In addition to some of the unfavorable traits of weedy rice, such as long shoots, strong tillering capacity, weak culms, pale leaf color, and red pericarp (Ziska et al., 2015; Tseng, 2017).

Seeds are vital reproductive units in higher plants, and the characteristics related to their germination and dispersal play a key role in determining plant performance, distribution, population establishment, and dynamics, ultimately guiding their evolutionary path. (Chen and Giladi, 2020; Huang et al., 2015; Razzaque et al., 2023).

Seed morphology is a key trait in plant biology. During the seedling stage, weedy plants are often difficult to differentiate from crops (Hoagland and Paul, 1978). However, after tillering, weeds can be identified based on several distinct morphological characteristics compared to rice varieties. These include a greater number of tillers that are longer and more slender, leaves that are often hispid on both surfaces, increased plant height, pigmentation in various plant parts, and a tendency for easy seed dispersal once seeds form in the panicle (Diarra et al., 1985; Coppo and Sarasso, 1990; Kwon et al., 1992; Suh et al., 1997).

The seeds of most weed biotypes of *Oryza sativa* (Asian Rice) and *Oryza glaberrima* (African Rice) possess a pigmented pericarp, which is attributed to varying levels of anthocyanins, catechins, and catecholic tannins (Baldi, 1971). Weedy rice directly impacts farmers' income by reducing crop yields and diminishing the market value of the harvested rice (Olofsdotter et al., 2000).

Therefore, the main objective of the present study is to examine the morphological variation in seeds between weedy rice and cultivated rice to explore this weedy rice. This understanding may serve as a foundational step towards managing and controlling the presence of this destructive weed, thereby preserving the culinary and quality of Egyptian rice cultivars. The data obtained from this investigation could be valuable in clarifying the relationship between weedy rice and cultivated rice.

Materials and methods

Field study

This investigation was based on field surveys and greenhouse farming. The selected seven sites were indicated in Table 1. The seeds of Twenty-five samples of weedy rice were collected and dried well, then stored for the next growing season. From site I, WR1, WR2, WR4, WR5, and WR6 were collected. From site II, WR 8 and WR 10 were gathered. From site III, WR 11, WR 12, WR 13, WR 15, and WR 16 were collected. From site IV, WR 17 and WR 19 were gathered. From site V, WR 20, WR 21, WR 22, and WR 23 were gathered. From site VI, WR 24, WR 25, WR 26, WR 27, and WR 28 were gathered. From site VII, WR 29 and WR 30 were collected. Cultivated rice seeds such as Giza 178, Giza 179, Sakha 101, Sakha 102, Sakha 103, Sakha 104, and Egyptian Hybrid 1 were provided by the Agricultural Research Center, Egypt. IR64 seeds were kindly supplied by International Rice Research Institute (IRRI), Manila, Philippines. The stored seeds of the cultivated and weedy rice were germinated in 15 cm x 20 cm trays containing perlite under field conditions. Trays were irrigated with a full-strength Ruakura nutrient solution (Smith et al., 1983). When the rice samples were 120 days old, morphological seed traits were measured.

Table 1: Geographical sites of the weedy rice

Sites Numbers	Sites	Longitude (E)	Latitude (N)
I	Ezbet Zakareya Zaher RD	31.401028	31.662861
II	Al-Hawashim village	31.404250	31.662194
III	Nagaa Al Jabaylah	31.403611	31.646500
IV	Kafr Al Batekh	31.394639	31.732917
V	Ezbet Ibrahim Hammad	31.393778	31.606333
VI	Ezbet Om El Reda	31.401833	31.621139
VII	International coastal road	31.425167	31.634972

Determination of seed morphological traits

The seed morphological traits of the rice cultivars and red rice were recorded according to (IRIR, 2007). The selected seed morphological traits with information on the methods for each attribute that was measured were shown in Table 2. The recorded morphological traits were hull color, pericarp (kernel) color, awn presence, awn length (cm), awn color, palea and lemma length (cm), seed width (cm), seed length (cm), seed length to width ratio, number of grains per panicle, and grain weight (g).

