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Morphological and grain characterisation of Macedonian weedy rice (*Oryza sativa* L.)

Карактеризација на морфолошките својства и зрното на Македонскиот див ориз (*Oryza sativa* L.)

Trajche Dimitrovski[1,*], Danica Andreevska[1], Dobre Andov[1]

[1]*Institute of Agriculture in Skopje, Ss. Cyril and Methodius University in Skopje, Republic of Macedonia*

Abstract

Rice fields in the main rice producing region of the Republic of Macedonia sown with San Andrea and Onice cultivars were investigated with the aim to evaluate some morphological and grain characteristics of the present weedy rice types. Six morphotypes (two fully awned, three partly awned and one awnless) with pigmented pericarp were identified on the basis of the panicle morphology and grain characteristics. The plant height, panicle length, number of tillers and panicles per plant were examined on 30 plant samples of each type and compared to the cultivar. The grain and caryopsis dimensions were examined on 30 grains of each type. The weedy morphotypes isolated from Onice showed significantly higher plant height (from 102.47 cm to 113.47 cm) and panicle length (from 19.90 cm to 23.07 cm) in the field conditions compared to the cultivar (plant height: 79.50 cm; panicle length: 12.13 cm). In the San Andrea field, the weedy morphotypes had a significantly lower plant height values (from 106.17 cm to 108.63 cm) and non-significant to significantly longer panicle (18.10 cm to 20.50 cm) compared to the cultivar (plant height: 114.07 cm; panicle length: 17.24 cm). Significantly higher number of tillers and panicles per plant was determined in weedy rice compared to the rice cultivars. The weedy rice grain dimensions (length, width and thickness) were ranged from 8.30 to 8.85 mm, from 3.29 to 3.61 mm and from 2.03 to 2.22 mm, respectively, while the caryopsis dimensions varied from 6.15 to 6.62 mm, from 2.74 to 3.02 mm and from 1.82 to 2.04, respectively. The weedy rice morphotypes had significantly lower values for the three grain dimensions compared to San Andrea cultivar. Regarding the caryopsis, weedy rice had significantly lower values for two to three dimensions compared to San Andrea, depending on the morphotype. The differences in grain dimension between WR1323232 and Onice cultivar were non-significant. The rest of the weedy morphotypes exhibited significantly lower values for one to three grain dimensions in comparison to Onice. Depending on the weedy morphotype, significantly lower values for one to two caryopsis dimensions were found in comparison to Onice. Weedy rice had significantly lower 100 grains weight (from 2.84 to 3.28 g) compared to San Andrea (4.07 g) and Onice (3.56 g). Significant differences in the studied characteristics were also evident between the weedy accessions.

On the basis of the results obtained in the current study can be concluded that different weedy rice morphotypes occur in the rice producing region of the Republic of Macedonia. The descriptive

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* Author for correspondence: dimitrovskitrajche@gmail.com

characteristics given in this study could be helpful in determining the presence of weedy rice in field conditions and in the harvested crop.

Key words: weedy rice, morphological characteristics, grain

Оризови полиња со сортите San Andrea и Onice во главниот оризопроизводен реон на Република Македонија беа испитани со цел да се проучат присутните форми див ориз. Според морфологијата на метличката и зрното беа идентификувани шест диви форми со пигментиран перикарп, од кои 2 форми со присуство на осилки, 3 форми со делумно присуство на осилки и 1 форма без осилки. Висината на растението, должината на метличката, бројот на братимки и метлички по растение беа испитани кај 30 примероци на растенија од секој тип во споредеба со култивираниот ориз. Димензиите на зрното (арпа) и кариопсисот беа испитани кај 30 примероци од секој тип. Дивите форми изолирани од сортата Onice покажаа значајно зголемени вредности за висината на растението (од 102,47 cm до 113,47 cm) и должината на метличката (од 19,90 cm до 23,07 cm) во однос на сортата во полски услови (висина на растение: 79,50 cm; должина на метличка: 12,13 cm). Во посевот со San Andrea, кај дивите форми беа констатирани сигнификантно намалени вредности за висината на растението (од 106,17 cm до 108,63 cm), а незначителни до значајно зголемени вредности за должината на метличката (од 18,10 cm до 20,50 cm) во однос на сортата (висина на растение: 114,07 cm; должина на метличка: 17,24 cm). Бројот на братимки и метлички по растение беа значајно зголемени кај дивите форми во споредба со сортите. Димензиите на зрното кај дивите форми (должина, ширина и дебелина) вариpаа од 8,30 до 8,85 mm, од 3,29 до 3,61 mm и од 2,03 до 2,22 mm, соодветно, додека пак, димензиите на кариопсисот изнесуваа од 6,15 до 6,62 mm, од 2,74 до 3,02 mm и од 1,82 до 2,04 mm, соодветно. Дивите форми покажаа значајно намалени вредности за трите димезии на зрното во однос на San Andrea. Во однос на кариопсисот, дивите ориз покажаа значајно пониски вредности за две до три димензии во споредба со San Andrea, во зависност од типот. Разликите во димензиите на зрното помеѓу дивиот тип WR1323232 и сортата Onice беа незначајни. Кај останатите форми див ориз беа утврдени значајно пониски вредности за една до три димензии на зрното во однос на Onice. Во зависност од типот, значајно пониски вредности за една до две димензии на кариопсисот беа утврдени во споредба со Onice. Масата на 100 зрна кај дивите форми беше значајно пониска (од 2,84 до 3,28 g) во споредба со сортите San Andrea (4,07 g) и Onice (3,56 g). Исто така, значајни разлики во испитуваните параметри беа констатирани помеѓу дивите форми.
Врз основа на резултатите од ова испитување може да се заклучи дека во оризопроизводниот регион на Република Македонија егзистираат различни форми на див ориз. Опишаните својства во оваа студија можат да бидат од помош при утврдување на присуството на дивиот ориз во полски услови и во суровиот ориз.

