DOI: 10.31276/VJSTE.65(4).77-83

Assessing the risk and morphological characteristics of weedy rice outbreak in Thap Muoi district, Dong Thap province, Vietnam

Cong Vinh Kieu, Ho Le Thi*

Department of Plant Protection, College of Agriculture, Can Tho University, Area II, 3/2 Street, Xuan Khanh Ward, Ninh Kieu District, Can Tho City, Vietnam

Received 11 September 2023; revised 27 October 2023; accepted 7 November 2023

Abstract:

The Thap Muoi district in Dong Thap province, Vietnam, is renowned as the largest rice producer, cultivating 112,762 hectares and specialising in three rice crops per year, with some areas achieving 3.5 annual crops. However, changing farming practices, low-quality rice seeds, and mechanisation have led to the emergence and spread of weedy rice (*Oryza* spp.) in Thap Muoi and the broader Mekong delta. This comprehensive assessment of weedy rice outbreak risks in Thap Muoi provides a vital foundation for effective management strategies to prevent its spread in the Mekong delta. Sixty questionnaires were collected from rice-farming households. Approximately 80% of farmers reported the appearance of weedy rice approximately five years ago. Alarmingly, 95% of surveyed farmers (57 individuals) reported weedy rice infestations, with 40% of them encountering infection levels ranging from 11 to 20 plants/m^2. To distinguish weedy rice from cultivated varieties, seven distinct types were identified based on various morphological characteristics, including growth time, leaf blade structure, plant height, leaf/stem colour and shape, grain beard/tail, seed/husk colour, grain length, ripening time, and seed dispersal potential. However, all seven weedy rice varieties exhibited short growth cycles and the capacity to produce seeds, posing significant challenges to rice production management in Thap Muoi. This research underscores the critical importance of assessing weedy rice outbreak risks in Thap Muoi and understanding its morphology and prevalence. This understanding is essential for developing effective preventive measures to mitigate the threat of weedy rice outbreaks across the entire Mekong delta in Vietnam.

Keywords: **assessment, morphological characteristics, rice pests, weedy rice.**

Classification numbers: **3.1, 3.4**

1. Introduction

Weedy rice (*Oryza sativa* f. *spontanea*) is a troublesome weed species that adversely affects rice production globally. With its widespread distribution and adaptability, weedy rice poses a significant threat to agricultural systems in various rice-growing regions. Weedy rice has been reported in several countries across different continents, with Asia being one of the most affected regions. Countries such as China, India, Bangladesh, Indonesia, the Philippines, and Thailand have faced persistent challenges from weedy rice infestations [1-3]. In Africa, weedy rice has been documented in countries like Nigeria and Madagascar, where it poses a considerable threat to rice production [4, 5]. Furthermore, the Americas and Oceania have also experienced weedy rice outbreaks, with the United States, Brazil, and Australia being among the affected countries [6-8]. The genetic diversity of weedy rice has been extensively studied, revealing its complex origin resulting from hybridisation events with cultivated rice and other wild relatives [9]. This genetic diversity contributes to its adaptability to various ecological and environmental conditions. Weedy rice exhibits traits such as seed shattering, dormancy, and competitive ability, which enhance its survival and spread in agricultural fields [10]. The impact of weedy rice on rice production is significant, causing yield losses ranging from 20 to over 80%, depending on the severity of infestation and management practices [11]. Additionally, weedy rice can hybridise with cultivated rice varieties, leading to the transfer of undesirable traits into the cultivated gene pool [12]. Researchers worldwide have been actively investigating effective management strategies to control weedy rice outbreaks. Integrated weed management approaches that combine cultural, mechanical, and chemical control methods have shown promising results [13]. However, the development of herbicide resistance in weedy rice populations has emerged as a concerning issue, emphasising the importance of sustainable weed control practices [14].