Table 2. Seed morphological traits of the cultivated and weedy Egyptian rice, containing details on how each attribute is measured (IRIR, 2007).

Seed traits	Description
Seed length (cm)	Distance from base to tip of the grain
Seed width (cm)	Maximum width perpendicular to the length
Length to width ratio	The percentage of seed length to seed width
Awn length (cm)	Length of the awn
Awn color	Pigmentation of the awn
grain weight	Mass of a grain
pericarp color	Pigmentation of pericarp
Hull color	Pigmentation of the hull
Grains number per panicle	Counting the number of grains per panicle

Determination of grain dry weight (g)

The seeds of the rice cultivars and weedy rice were collected and stored in separate seed bags made of paper, dried in air, and then the dry weights of each seed were recorded individually using a precision analytical balance for all collected rice samples.

2.4 Cladistic analysis based on seed morphological traits

The morphological characteristics of the seeds were detected for cultivated rice and weedy rice, and the data were examined using Past Software V 3.23 (folk.uio.no/ohammer/past).

2.5 Statistical analysis

All measurements were replicated as stated in each section. The morphological characteristics of the seeds for the cultivated and weedy rice were recorded, and the data were analyzed using Past Software V 3.23 to generate cladograms. A one-way ANOVA was performed using SigmaPlot v11.0 to assess differences in grain weight. Significance was defined at $P \leq 0.05$.

Results

Morphological traits of the seed for cultivated and weedy rice

Significant variation in seed morphology is observed between the cultivated rice and weedy rice, as illustrated in (Table 3) (Fig. 1). The hull color of all examined cultivated rice as well as WR 6, WR 10, WR 16, WR 20, WR 21, WR 23, and WR 30 is straw. The pericarp color is white in all studied cultivated rice and in WR 2, WR 6, WR 10, WR 11, WR 12, WR 13, WR 15, WR 17, WR 22, WR 23, WR 27, WR 29, and WR 30. In contrast it is light red-brown in WR 4, WR 5, WR 8, WR 20, WR 25, WR 26, and WR 28, and red-brown in WR 1, WR 16, WR 19, WR 21, and WR 24. All examined cultivated rice along with WR 16, WR 19, WR 20, WR 24, WR 25, WR 26, and WR 28 are awnless; whereas, the remaining weedy rice samples possess awns. The awn color among the studied weedy rice population varies with WR 1, WR 2, WR 4, WR 6, WR 11, WR 12, WR 13, WR 16, WR 17, and WR 23 exhibiting white awns; WR 5, WR 8, WR 10, WR 15, WR 21, WR 22, and WR 27 displaying straw-colored awns; and WR 29 and WR 30 having red awns. Awn length also varies among the weedy rice samples, specifically WR 1, WR 2, WR 5, WR 8, WR 13, WR 21, WR 23, WR 17, WR 27, and WR 29. Most weedy rice plants exceed cultivated rice in seed length-to-width ratio with the exception of IR64. Additionally, most weedy rice plants surpass cultivated rice in the number of grains per panicle, except for G 178.

Table 3. Seed morphological characters and character state of the studied cultivated and weedy rice.