Клучни зборови: див ориз, морфолошки карактеристики, зрно

Introduction

Weed vegetation in Macedonian rice fields is very versatile, including algae (*Spirogyra* spp., *Hydrodiction* spp., *Anabaena* spp.), submersed vascular plants (*Potamogetum* spp.) and emersed vascular plants belonging to several botanical families: Poaceae (*Echinochloa* spp., *Lerzia oryzoides)*, Cyperaceae (*Scirpus* spp., *Cyperus* spp.), and Pontederiaceae (*Heteranthera* spp.), (Andreevska et al. 2008). A specific problem in this region is the widespread of weedy rice-populations belonging to the *Oryza sativa* L. species exhibiting weedy characteristics, such as seed shattering (Delouche et al. 2007) and dormancy (Vidotto and Ferrero 2000; Gu et al. 2003) that negatively affect rice production (Pantone and Baker 1991; Ottis et al. 2005; Xu et al. 2017). Weedy rice infestation can also affect the milling quality of rice, as extra milling is required to remove the dark pigmented bran of the weedy rice present in the crop. As rice is milled to greater extents (higher degree of milling) the head rice yield decreases linearly (Reid et al. 1998).

Several factors attribute to the spread of this dangerous weed in Macedonian rice fields, such as the traditional monoculture farming (Andov and Andreevska 2015) and direct seeding (Andreevska et al. 2013), the use of modern machinery and abandonment of hand weeding. The hand weeding is nowadays replaced with the usage of herbicides to suppress the other weed species (Ilieva 2015). Due to genetic similarity with cultivated rice (Ilieva et al. 1998; Xia et al. 2015), these preparations are ineffective on weedy rice. Consequently, weedy rice is widespread throughout the rice producing region of the Republic of Macedonia (observation of the authors). The study of weedy rice in Macedonian rice fields is very limited. Previous research on this subject was conducted by Ilieva and Matveeva (1998), who identified three taxa of red rice present in the Kochani rice fields.

This study was conducted to evaluate some important morphological characteristics of the present weedy rice types in the main rice producing region (Kochani). A total of six weedy rice types were identified from two rice fields, sown with the rice cultivars San Andrea and Onice. The findings obtained from this study will be useful to develop good agricultural practices and protocols for management of the weedy rice types that infest the rice fields in the Republic of Macedonia.

Material and methods

Rice fields sown with Italian cultivars San Andrea and Onice in Sredorek area in Kochani that belong to the Rice experimental station of the Institute of Agriculture Skopje were inspected for weedy rice in 2016. The area was naturally infested with weedy rice. It is located within the main rice producing region representing the typical rice growing conditions in the country. It belongs to the temperate continental-sub-Mediterranean region of the Republic of Macedonia (Filipovski et al. 1996). Plant samples in the studied area were evaluated during anthesis and grain maturation, since the visual differentiation between weedy and cultivated rice was easy to perform on fully developed plants and panicles. Six weedy rice forms were identified in the field conditions on the basis of the visual assessment of the panicle morphology and grain characteristics according to Descriptors for wild and cultivated rice (Oryza spp.) by Bioversity International, IRRI and WARDA (2007). The plant height, panicle length, number of tillers and number of panicles per plant were examined in field conditions, on a sample population of 30 randomly selected plants of each weedy type and the cultivar.