In the Mekong delta region of Vietnam, rice (*Oryza sativa*) constitutes the predominant crop, covering an extensive cultivation area of 1.418,2 thousand hectares,

*Corresponding author: Email: hlthi@ctu.edu.vn

which represents 79,28% of the total rice cultivation area in the Summer-Autumn crop of 2023 (General Statistics Office, 2023). The escalating encroachment and detrimental effects caused by weedy rice are intricately linked to the continuous adoption of straight-line rice cultivation in recent years, with over 90% of the rice cultivation area in the Mekong delta region employing this method. Thap Muoi district, situated in Dong Thap province within the Mekong delta, is an area where three rice crops are cultivated annually, with certain locations even experiencing three and a half rice crops per year. The sustained and expanded implementation of straight-line rice cultivation, combined with specific agricultural practices and intensified cropping, has led to the widespread and vigorous proliferation of weedy rice. Consequently, this situation exerts adverse effects on the quality, productivity, and income of local farmers, as well as on the overall rice export of Vietnam.

The primary objective of this research is to address the challenges associated with weedy rice in straight-line rice fields in Thap Muoi district, Dong Thap province. To achieve this, the study employed diagnostic surveys to ascertain and document the cultural practices of farmers engaged in rice cultivation. Furthermore, it involved morphological observations and agronomic characteristics of the prevalent weedy rice within the rice fields of Thap Muoi district, Dong Thap province, Vietnam. Additionally, the research aims to assess the production constraints, evaluate the current extent of weed invasion, determine the magnitude of damage inflicted, and assess the potential risk of weedy rice evolving into pests within the rice fields of Thap Muoi district. In particular, the study examined the farmers' familiarity with weedy rice, with a focus on its distribution, occurrence, and impact within the area. Moreover, it identifies the morphological and agronomic traits that aid in the identification of weedy rice species present in the fields. Based on these findings, appropriate and effective weed management strategies can be proposed and recommended to the farmers in the region.

2. Materials and methods

Surveys were conducted in Thap Muoi district, Dong Thap province during the Summer-Autumn rice crop of 2022. A random selection of 60 households of farmers was made, with each household located at least 200 m apart and having a cultivated area of 1 ha or more.

The primary data collection method involved structured interviews, where all participating farmers were asked the same set of questions. Information was gathered through direct interviews using pre-prepared survey questionnaires. The collected data covered the following main aspects: i) General information about the farmers, ii) Farmers' knowledge and understanding of weedy rice, iii) Extent of weedy rice infestation in the rice fields (infection rate), iv) Yield losses caused by weedy rice, v) Farmers' experiences and weed control measures applied during the Summer-Autumn rice crop of 2022.

Weedy rice samples were collected in Thap Muoi district during the Summer-Autumn rice crop of 2022. Seven weedy rice samples were selected for this study and designated as WR1, WR2, WR3, WR4, WR5, WR6, and WR7. The commonly cultivated rice variety in Thap Muoi district is OM18.

Seeds of the seven weedy rice lines were soaked and placed on Petri dishes for germination in a controlled temperature incubator (Daichi warm germination cabinet). After approximately 7 days, healthy seedlings were transplanted into experimental plots with an area of 2,2x3 m and spaced 20-25 cm apart. The experiment was arranged sequentially (10 seedlings per line) without replication. The cultivation process for the weedy rice lines was similar to that of the OM18 rice variety, with a fertiliser formula of 80:60:30 kg NPK/ha.

The growth and development of the weedy rice lines and the OM18 rice variety were observed and recorded from the seedling stage to maturity using the Standard Evaluation System for Rice of the International Rice Research Institute [15, 16]. Morphological and agronomic characteristics were visually observed, measured, and recorded between 60 to 80 days after transplanting (DAT). Fifteen morphological traits were assessed, including plant height, growth duration, stem angle, tiller number per plant, panicle number per plant, flag leaf length, panicle type, panicle length, seed shattering trait, hull colour, grain colour, grain length, grain width, awn length, and 1000-grain weight. The data obtained from the weedy rice lines were averaged and comparatively analysed with the OM18 rice variety.

3. Results

Results from the investigation involving 60 farming households revealed a total surveyed area of 161,50 ha, with an average of 2,69 ha per household. The educational attainment of rice farmers was relatively low, with 61,7% (37 households) having received only primary education. The survey indicated that 100% of the farmers were familiar with weedy rice and perceived its presence in their fields for over a decade. However, 80% of them reported weedy rice emergence around 5 years ago, while 16,7% mentioned its presence for more than 10 years. Moreover, 3,3% of the farmers believed that weedy rice appeared between 5 to 10 years ago (Fig. 1). These findings align with historical records indicating the initial occurrence of weedy rice in Vietnam in 1994 [17].