Seed traits		Rice samples																																
characters	Character state	G 178	G 179	S 101	S 102	S 103	S 104	IR64	HYR	WR1	WR2	WR4	WR5	WR6	WR8	WR10	WR11	WR12	WR13	WR15	WR16	WR17	WR19	WR 20	WR 21	WR 22	WR 23	WR 24	WR 25	WR 26	WR 27	WR 28	WR 29	WR 30
1. hull color	1.straw 2.brown	1	1	1	1	1	1	1	1	2	2	2	1	1	2	1	2	2	2	2	1	2	2	1	1	2	1	2	2	2	2	2	2	1
2. pericarp color	1.white 2.light red brown 3.red brown	1	1	1	1	1	1	1	1	3	1	2	2	1	2	1	1	1	1	1	3	1	3	2	3	1	1	3	2	2	1	2	1	1
3. palea/lemma length(cm)	-	0.8	0.8	0.9	0.9	0.8	0.9	1	1	0.7-0.8	0.6	0.8	0.7-0.8	0.8	0.8	0.9-1	0.8	1	1	0.9	0.7	1	0.7	0.7-0.9	0.8-0.9	0.8	0.7	0.7	0.8	0.9	0.7	1	0.9	0.7
4. seed length (cm)	-	0.7	0.7	0.8	0.8	0.7	0.8	0.9	0.8	0.6	0.5	0.7	0.6	0.7	0.7	0.8	0.7	0.9	0.9	0.8	0.6	0.9	0.6	0.7	0.7	0.7	0.6	0.6	0.7	0.8	0.6	0.6	0.8	0.9
5. seed width (cm)	-	0.3	0.3	0.3	0.4	0.3	0.4	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3
6. seed length/width%	-	2.1	2.3	2.6	2	2.3	2	4.5	2.6	2	1.6	3.5	2	3.5	2.3	2.4	2.3	3	3	4	3	3	2	2.3	2.4	3.5	2	2	1.75	2.7	2	3	2.6	2
7. Awn presence)	1.present 2.abscent	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	2	2	2	1	2	1	1
8. Awn length(cm)	1.short 2.long 3.awnless	3	3	3	3	3	3	3	3	1	1	2	1	2	1	2	2	2	1	2	3	2	3	3	1	2	1	3	3	3	1	3	1	2
9. awn color	1.white 2.straw 3.red 4.awnless	4	4	4	4	4	4	4	4	1	1	1	2	1	2	2	1	1	1	2	1	1	4	4	2	2	1	4	4	4	2	4	3	3
10. no of grains/panicle	-	120-124	29-35	30-33	41-47	79-83	75-80	53-58	53-55	32-37	11-15	34-38	73-77	39	49-55	53-59	40-43	84-90	65-71	135-141	21-29	66	102-110	43-45	98-104	38-40	60-61	85-89	79-85	19-23	66-70	111-114	45-51	43-47
11. grain weight (g)	-	0.02	0.024	0.02	0.024	0.03	0.03	0.024	0.03	0.021	0.03	0.02	0.018	0.023	0.024	0.013	0.023	0.018	0.019	0.02	0.017	0.017	0.022	0.02	0.02	0.023	0.019	0.02	0.018	0.02	0.019	0.02	0.03	0.015

Fig.1 Seed morphological traits of Egyptian cultivated and weedy rice.

Determination of grain weight of the cultivated and weedy rice

Grain weight was observed to be significantly higher in S 104, followed by HYR and WR 29, in comparison to other rice samples (Fig. 2). The maximum grain weight among cultivated rice was recorded in G 104, whereas the minimum grain weight was observed in G 178. In the case of weedy rice, WR 29 exhibited the highest grain weight, while WR 10 had the lowest grain weight. Generally, most cultivated rice tends to exceed in terms of grain weight.

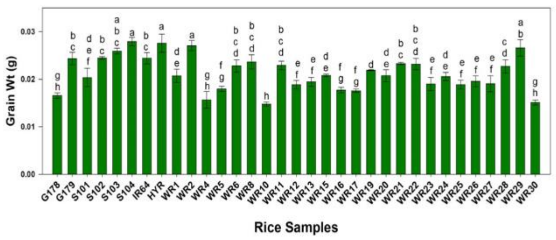

Fig. 2 Changes of grain weight of the cultivated and weedy rice. Data are means ± SE. Bars labeled with different letters are significantly different at P≤ 0.05.