Matured seeds (paddy rice) from each type and the cultivar were manually collected in order to evaluate the grain characteristics. The grain and caryopsis dimensions (length, width and thickness) were measured on a sample of 30 typical grains from each type and the cultivar using a digital caliper. The dimensions of each grain in the sample were measured, after which the grain was manually dehulled for determination of caryopsis dimensions. Awn length was determined by measuring 30 random awns from each type. The 100 grains weight (paddy) was determined by measuring eight samples of 100 grains from each type and the cultivar.

The results were statistically analyzed by the analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 significance level. Correlation analysis was determined by calculation of the Pearson's correlation coefficient.

Results and discussion

In the present study, four weedy rice morphotypes were found in the Onice rice field compared to two weedy types in the field sawn with San Andrea, which is a taller cultivar compared to Onice. These results are in accordance with those observed by Kwon et al. (1991) indicating that shorter rice cultivars are more susceptible to weedy rice competition compared to tall rice cultivars.

Weedy types identification based on the panicle and grain characteristics

The examined weedy rice morphotypes are shown on Fig 1 and Fig. 2. Table 1 presents the panicle and grain morphology. A code was given for each weedy rice morphotype based on the following characteristics: attitude of branches (compactness of the panicle), main axis attitude, awns presence and colour, lemma and palea colour, caryopsis shape and colour. The weedy rice morphotypes WR1323232 and WR1313632 are similar to the taxon No. 2 and taxon No. 3 described by Ilieva and Matveeva (1998). The authors determined these taxa as *Oryza sativa* L. var. *desvauxii* Korn. and *Oryza sativa* L. var. *caucasica* Bat., respectively. It should be noted that plants similar

Table 1 Panicle morphology and grain characteristics of the examined weedy rice morphotypes.*

	Weedy rice found in San Andrea rice field		*Weedy rice found in Onice rice cultivar*			
	WR1200234	*WR3311234*	*WR1313632*	*WR1323232*	*WR1311234*	*WR1321232*
FLA	3 to 5	5	5 to 7	5 to 7	5 to 7	5 to 7
PAPB	alternate (2) with some opposite arrangement in lower half of the panicle					
PNBPB	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2
PDBLSI (mm)	0	0	0	0	0	0
PTMA	2	2	2	2	2	2
PAMA	2	3	3	3	3	3
PAB	1	3	1	1	1	1
PSB	2	2	2	2	2	2
PE	9	9	9	5 - 9	9	7-9
AP	0	1	1	2	1	2
AC	0	1	3	3	1	1
LPP	4	4	4	4	4	4
LPC-LO	2	2	6	2	2	2
LCA-LO	2	2	3	3	2	2
LSA	1	1	1	1	1	1
SLL (mm)	3.42	3.35	3.36	3.49	2.93	3.31
SLS	1	1	1	1	1	1
SLC-LO	1	1	1	1	1	1
CS	3	3	3	3	3	3
CPC	4	4	2	2	4	2
ET	2	2	2	2	2	2

* FLA - flag leaf attitude, PAPB - panicle: arrangement of primary branches, PNBPB - panicle: number of basal primary branches, PDBLSI - panicle: distance from base to lowest spikelet insertion (mm), PTMA - panicle: texture of main axis, PAMA - panicle: attitude of main axis, PAB - panicle: attitude of branches (compactness of the panicle), PSB - panicle: secondary branching, PE - panicle exsertion, AP - awns presence, AL - awn length, AC - awn color, LPP - lemma and palea pubescence, LPC - lemma and palea colour, LACK - lemma: anthocyanin colouration of keel, LACABA - lemma: anthocyanin colouration of area below apiculus, LC A- lemma: colour of apiculus, LSA - lemma: shape of apiculus, SLL - sterile lemma length, SLS - sterile lemma shape, SLC - sterile lemma: colour, C - caryopsis shape, CPC - caryopsis pericarp colour, ET - endosperm type, (LO)- train recorded at late observation. Numbers correspond to Descriptors for wild and cultivated rice (*Oryza* spp.) by Bioversity International, IRRI and WARDA (2007).