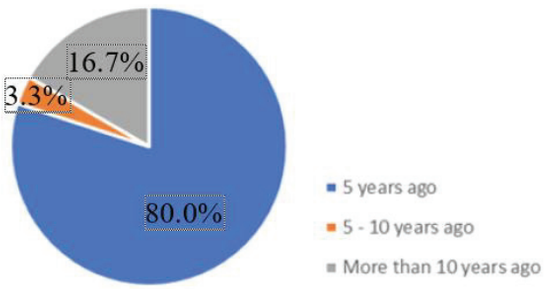

Fig. 1. Farmers' response (%) to the appearance of weedy rice in Thap Muoi district.

Regarding the morphological traits of weedy rice, farmers observed a higher prevalence of weedy rice in transplanted and broadcast-sown rice fields compared to direct-seeded ones. They noted that weedy rice seeds are easily shed and recognised it as a wild grass species in rice fields. Some weedy rice varieties lack awns and display high germination rates upon soil contact. Farmers could easily identify weedy rice seeds due to their characteristic colour, which persists even after milling. However, when queried about specific characteristics related to seed dormancy and persistence, such as the shorter stature of weedy rice compared to cultivated rice and the longevity of weedy rice seeds in the soil (over 1 year), 33,3 to 51,7% of farmers were not aware of these traits (Table 1). This lack of knowledge might lead farmers to misidentify weedy rice outside rice fields.

Table 1. Survey results of some characteristics of weedy rice in Thap Muoi district, Dong Thap province.

No.	Attributes of weedy rice	Number of responses and percentage (%) of surveys			
		Known	*Percentage*	*Unknown*	*Percentage*
1	Weedy rice is commonly found in fallow rice fields rather than in planted or cultivated fields	57	95,0%	3	5,0%
2	Weedy rice seeds exhibit a state of dormancy	29	48,3%	31	51,7%
3	Weedy rice seeds are prone to shattering	60	100,0%	0	0,0%
4	Weedy rice plants have shorter height compared to cultivated rice	39	65,0%	21	35,0%
5	Weedy rice is a type of weed found in rice fields	58	96,7%	2	3,3%
6	Some types of weedy rice do not have awns (beard-like structures on seeds)	60	100,0%	0	0,0%
7	Weedy rice seeds readily germinate and sprout when they fall to the ground	59	98,3%	1	1,7%
8	Weedy rice seeds have distinct coloration	60	100,0%	0	0,0%
9	Even seeds after milling, weedy rice retain their colour	58	96,7%	2	3,3%
10	Weedy rice can be consumed as food	55	91,7%	5	8,3%
11	Weedy rice can be cultivated as normal rice	40	66,7%	20	33,3%
12	The lifespan of weedy rice in the soil can exceed one year	33	55,0%	27	45,0%

The survey findings demonstrated varying degrees of weedy rice infestation, ranging from mild (2-5 plants/m²) to severe (11-20 plants/m²), with 95% of the fields being affected. Notably, 40% of the fields exhibited an infestation level of 11-20 plants/m² (Fig. 2). Only 3,3% of farmers reported the presence of a single weedy rice species in their rice fields, while 58 farmers acknowledged the coexistence of two or more weedy rice species in their fields (Fig. 3).

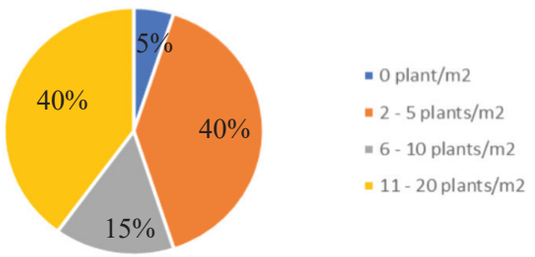

Fig. 2. Density of weedy rice infection (%) in Thap Muoi district.

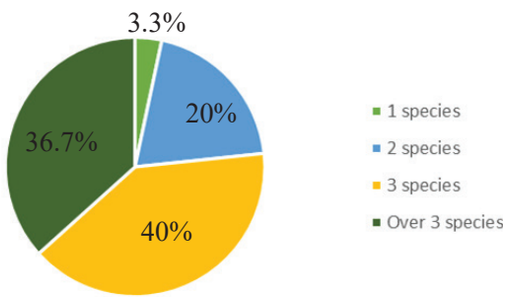

Fig. 3. Farmers' observation (%) of the number of weedy rice species appearing in rice fields in Thap Muoi district.