Cladistics analysis of the cultivated rice and weedy rice according to seed morphological traits

Cladistic analysis categorized the 33 samples into three principal groups (GI–GIII) (Fig. 3), with distinct subgroups comprised both cultivated and weedy samples. The first group

(GI) was further divided into two subgroups (SGI-SGII); the first subgroup included WR 15, while the second subgroup comprised WR 19, WR 21, WR 28, and G 178. The second group (GII) was subdivided into four subgroups (SGI-SGIV); the first subgroup contained WR 8, WR 29, WR 10, IR64, and HYR; the second subgroup comprised WR 13, WR 27, WR 17, and WR 23; the third subgroup included WR 5, WR 25, S 103, and S 104; and the fourth subgroup involved WR 12 and WR 24. The third group (GIII) was subdivided into three subgroups (SGI-SGIII); the first subgroup comprised WR 6, WR 22, WR 11, WR 20, WR 30, and S 102; the second subgroup included WR 4, WR 1, G 179, and S 101; and the third subgroup comprised WR 16, WR 26, and WR 2.

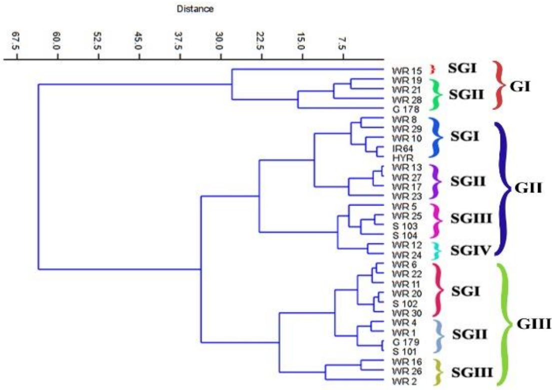

Fig. 3. Cladograms illustrate the relationship between cultivated rice and weedy rice based on seed morphological traits.

Discussion

Egyptian weedy rice is an invasive paddy weed that infests rice paddies, leading to significant rice yield losses (Abdallah et al. 2025). Distinguishing cultivated rice from weedy rice is only feasible after the formation of panicles and seeds. Seed characteristics are believed to undergo strong environmental selection due to their substantial implications for fitness (Hierro et al., 2009; Chen and Giladi, 2020). Notable differences in seed morphological characteristics between the cultivated and weedy rice have been observed (Fig. 1). However, these seed traits have not been extensively studies in biogeographical research. Cultivated rice exhibits straw-colored hulls and white seed pericarps; whereas, more than half of the collected weedy rice samples exhibit brown hulls and reddish-brown pericarps, traits associated with genes like Rc (Debeaujon et al., 2000). These pigments in weedy rice seeds may specify advantages such as protection from predators and environmental stresses; although they also reduce the quality of Egyptian milled rice.

The seed length-to-width ratio is generally higher in most weedy rice plants compared to cultivated rice, with the exception of IR64. Additionally, the presence of awns in most weedy rice indicates an adaptation for dispersal, either by attachment to animals or wind transport. The variation in the awn color and length among all the studied weedy rice populations reflects differing degrees of environmental adaptation and evolutionary advancement. Most weedy rice plants surpass cultivated rice in grain quantity per panicle, except for G 178, which may enhance their survival and proliferation under agricultural and natural selection pressures, thereby increasing their evolutionary fitness. This is indicative of their resilience in agroecosystems, fitness advantages, and reproductive strategy. The grain weight of most cultivated rice is higher than that of weedy rice (Fig. 2). Grain filling influences both grain weight and quality (Zhou et al., 2013), suggesting that grain filling is more efficient in cultivated rice than in weedy rice. This efficiency is attributed to the more complete endosperm development in cultivated rice than weedy rice resulting in higher grain mass. The lower grain weights of weedy rice may reflect trade-offs between seed quantity and investment per seed. The variations in seed traits of weedy rice confer an advantage over the crop, enabling it to withstand various abiotic stresses and adapt to diverse cropping techniques and changing environmental conditions (Fogliatto et al., 2012). Seed morphological traits are instrumental in the identification and classification of plants and weeds (Noda et al., 1985). Seed morphology has been shown to provide valuable characters for taxonomic relationships of plant families (Barthlott, 1981; Barthlott, 1984; Shetler, 1986). Understanding the variations in seed morphology between cultivated and weedy rice can aid in the management of weedy rice. These visible variations can be used by farmers for early identification and removal before complete heading to prevent seed dispersal. Additionally, they can guide the development of **selective herbicides** that allow control of targeted weedy rice.