Figure 1. Weedy rice found in San Andrea rice field: 1- WR3311234, 2- WR1200234

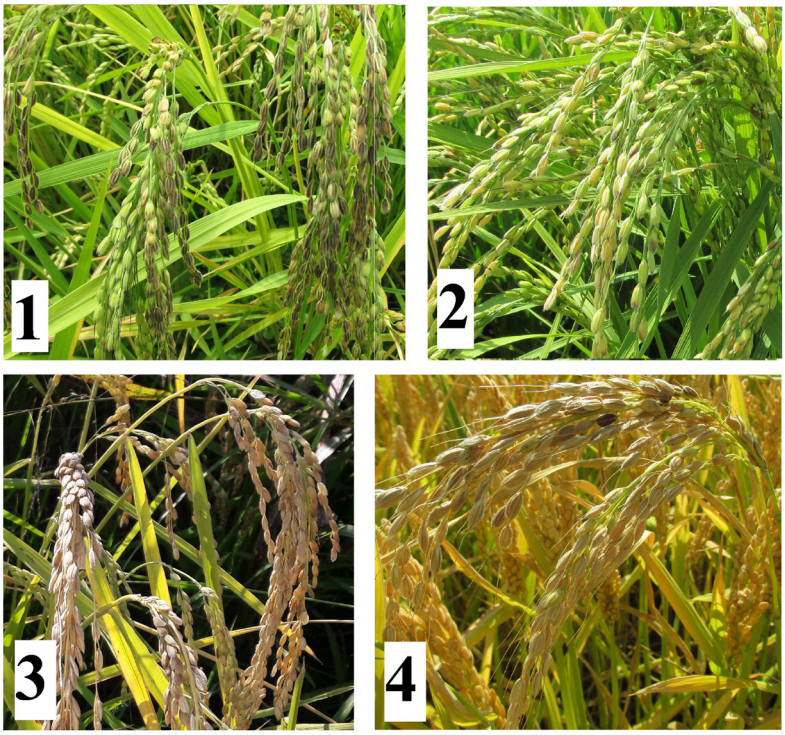

Figure 2. Weedy rice found in Onice rice field: 1- WR1313632, 2- WR1323232, 3- WR1311234, 4- WR1321232

to the taxon No. 1 identified as *Oryza sativa* L. var. *bicolorata* Kanevsk. were also observed in this study, but they were not evaluated as only few individuals were found.

Plant height and panicle length

Weedy rice can be taller, shorter or similar as the cultivated rice (Jana and Mallick 2013). Different plant height values are reported for weedy rice populations from different regions (Vidotto and Ferrero 2009; Fogliato et al. 2011; Ahmed et al. 2012; Jose et al. 2016; Rathore et al. 2016). The results for the plant height and panicle length are presented in Table 2 and Table 3, respectively. It has been shown that the cultivars differed in plant height, since Onice is a shorter cultivar compared to San Andrea (Andov et al. 2015). According to the Standard Evaluation System for Rice (IRRI 2013), Onice is a semi dwarf variety (79.50 cm), while San Andrea is intermediate variety (114.07 cm). Present results demonstrated that weedy rice in the Onice field had a significantly higher plant

Table 2 Plant height (cm) of the studied weedy morphotypes and cultivars.*

	Weedy rice in San Andrea			Weedy rice in Onice				
Code	1200234	3311234	cult.	1313632	1323232	1311234	1321232	cult.
Mean	106.17 a	108.63 a	114.07 b	113.33 c	102.47 b	113.47 c	111.33 c	79.50 a
S	6.56	8.28	4.82	6.74	9.50	5.60	6.18	2.13
CV	6.18	7.62	4.23	5.95	9.27	4.94	5.55	2.68
Min	93	88	104	102	85	104	102	77
Max	119	125	125	124	120	124	126	85
LSD	3.44 ($\alpha_{0.05}$); 4.56 ($\alpha_{0.01}$)			3.46 ($\alpha_{0.05}$); 4.57 ($\alpha_{0.01}$)				

* Means are average values of 30 samples. S - standard deviation, CV - coefficient of variation; Min and Max – the lowest and the highest value in the samples, respectively. Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α).The values in the row marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

Table 3 Panicle length (cm) of the studied weedy morphotypes and cultivars.*

Code	1200234	3311234	cult.	1313632	1323232	1311234	1321232	cult.
Mean	20.50 b	18.10 a	17.24 a	20.93 b	19.90 b	23.07 c	20.00 b	12.13 a
S	2.33	2.55	1.20	2.46	2.74	1.63	3.53	0.90
CV	11.37	14.09	6.96	11.75	13.77	7.07	17.65	7.42
Min	15	11	15	10	13	19	9	10
Max	25	23	19	23	28	26	24	14
LSD	1.08 ($\alpha_{0.05}$); 1.43 ($\alpha_{0.01}$)			1.20 ($\alpha_{0.05}$); 1.58 ($\alpha_{0.01}$)				

* Means are average values of 30 samples. S- standard deviation, CV- coefficient of variation; Min and Max – the lowest and the highest value in the samples, respectively. Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α). The values in the row marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

height and panicle length compared to the cultivar. The highest plant (113.47 cm) and the longest panicle (23.07 cm) were observed for WR1311234 morphotype.

In the San Andrea rice field, the weedy rice morphotypes showed a significantly lower plant height compared to the cultivar San Andrea. The morphotype WR1200234 had the lowest plant height (106.17 cm). The WR1200234 had significantly longer panicle (20.50 cm) compared to the cultivar San Andrea, where the shortest panicle was found (17.24 cm).