The survey showed that 55 households used certified rice varieties for cultivation, accounting for 91,7%, while 5 households reused planted rice to make seeds for the next crop (8,3%). This also increases the possibility of spreading weedy rice from the previous crop to the next crop. There are 4 main rice varieties grown in Thap Muoi including OM5451, OM18, OM9582, and IR4625. Specifically, OM18 (48,3%) rice variety is most commonly grown in Thap Muoi district (Fig. 4).

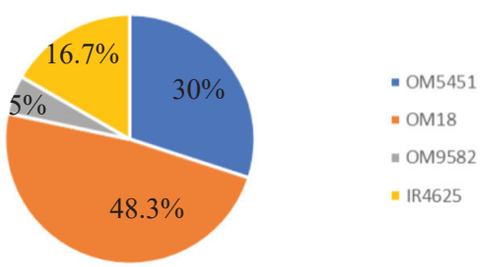

Fig. 4. Observation of rice varieties (%) grown in Thap Muoi district.

Regarding agricultural practices, 100% of farmers practiced triple cropping of rice per year and synchronised

their rice planting schedule based on local water availability. The interval between harvest and subsequent planting ranged from 7 to 10 days. With regard to crop residue management and weedy rice at the beginning of the planting season, only 24% of farmers burned straw before ploughing the field. The majority of farmers incorporated straw into the soil immediately after harvest and then flooded the fields for 5 to 7 days. This practice might bury weedy rice seeds from the previous crop, resulting in an increased weed seed bank in the soil. After 1 to 2 days, they allow the land to emerge, during which buried weeds start to germinate. Land shaft and grooving follow, with proper channels facilitating water management and herbicide application. Sowing is done after these preparations, enabling farmers to manage weed growth from the start of the crop cycle. However, weedy rice seeds can last in the soil and emerge in the next rice season, affecting the rice yield. Notably, 100% of farmers did not clean their combined harvesters before rice harvest, potentially contributing to the spread of weedy rice from one field to another.

In terms of weed management, the primary herbicides used by the majority of farmers (91,7%) were pretilachlor and butachlor, applied at 5 different timings. Most farmers (95,0%) applied the herbicides between 0 to 4 days after planting (DAP), using a single application. Only 8,3% of farmers applied pretilachlor twice, one day before planting and two days after planting (Table 2). Considering the close relation of weedy rice and cultivated rice, both belonging to the same species [18], early pre-emergence herbicide application on rice to manage weedy rice is crucial for effective weed control.

Table 2. Chemical methods used by farmers to manage weedy rice in Thap Muoi district, Dong Thap province.

No	Herbicide active ingredient	Treatment	No. of farmers applying	Farmers applying (%)
1	Pretilachlor 300 g/l Fenclorim 100 g/l	Spray 1-1.2 l/ha after 2 DAP, irrigate field 5 DAP.	23	38,3
2	Pretilachlor 300 g/l Fenclorim 100 g/l	Spray 1-1.2 l/ha 1DBP; repeat 2 DAP and irrigate field 5 DAP.	5	8,3
3	Pretilachlor 360 g/l Fenclorim 150 g/l	Spray 1-1.2 l/ha 0-4 DAP. Irrigate field after 3 to 5 days	8	13,3
4	Butachlor 620 g/l	Spray 1,2 l/ha 1-4 DAP, then irrigate field 5-7 DAP	20	33,3
5	Butachlor 600 g/l	Spray 1 l/ha 0 to 3 DAP. Then add irrigate field 5-7 DAP.	4	6,7

The survey revealed an average yield of 7,06 t/ha from the 60 households during the Summer-Autumn crop of 2022, which was 0,24 t lower than the average yield in the previous Summer-Autumn crop of 2021 in Thap Muoi district (7.30 t/ha) (Department of Agriculture and Rural Development of Dong Thap province, 2021). These findings suggest that the decrease in yield during the Summer-Autumn crop of 2022 could be influenced by various factors, including weather conditions, pests, and weeds, including weedy rice.