According to seed morphology, cladogram analysis reveals a close relationship between cultivated rice and weedy rice (Fig. 3). Specifically, WR 15, WR 19, WR 21, and WR 28 are grouped with G 178, while WR 8, WR 29, and WR 10 are categorized in the same subgroup as IR64 and HYR. Additionally, WR 5 and WR 25 are clustered with S 103 and S 104; WR 6, WR 22, WR 11, WR 20, and WR 30 are grouped with S 102. Furthermore, WR 4 and WR 1 are clustered with G 179 and S 101, indicating the seed morphological similarities. These similarities suggest a common genetic background and a potentially shared origin.
The accurate identification and differentiation of weedy rice from cultivated rice cannot depend on seed morphology alone due to the high seed morphological similarities between cultivated rice and some weedy rice. Therefore, it should be combined with physiological traits and genetic analysis.

Conclusion

This study offers a comprehensive morphological assessment of Egyptian cultivated and weedy rice seeds, emphasizing significant differences that are useful for identification and management. Cladogram analysis supports the hypothesis of shared ancestry and evolutionary convergence. These findings are foundational for developing targeted weed control strategies and preserving rice grain quality in Egypt.

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الملخص العربي

عنوان البحث: التحليل المقارن للصفات الشكلية لبذور الأرز المصري المزروع والأرز العشبي

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[١] قسم النبات والميكروبيولوجي-كلية العلوم –جامعة دمياط – دمياط - مصر

الأرز العشبي هو حشيشة من نفس نوع الأرز المزروع، ويُشكّل تهديدًا لإنتاج الأرز العالمي. هدفت الدراسة الحالية إلى التمييز بين الأرز المصري المزروع والأرز العشبي استنادًا إلى الصفات الشكلية للبذور. تم جمع بذور من ثمانية أصناف مزروعة من الأرز وخمسة وعشرين نباتًا من الأرز العشبي من حقول أرز مختلفة. إن التشابه المورفولوجي بين الأرز العشبي والمزروع، إلى جانب النمو السريع للأرز العشبي ووجود طور الكمون للبذور وسهولة تساقطها، يستدعي بذل الجهود للتمييز بينهما من أجل الإدارة الفعالة لهذه الحشيشة المزعجة.

تم توثيق الصفات الشكلية للبذور مثل لون الحبة، والطبقة الخارجية (الغلاف)، ولون السفا (الزوائد الشبيهة بالشعيرات)؛ وطول السفا، وطول وعرض الغمد والقنابة؛ وعرض وطول البذرة؛ وعدد الحبوب ووزن الحبوب. وأُجري تحليل تفرعي (Cladistic analysis) باستخدام هذه الصفات. وقد لوحظت اختلافات واضحة في شكل البذور بين الأرز المزروع والعشبي. تظهر بذور الأرز المزروع غلافا بلون قشي وحبة لونها أبيض، وتفتقر إلى سفا. في حين أن معظم بذور الأرز العشبي تمتلك اغلفة بنية اللون، وحبة لونها بني محمر، مع وجود سفا قصيرة أو طويلة . يمكن اعتبار أن وجود السفا والنسبة العالية لطول البذرة إلى عرضها في معظم الأرز العشبي آليات تكيفية تساعد في انتشار البذور. عمومًا، يتميز الأرز المزروع بوزن حبة أعلى من الأرز العشبي، مما يعكس تطور الإندوسبيرم (السويداء) بشكل أفضل وبالتالي زيادة كتلة الحبة. إن فهم هذه الاختلافات الشكلية يمكن أن يساعد المزارعين في التعرف المبكر على الأرز العشبي وإزالته لمنع انتشار بذوره والسيطرة عليه..