In previous research, Ilieva and Matveeva

Table 4 Number of tillers per plant in the examined weedy types and cultivars.*

	Weedy rice in San Andrea			Weedy rice in Onice				
Code	1200234	3311234	cult.	1313632	1323232	1311234	1321232	cult.
Mean	4.40 b	7.10 c	2.10 a	6.90 b	6.33 b	7.80 b	7.43 b	3.30 a
S	3.08	4.84	0.93	3.81	3.22	5.34	4.46	1.73
CV	70.00	68.17	44.29	55.22	50.87	68.46	60.05	52.42
Min	1	2	1	1	2	2	2	1
Max	14	24	6	17	16	22	23	9
LSD	1.65 ($\alpha_{0.05}$); 2.19 ($\alpha_{0.01}$)			1.88 ($\alpha_{0.05}$); 2.48 ($\alpha_{0.01}$)				

* Means are average values of 30 samples. S- standard deviation, CV- coefficient of variation; Min and Max – the lowest and the highest value in the samples, respectively. . Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α). The values in the row marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

Table 5 Number of panicles per plant in the examined weedy types and cultivars.*

Number of panicles per plant								
Code	1200234	3311234	cult.	1313632	1323232	1311234	1321232	cult.
Mean	4.20 b	6.70 c	2.10 a	6.50 b	5.97 b	7.70 b	7.40 b	3.30 a
S	2.96	4.48	0.93	3.47	3.05	5.42	4.49	1.73
CV	70.48	66.87	44.29	53.38	51.09	70.39	60.63	52.42
Min	1	2	1	1	2	2	2	1
Max	13	24	6	14	15	22	23	9
LSD	1.55 ($\alpha_{0.05}$); 2.05 ($\alpha_{0.01}$)			1.20 ($\alpha_{0.05}$); 1.58 ($\alpha_{0.01}$)				

* Means are average values of 30 samples. S- standard deviation, CV- coefficient of variation; Min and Max – the lowest and the highest value in the samples, respectively. . Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α). The values in the row marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

(1998) reported culm height from 75.9 to 84.5 cm and panicle length from 17.4 to 19.6 cm for the Macedonian red rice from the same region.

Significant differences for the plant height and panicle length in this study were also found between different weedy morphotypes. Weedy rice had a higher variation for the plant height compared to cultivated rice. Higher standard deviation, coefficient of variation and higher difference between the minimal and maximal values in the sample populations were obtained in the weedy rice morphotypes as compared to cultivated rice. Similar results were obtained for the panicle length, with the exception of WR1311234 that showed lower coefficient of variation in comparison to the cultivar.

Number of tillers and number of panicles per plant

The tillering in rice depends on the genotype (Lafarge et al. 2004; Shahidullah et al. 2009), seeding density (Wang et al. 2014), crop density and nutrition (Haque et al. 2015; Wang et al. 2017) and weed infestation (Hoque et al. 2003; Chadhar et al. 2014). Weedy rice exhibits wider variation in tillering ability compared to cultivated rice (Sánchez-Olguín et al. 2007).

As shown in Table 4 and Table 5, the weedy types at maturity had significantly higher number of tillers and panicles per plant compared to the cultivars Onice (3.30) and San Andrea (2.10). In the Onice field, WR1311234 had the highest number of tillers (7.80) and panicles (7.70). In the San Andrea field, the highest average was determined for WR3311234 (7.10 tillers and 6.70 panicles per plant). Significant differences between the weedy rice types were found in the San Andrea rice field.

Similar results were obtained by Sales et al. (2011), who examined the morphological and physiological responses of weedy and cultivated rice upon nitrogen supply, where weedy rice type Stf-3 produced more tillers (7 in year 1 and 8 in year 2) than Wells cultivar (3 in both years). Jose et al. (2016) reported significant difference in the number of tillers per plant between the weedy rice morphotypes (from 2.5 to 10.8) in Indian direct seeded rice, while the values in the cultivar MO 16 ranged from 4 to 5.

In the current study, weedy rice morhotypes had a higher standard deviation for the number of tillers and panicles per plant compared to cultivated rice, as well a higher coefficient of variation (with the exception of WR1323232) suggesting higher variation for this characteristics in weedy rice.

Awning

Wild rice types typically display long awns, whereas the domesticated types have short awns if any (Sweeney and McCouch 2007). In this study, two morhotypes were fully awned, three were partly awned, while one type was awnless. As shown in Table 6, the shortest awn was determined in the cultivar San Andrea (3.83 mm), while the longest awn was found for the WR1313632 (27.40 mm).

The morphotype WR1311234 with the lowest average awn length among the weedy morphotypes (4.40 mm) and the cultivar San Andrea belong to very short group according to Descriptors for wild and cultivated rice (Oryza spp.) by Bioversity International, IRRI and WARDA (2007).