General Morphological Characteristics of Weedy Rice Strains:

- Growth duration (GD): All 7 weedy rice strains exhibited a significantly shorter GD compared to the cultivated rice OM18 (103 days). The GD ranged from 84 to 94 days, with an average of approximately 89 days after sowing (DAS). This particular trait observed in weedy rice strains within Thap Muoi district is consistent with the findings reported in the study conducted by [19].

- Plant height: The plant height of the weedy rice strains demonstrated considerable variability, with strain WR5 attaining the tallest height at 150,0 cm and strain WR6 being the shortest at 104.4 cm. The average plant height was 128,4 cm, which exceeded the average height of the OM18 rice variety (108 cm). Most weedy rice strains exhibited taller average plant heights than the cultivated OM18 rice, except for strain WR6, which displayed a lower average height. A study by A.D. Morat, et al. (2018) [20] also corroborated

Table 3. Comparison of agronomic characteristics between weedy rice strains and commonly cultivated rice variety OM18.

Description of basic characteristic	WR1	WR2	WR3	WR4	WR5	WR6	WR7	OM18
1. GD (days)	94	89	84	89	91	87	89	103
2. Plant height (cm)	126.8±3.2	148.7±3.0	141.0±2.8	114.1±2.9	150±2.6	104.4±2.9	114.1±2.9	108.4±2.6
3. Stem angle	Medium	Erect	Erect	Erect	Medium	Medium	Erect	Erect
4. Tillers per plant	16±2	20±3	18±1	15±3	13±2	23±3	21±3	19±2
5. Panicles per plant	13±1	9±1	12±1	10±2	12±2	18±1	16±2	13±2
6. Flag leaf length (cm)	44.3±2.32	42.1±2.85	34.0±1.42	35.0±1.49	33.9±1.58	41.0±1.92	35.0±1.49	32.3±3.5
7. Chlorophyll content (SPAD)	38.0±1.07	33.7±6.93	36.5±2.24	36.5±2.67	38.1±1.82	38.8±2.15	40.0±2.12	39.2±2.43
8. Panicle type	Compact	Compact	Compact	Compact	Compact	Medium	Compact	Compact
9. Panicle length (cm)	27.2±1.2	21.8±0.6	26.5±1.9	21.0±1	31.3±2.0	22.9±0.7	21.0±1	22.8±0.4
10. Seed shattering characteristics	Difficult	Quite easy	Easy	Easy	Easy	Easy	Easy	Difficult
11. Hull colour	Bright yellow	Bright yellow	Black	Bright yellow	Brown	Black	Straw yellow	Straw yellow
12. Grain colour	Red	Red	Red	Red	Red	Red	Red	White
13. Grain length (mm)	9.20	8.16	7.72	10.20	8.40	7.84	8.54	9.80
14. Grain width (mm)	2.10	2.49	2.76	2.36	2.16	2.20	2.56	2,04
15. Awn length (mm)	0	0	0	2-12	9-27	12-38	41-63	0
16. 1000-grain weight	25,11	16,94	14,88	28,39	15,56	15,96	18,64	23,70

that weedy rice strains generally possess greater plant height compared to cultivated rice. This trait suggests that weedy rice exhibits potential adaptability and evolution under changing climate conditions and rice cultivation practices in the Mekong delta region.

- Tillering ability: The weedy rice strains demonstrated similar tillering capabilities ranging from 13 to 23 tillers/plant, with an average of 18 tillers/plant, though slightly lower than the average tillering of the OM18 rice, which had 19 tillers/plant. The average number of panicles/plant for the weedy rice strains was 12.9, closely resembling the average panicle count of the OM18 rice (13 panicles/plant) (Table 3). With comparable tillering and panicle numbers to cultivated rice, weedy rice exhibits the ability to competitively acquire nutrients, water, and light within the agricultural field.

- Leaf shape: Certain weedy rice strains displayed elongated, narrow, and thin leaves. This particular leaf morphology was evident during the vegetative growth stage. The average length of the flag leaf for weedy rice was 37.9 cm, with the longest leaf measuring 44.3 cm and the shortest 33.9 cm, all exceeding the flag leaf length of OM18 (32.3 cm).