Table 6 Awns length (mm) in the examined weedy types and cultivars.*

	Weedy rice in San Andrea			Weedy rice in Onice				
Code	1200234	3311234	cult.	1313632	1323232	1311234	1321232	cult.
Mean	awnless	11.80	3.83	27.40	22.63	4.40	21.72	awnless
S	awnless	4.47	1.91	10.07	8.06	2.49	7.07	awnless
CV	awnless	37.88	49.87	36.75	35.60	56.59	32.55	awnless
Min	awnless	4	1	10	4	1	9	awnless
Max	awnless	20	11	51	36	11	37	awnless

* Means are average values of 30 samples. S- standard deviation, CV- coefficient of variation; Min and Max – the lowest and the highest value in the samples, respectively.

Table 7 Grain (paddy rice) length, width and thickness (mm) in the examined weedy morphotypes and cultivars.*

	Grain length			Grain width			Grain thickness		
Code	Mean	S	CV	Mean	S	CV	Mean	S	CV
WR1200234	8.30a	0.18	2.17	3.46b	0.19	5.49	2.14b	0.12	5.61
WR3311234	8.57b	0.25	2.92	3.50b	0.12	3.43	2.20cd	0.11	5.00
WR1313632	8.73c	0.33	3.78	3.58c	0.15	4.19	2.17bc	0.09	4.15
WR1323232	8.85cd	0.24	2.71	3.61c	0.19	5.26	2.16bc	0.09	4.17
WR1311234	8.77c	0.25	2.85	3.29a	0.16	4.86	2.03a	0.06	2.96
WR1321232	8.35a	0.40	4.79	3.59c	0.17	4.74	2.22d	0.09	4.05
San Andrea	9.05e	0.28	3.09	3.85d	0.16	4.16	2.30e	0.09	3.91
Onice	8.97de	0.23	2.56	3.63c	0.15	4.13	2.21cd	0.04	1.81
LSD	0.14($\alpha_{0.05}$);0.19 ($\alpha_{0.01}$)			0.08 ($\alpha_{0.05}$); 0.11 ($\alpha_{0.01}$)			0.05($\alpha_{0.05}$);0.06 ($\alpha_{0.01}$)		

* Means are average values of 30 samples. S- standard deviation, CV- coefficient of variation. Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α). The values in the column marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

Grain dimensions (length, width and thickness)

As shown in Table 7, the weedy types had significantly lower grain length, width and thickness compared to San Andrea, where the highest obtained values were 9.05 mm, 3.85 mm and 2.30 mm, respectively. The differences in grain dimension between WR1323232 and Onice cultivar were non-significant. The rest of the weedy morphotypes exhibited significantly lower values for one to three grain dimensions in comparison to Onice. The WR1200234 had the shortest grain of 8.30 mm, while WR1311234 had the lowest width of 3.29 mm and thickness of 2.03 mm. Among the weedy accessions, WR1323232 had the longest (8.85 mm) and widest (3.61 mm) grain, while WR1321232 had the highest thickness (2.22 mm). Jose et al. (2016) reported that grain length of the Indian weedy rice varied from 0.7 to 0.9 cm and the width is ranged from 0.3 to 0.4 cm. Fogliato et al. (2012) reported grain length from 7.6 mm to 8.0 mm and grain width from 3.5 to 3.7 mm for Italian weedy rice.

The grain (paddy rice) and caryopsis (brown rice) of the examined weedy types and cultivars are shown on Fig. 3.

The 100 grains weight

As shown in Table 8, the weedy rice had significantly lower 100 grains weight of paddy compared to the cultivars San Andrea (4.07 g) and Onice (3.56 g). This parameter ranged from 2.84 g in WR1311234 to 3.28 g in WR1313632. Significant differences among weedy types were also obtained. Similar results were previously reported by Ilieva and Matveeva (1998), with 1000 grains weight in weedy rice ranging from 28.8 g to 32.1 g.

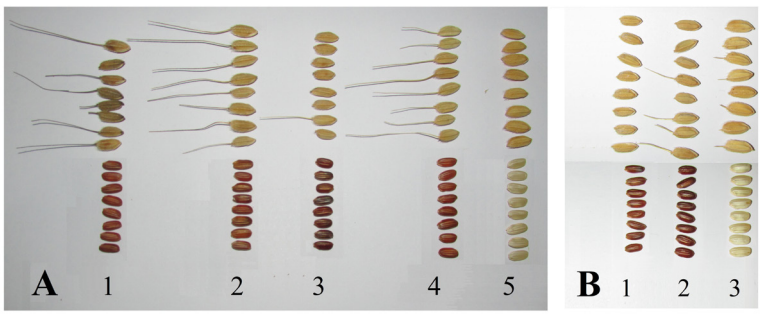

Figure 3. Grain (paddy rice) and caryopsis (brown rice). A- weedy rice found in Onice: 1- WR1313632, 2- WR1323232, 3- WR1311234, 4- WR1321232 5- Onice cultivar. B- weedy rice found in San Andrea: 1- WR1200234, 2- WR3311234, 3- San Andrea cultivar

Table 8 The 100 grains weight of paddy (g) in the studied weedy rice types and Onice cultivar.*

Code	1200234	3311234	1313632	1323232	1311234	1321232	San Andrea	Onice
Mean	2.99b	3.22de	3.28e	3.08c	2.84a	3.19d	4.07g	3.56f
S	0.08	0.10	0.05	0.04	0.05	0.05	0.15	0.09
CV	2.53	3.11	1.67	1.18	1.91	1.51	3.79	2.59
LSD	0.08 ($\alpha_{0.05}$); 0.11 ($\alpha_{0.01}$):							

* Means are average values of 30 samples. S- standard deviation, CV- coefficient of variation. Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α). The values in the row marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

Table 9 Caryopsis length, width and thickness (mm) in the examined weedy rice and the cultivars.*

	Caryopsys length			Caryopsis width			Caryopsys thickness		
Code	Mean	S	CV	Mean	S	CV	Mean	S	CV
WR1200234	6.15a	0.23	3.74	3.00c	0.12	4.00	1.96bc	0.10	5.10
WR3311234	6.41b	0.26	4.06	2.91b	0.11	3.78	1.99cd	0.09	4.52
WR1313632	6.58cd	0.26	3.95	2.92b	0.10	3.42	1.95bc	0.06	3.08
WR1323232	6.56cd	0.24	3.66	3.02c	0.15	4.97	1.93b	0.09	4.66
WR1311234	6.62cd	0.29	4.38	2.74a	0.12	4.38	1.82a	0.07	3.85
WR1321232	6.17a	0.24	3.89	3.02c	0.17	5.63	2.04e	0.09	4.41
San Andrea	6.67d	0.23	3.45	3.18d	0.10	3.14	2.09f	0.09	4.31
Onice	6.55c	0.18	2.75	2.99c	0.11	3.68	2.01de	0.06	2.99
LSD	0.12 ($\alpha_{0.05}$); 0.16 ($\alpha_{0.01}$)			0.07 ($\alpha_{0.05}$); 0.09 ($\alpha_{0.01}$)			0.04 ($\alpha_{0.05}$); 0.05 ($\alpha_{0.01}$)		

* Means are average values of 30 samples. S - standard deviation, CV - coefficient of variation. Analysis of variance (ANOVA) followed by LSD test at 0.05 and 0.01 levels of probability (α). The values in the columns marked with different lower-cases denoted significant differences at $p<0.05$ between samples.

Table 10 Length/width ratio of caryopsis in the examined weedy rice and the cultivars.*

Code	1200234	3311234	1313632	1323232	1311234	1321232	San Andrea	Onice
Mean	2.05	2.21	2.26	2.18	2.42	2.05	2.09	2.19
S	0.13	0.12	0.13	0.13	0.18	0.12	0.06	0.08

* Means are average values of 30 samples. S - standard deviation.

Table 11 Correlation analysis of grain and caryopsis characteristics in the examined weedy rice and the cultivars.*

	AL	GL	GW	GT	CL	CW	CT	RLW	100W
AL	1								
GL	0.368	1							
GW	0.799	-0.059	1						
GT	0.562	-0.408	0.859*	1					
CL	0.288	0.972**	-0.201	-0.493	1				
CW	0.374	-0.439	0.840*	0.781	-0.604	1			
CT	0.383	-0.640	0.743	0.961*	-0.705	0.784	1		
RLW	-0.071	0.766	-0.608	-0.725	0.877*	-0.912*	-0.835*	1	
100W	0.743	-0.101	0.804	0.874*	-0.116	0.497	0.761	-0.365	1
df = 4; Critical values: 0.811 (α 0.05); 0.917 (α 0.01).									

* AL - awn length, GL - grain length, GW - grain width, GT - grain thickness, CL - caryopsis length, CW - caryopsis width, CT - caryopsis thickness, LWR - length/width ratio, 100W - 100 grains weight. Significant correlation at 0.05 level (*) and at 0.01 level of significance (**).

Table 12 Correlation analysis of grain and morphological characteristics in the examined weedy rice and the cultivars.