- Leaf colour: During the vegetative growth stage, some weedy rice strains exhibited lighter leaf coloration compared to cultivated rice, facilitating early differentiation by farmers. The average chlorophyll content index (SPAD) for the weedy rice strains was 37.4, lower than that of the cultivated OM18 rice (39.2) (n=10)

- Seed shape and colour: The OM18 rice variety produced elongated and slender seeds with a length-to-width ratio exceeding 4. The seed colour was straw yellow, while the brown rice exhibited a white hue, with a 1000-grain weight ranging from 25-26 g. Conversely, the weedy rice seeds displayed diverse shapes, including round, medium-long, and long. The seed coloration also exhibited variation, with certain seeds appearing black, yellow, and occasionally presenting multiple colours within the same panicle. Red rice was prevalent among the rice samples. The 1000-grain weight of the weedy rice strains ranged from 14.88 to 28.39 g, reflecting variations in maturation rates and shattering tendencies.

- Awn and awn colour on weedy rice seeds: The weedy rice strains exhibited considerable diversity in awn shape and length. Some strains possessed awns with lengths ranging from 0 to 63 mm, while others lacked awns, akin to the OM18 rice seeds (Table 3, Fig. 5).

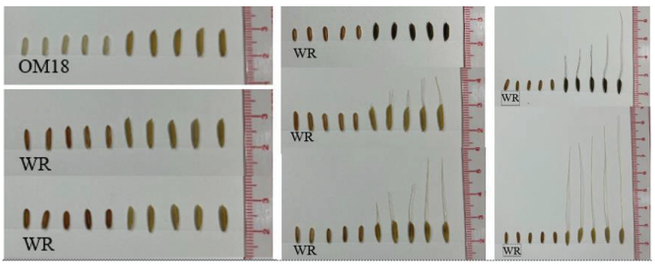

Fig 5. Weedy rice seeds.

- Seed shattering characteristic: Most weedy rice strains experienced seed shattering prior to physiological maturity (80% of seed weight). Easy seed shattering is the principal cause of yield loss in rice fields as weedy rice strains vie for nutrients, water, and light akin to cultivated rice. Survey results indicated that numerous weedy rice strains-initiated shattering approximately 15 days after the milk stage, with shattering intensity increasing towards the ripening stage. The average seed shattering rate was 50%, with certain strains exhibiting shattering rates as high as 90%. The well-filled seeds situated at the apex of the panicles were particularly susceptible to shattering, while only a few small, suspended seeds remained near the rachis at the base of the panicle.

4. Discussion

Based on the survey conducted with 60 farmers in Thap Muoi district, Dong Thap province, Vietnam, it was observed that although the farmers had limited education levels, they demonstrated awareness of weedy rice. Weedy rice has been present in the region for several decades, but its occurrence has notably increased in recent years, particularly in fallow fields. However, more than 50% of the farmers lacked knowledge about specific characteristics of weedy rice, such as seed dormancy, the potential for simultaneous harvesting with cultivated rice, its persistence in the soil for over one year, and the typical shorter stature compared to cultivated rice.

The escalating presence of weedy rice over the past five years can be attributed to farmers' incomplete understanding of all aspects of weedy rice, with recognition limited to easily identifiable traits. This, combined with a higher frequency of rice cultivation within the year, has led to changes in farming practices, including failure to clean harvesters before re-seeding and leaving seeds for subsequent crops. Additionally, ploughing rice straw into the soil instead of burning it has contributed to the proliferation of weedy rice in rice fields [21]. The limited interval for land preparation before sowing (5 to 7 days) does not provide sufficient time

to completely eliminate weedy rice seeds. Moreover, post-sowing herbicide application has proven ineffective due to the shared species between weedy rice and cultivated rice, resulting in normal growth of weedy rice. The average yield of the Summer-Autumn crop in 2022 has decreased compared to the previous year, and the influence of weedy rice on the yield cannot be disregarded.

Upon observing and analysing the characteristics of 7 representative weedy rice strains and one common cultivated variety (OM18), a diverse range of morphological and biological traits were identified among the weedy rice strains collected in Thap Muoi district. Distinct characteristics, such as plant height, leaf colour and shape, stem structure, presence of awns, and hull colour, were found useful in differentiating weedy rice strains from cultivated rice varieties at various growth stages in the field.

Overall, the study highlights the importance of raising farmers' awareness and understanding of the complete range of weedy rice characteristics to implement effective management strategies. Additionally, optimising land preparation practices and employing proper post-sowing weed control measures are critical to mitigate the spread of weedy rice and minimise its impact on rice yields.