	AL	GL	GW	GT	CL	CW	CT	RLW	100W
PH	0.068	-0.005	-0.381	-0.239	0.189	-0.629	-0.176	0.478	0.063
PL	-0.251	0.290	-0.631	-0.848*	0.379	-0.623	-0.778	0.577	-0.685
NT	0.391	0.443	-0.133	-0.091	0.497	-0.532	-0.173	0.590	0.124
NP	0.334	0.369	-0.179	-0.123	0.424	-0.532	-0.175	0.555	0.055
df = 4; Critical values: 0.811 (α 0.05); 0.917 (α 0.01).									

* PH - plant height, PL - panicle length, NT - number of tillers, NP - number of panicles, AL - awn length, GL - grain length, GW - grain width, GT - grain thickness, CL - caryopsis length, CW - caryopsis width, CT - caryopsis thickness, LWR - length/width ratio, 100W - 100 grains weight. Significant correlation at 0.05 level (*) and at 0.01 level of significance (**).

Caryopsis characteristics

The highest values for the caryopsis length, width and thickness were found for the cultivar San Andrea (6.67 mm, 3.18 mm and 2.09 mm, respectively). The WR1200234 had the shortest caryopsis (6.15 mm), while the WR1311234 had the lowest width (2.74 mm) and thickness (1.82 mm) (Table 9). Among the weedy accessions, the WR1311234 had the highest length (6.62 mm), WR1323232 and WR1321232 showed the highest width (3.02 mm), while WR1321232 had the highest thickness (2.04 mm). Fogliatto et al. (2012) reported mean dehulled seed length and width from 6.0 mm to 6.1 mm and from 2.9 mm to 3.1 mm, respectively among different populations of Italian weedy rice.

The weedy rice showed significantly lower width and thickness and significantly lower to non-significant differences for the caryopsis length compared to San Andrea, depending on the morphotype. Depending on the weedy morphotype, significantly lower values for one to two caryopsis dimensions were found in comparison to Onice.

The Table 10 presents the caryopsis length/width ratio. The classification system regarding the brown rice (kernel) size and shape is not unified, and differs among different organizations. According to UPOV (2004), the weedy morphotypes and the cultivars have a half-spindle shaped caryopsis. According to the classification by Khush et al. (1979), the WR1200234 and San Andrea are on the bold to medium limit, while Onice and the rest of the weedy rice types are medium. According to the ratio classification by CAC (1995), WR1200234 and San Andrea are on the short to medium limit, while Onice and the rest of the weedy rice types are medium. On the basis of the combined ratio and length classification by CAC (1995), the weedy rice types and the cultivars have a long grain.

As shown in Table 11, the grain dimensions were in significant positive correlation with the caryopsis dimensions. The length/width ratio was positively correlated with the caryopsis length, but negatively correlated to the caryopsis width and thickness. Regarding the morphological characteristics, the grain thickness was negatively correlated with the panicle length (Table 12).

Conclusions

On the basis of the results obtained in the current study, it can be concluded that different morphotypes of weedy rice coexist with cultivated rice in the rice producing region of the Republic of Macedonia. Differences in plant height, panicle length, panicle and grain morphology, including grain and caryopsis dimensions were evident among the different weedy morphotypes. In comparison to cultivated rice, differences for weedy rice were evident both in the descriptive and statistically analyzed characteristics.

Significant differences in the plant height, panicle length, number of tillers and panicles per plant were found for weedy rice isolated from both cultivars. The descriptive characteristics given in this study could be helpful in determining the presence of weedy rice in field conditions. The caryopsis color (dark pigmented pericarp) was a clearly distinguished characteristic in all weedy rice accessions as compared to cultivated rice. This property allows detection and separation of the weedy morphotypes from harvested rice using color selector machines. The significantly

higher number of tillers and panicles per plant in weedy rice suggest greater competitive ability in typical rice field conditions. Weedy morphotypes WR3311234, WR1313632, WR1323232 and WR1321232 can clearly be distinguished from anthesis to maturity due to the presence of long awns and awn color, as compared to the cultivated varieties. Thus, early hand removal of the panicles of these morphotypes is possible. The morphotypes WR1200234 which is awnless and WR1311234 with very short awn length could be problematic for easy visual detection in field conditions, especially if found in field sown with higher cultivars. This was the case with WR1200234, which was significantly shorter compared to the cultivar San Andrea. Based on the panicle and grain morphology, WR1311234 was more similar in general appearance to cultivated rice than the WR1200234. Still, in the current study this morphotype was easy to detect due to the occurrence in a field with significantly shorter variety Onice.

The weedy rice had significantly lower 100 grains (paddy) weight compared to cultivated rice. The cultivar San Andrea had significantly higher values for the grain dimensions in comparison to weedy rice. These differences were not as prominent in Onice, a cultivar with smaller grain compared to San Andrea. Accordingly, mechanical separation of weedy rice grains in the crop could present a difficulty in rice cultivars with smaller grain, such as Onice.

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