5. Conclusions and recommendations

5.1. Conclusions

a) The education level of farmers in Thap Muoi district, Dong Thap province, Vietnam, is still low, but most of them are familiar with weedy rice.

b) Weedy rice has been present in the area for several decades, though its occurrence has significantly increased in the past 5 years, especially in fallow fields.

c) More than 50% of farmers are unaware of some characteristics of weedy rice, leading to ineffective management and widespread distribution of weedy rice in rice fields.

d) Changes in farming practices, such as not cleaning harvesters before reseeding, reserving seeds for the next crop, and ploughing rice straw into the soil after harvest, also contribute to the spread of weedy rice in rice fields.

e) The duration of land preparation before sowing is only 5 to 7 days, which is not enough to completely eliminate weedy rice seeds. The use of herbicides for post-sowing management is not highly effective, as weedy rice and cultivated rice are of the same species, leading to normal growth of weedy rice.

f) The average yield in the Summer-Autumn crop of 2022 decreased compared to the same period in the previous year, and the influence of weedy rice cannot be ruled out as a possible cause.

g) Observations and analysis of the characteristics of 7 typical weedy rice strains and one popular cultivated rice strain, OM18, revealed a diversity of morphological and biological traits among weedy rice strains in the region.

h) Characteristics such as plant height, leaf colour and shape, stem shape, presence of awns, and hull colour can be used to differentiate between different weedy rice strains and the cultivated rice strain at various growth stages in the field.

i) Most weedy rice strains have taller plant height and shorter GD compared to the cultivated rice strain, OM18.

j) The weedy rice strains show a high propensity for seed shattering and early seed shattering, but there were differences in the difficulty of seed shattering among the different strains.

k) The diversity, as well as similarities in morphological and biological traits among weedy rice strains compared to cultivated rice strains, indicate a highly diverse evolution and rapid adaptation of weedy rice to the current climate change and rice farming conditions. This may lead to increased spread and distribution of weedy rice, posing challenges in weedy rice control and potentially increasing threats to rice production and exports in the Mekong delta region and the entire country.

5.2. Recommendations

a) Enhance farmers' education and provide them with more information about the characteristics of weedy rice to improve their understanding and effective management of weedy rice in farming practices.

b) Provide guidance and training to farmers on proper cleaning of harvesters before harvesting and proper handling of rice straw after harvest to reduce the risk of weedy rice spread in rice fields.

c) Conduct research and apply more effective weed management methods that are suitable for the biological characteristics of weedy rice in the region, in order to minimise the impact of weedy rice on rice crop yields.

d) Strengthen monitoring and tracking of weedy rice development in rice fields to implement timely preventive and management measures for weedy rice.

e) Investigate and analyse the factors contributing to reduced rice crop yield in the Summer-Autumn crop of 2022 to determine the extent of weedy rice's impact and propose specific solutions to improve yields in the future.

CRediT author statement

Cong Vinh Kieu: Data curation, Writing original draft preparation; Ho Le Thi: Conceptualisation, Methodology, Investigation, Writing - Reviewing and Editing.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

REFERENCES

[1] P.K. Kimwemwe, C.B. Bukomarhe, E.G. Mamati, et al. (2023), "Population structure and genetic diversity of rice (*Oryza sativa* L.) germplasm from the democratic Republic of Congo (DRC) using DArTseq-Derived single nucleotide polymorphism (SNP)", *Agronomy*, **13(7)**, DOI: 10.3390/agronomy13071906.

[2] S. Shrestha, S. Stallworth, T.M. Tseng (2019), "Weedy rice: Competitive ability, evolution, and diversity", *IntechOpen*, DOI:10.5772/intechopen.81838.

[3] L.M. Juliano, D.K.M. Donayre, E.C. Martin, et al. (2020), "Weedy rice: An expanding problem in direct-seeded rice in the Philippines", *Weed Biol. Manag*, **20(2)**, pp.27-37, DOI: 10.1111/wbm.12196.

[4] M. Shuaib, S. Bahadur, F. Hussain, (2020), "Enumeration of genetic diversity of wild rice through phenotypic trait analysis", *Gene Reports*, **21**, DOI: 10.1016/j.genrep.2020.100797.

[5] N. Danbaba, P.Y. Idakwo, A.L. Kassum, et al. (2019), "Rice postharvest technology in nigeria?: An overview of current status, constraints and potentials for sustainable development", *Open Access Library Journal,* **6(8)**, pp.1-23, DOI: 10.4236/oalib.1105509.

[6] N.R. Burgos, V. Singh, T.M. Tseng, et al. (2014), "The impact of herbicide-resistant rice technology on phenotypic diversity and population structure of United States weedy rice", *Plant Physiology*, **166(3)**, pp.1208-1220, DOI: 10.1104/pp.114.242719.

[7] G. Dinelli, I. Marotti, A. Bonetti, et al. (2008), "Physiological and molecular bases of glyphosate resistance in Conyza bonariensis biotypes from Spain", *Weed Research*, **48(3)**, pp.257-265, DOI: 10.1111/j.1365-3180.2008.00623.x.

[8] R.S. Baucom (2019), "Evolutionary and ecological insights from herbicide-resistant weeds: what have we learned about plant adaptation, and what is left to uncover?", *New Phytol.*, **223(1)**, pp.68-82, DOI: 10.1111/nph.15723.

[9] X. Zhang, J. Tong, A. Bai, et al. (2020), "Phytohormone dynamics in developing endosperm influence rice grain shape and quality", *J. Integr. Plant Biol.*, **62(10)**, pp.1625-1637, DOI: 10.1111/jipb.12927.

[10] S. Nadir, H.B. Xiong, L.J. Chen (2017), "Weedy rice in sustainable rice production - A review", *Agronomy for Sustainable Development*, **37(5)**, pp.14-46, DOI: 10.1007/s13593- 017-0456-4.

[11] S. Saha, S. Munda, S. Singh, et al. (2021), "Crop establishment and weed control options for sustaining dry direct seeded rice production in eastern India", *Agronomy*, **11(2)**, DOI: 10.3390/agronomy11020389.

[12] C.C. Vigueira, X. Qi, B.K. Song, et al. (2018), "Call of the wild rice: *Oryza rufipogon* shapes weedy rice evolution in Southeast Asia", *Evol. Appl.*, **12(1)**, pp.93-104, DOI: 10.1111/eva.12581.

[13] C.Q. Fernández, J. Barroso (2020), "Impact of climate change on weed management systems", *ITEA-Agricultural Economic Technical Information*, **116(5)**, pp.396-404.

[14] C. Liu, M.E. Bridges, S.S. Kaundun, et al. (2017), "A generalised individual-based algorithm for modelling the evolution of quantitative herbicide resistance in arable weed populations", *Pest Management Science*, **73(2)**, pp.462-474, DOI: 10.1002/ps.4317.

[15] IRRI (2013), *Standard Evaluation System of Rice*, 56pp.

[16] Z.P. Hussain, A. Man, A.S. Othman (2010), "Morphological study of the relationships between weedy rice accessions (*Oryza sativa* complex) and commercial rice varieties in Pulau Pinang rice granary area", *Tropical Life Sciences Research*, **21(2)**, pp.27-40.

[17] R. Busi (2016), "Weedy Rice in the Philippines and Vietnam", https://www.aciar.gov.au/publication/technical-publications/weedy-rice-philippines-and-vietnam-final-report, accessed 15 July 2021.

[18] B.L. Gross, F.T. Steffen, K.M. Olsen (2010), "The molecular basis of white pericarps in African domesticated rice: Novel mutations at the Rc gene", *Journal of Evolutionary Biology*, **23(12)**, pp.2747-2753, DOI: 10.1111/j.1420-9101.2010.02125.x.

[19] M. Reagon, C.S. Thurber, K.M. Olsen, et al. (2011), "The long and the short of it: SD1 polymorphism and the evolution of growth trait divergence in U.S. weedy rice", *Molecular Ecology*, **20(18)**, pp.3743-3756, DOI: 10.1111/j.1365-294X.2011.05216.x.

[20] A.D. Morat, L.L. Nalley, G. Thoma (2018), "The implications of red rice on food security", *Global Food Security*, **18**, pp.62-75. DOI: 10.1016/j.gfs.2018.08.004.

[21] K. Lasko, K.P. Vadrevu, V.T. Tran, et al. (2017), "Satellites may underestimate rice residue and associated burning emissions in Vietnam", *Environmental Research Letters*, **12(8)**, pp.1-14, DOI: 10.1088/1748-9326/aa751d.