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The weed and weedy rice impact on direct seeded rice production in North Macedonia

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Abstract

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A study from 2017 to 2019 in 10 vilages in the rice producing region of North Macedonia was undertaken to estimate the effect of weed flora on some productive rice properties. The common production technology was implemented. Rice was direct seeded in wet conditons. The weed managent included water bed regulation in combination with herbicide application. The following properties were investigated in three replications: density and infestation of the total weeds, weedy rice and other weed species, crop density, biological, straw and paddy rice yield, harvest index and head rice yield. The results were pooled in 5 groups depending on the weed infestation level. A correlation analysis revaled significant negative effect of the total weeds and the weedy rice component on the crop density, biological yield, harvest index and paddy rice yield. The weeds controled with herbicides were not significanlty correlated and affected the productive properties indirectly as a contributing factor in the total weed density. Low infestation (0.01% to 1.00%) caused drop in paddy rice yield of 6.73%. The most severe cases of weed infestation (15.01% to 25.00%) averaged 100.08 weed tillers/m^2 and caused paddy yield drop of 35.30%. These field parcels were located in a region with extensive monoculture, where weedy rice populations constituted 90.68% of the total weed flora, or 90.75 panicles/m^2 against 9.33 tillers/m^2 from other weed species. Some weedy rice morphotypes were easily distinguished against cultivated rice in field conditions as early as anthesis, while others were more difficult to recognize. This study confirms weedy rice as a serious threat for the direct seeded rice production in the region, and addresses the need to investigate its biology and the most suitable management practices.

Keywords: weed infestation; crop density; yield; productive properties
Abbreviations: TWT/m^2 total number of weed tillers; WRP/m^2 number of weedy rice panicles; OWT/m^{2}number of tillers from other weeds found in each 1 m^2 crop sample; TWI total weed infestation; WRI weedy rice infestation; OWI – infestation with other weed species; NPP/m^2 – number of productive rice panicles/m^2; NNP/m^2 – number of non-productive rice panicles/m^2; TNP– total number of rice crop panicles/m^2; NPP –number of productive (ripen) panicles/m^2; NNP– number of non-productive (sterile and unripe) panicles/m^2; BY–biological yield; PRY –paddy rice yield; SY– straw yield; HI – harvest index; HRI– head rice yield; PC – panicle compactness; MAA – main axis attitude; APC –awns presence and color; LPC – lemma and palea color; EO – early observation; LO – late observation.

Introduction

The weed flora plays an important factor in agriculture and rice production. Weeds compete with crop species for water (Abouziena et al., 2014-2015), nutrients (Aynehband et al., 2012), space and light. If not properly managed, they can decrease the photosithetic rate and grain filing rate (Xu et al., 2017), ultimately causing yield loss (Ottis et al., 2005; Mamun, 2014; Hosoya & Sugiyama, 2017). For effective long term control of the weed flora in rice production, a complex of several methods and measures should be undertaken, including operations such as the use of herbicides, crop rotation, regulation on the water level depth, increased crop density, use of certified (weed free) seeding material.

In North Macedonia, rice is direct seeded in wet conditions. The weed flora is versatile, incorporatiing different algae, broaleaf weeds (both submesed and emersed), grasses and sedges. The weed control is performed by regulation of the wated bed level in combination with herbicides application agains the common weed species. Hand weeding, a control measure from the past is nowadays completely abandoned. An emerging problem in the region is the widespread of weedy rice-populations (*Oryza sativa* L.) with weedy characteristics such as seed shattering (Delouche et al., 2007) and dormancy (Dimitrovski et al., 2018a). Since weedy rice is conspecific to cultivated rice, the common practices used to suppress the other weed species are ineffective. Crop rotation, considered a good method for weed supression is not a commomn practise. Rice is largely grown in monoculture, and crop rotation is done spontaneously due to water deficit. In this case, the parcels are sown with crops such as wheat, rye, corn and pepper. The effect of the weed flora in the rice production of North Macedonia has not been extensivly studied. Glatkova et al. (2019), reported that water deficit in the rice producing region stimulated the infestation and spread of *Eragrostis pilosa* (L.) P. Beauv. Dimitrovski et al. (2018b) described 6 weedy rice morhotypes. Andreevska et al. (2008) studied the effect of crop rotation on weed infestation.

In order to investigate the efficacy of the common weed control measures in the region and the effect of the weed flora on the productive properties of rice, including the contribution of the different components of the weed flora, especially weedy rice which is of significant concearn, a 3 year study was conducted to adress this issues.

Materials and Methods

The study was conducted during 2017, 2018 and 2019 in the rice producing region of North Macedonia. Field parcels in 10 villages were investigated. The location, number and area of the examined field parcels and the grown cultivars during the 2017-2019 periods are given in Table 1. The farmers involved in the study applied the standard (common) rice production technology of North Macedonia. The rice crop was direct seeded in wet conditions by broadcasting seeds in flooded field parcels. Certified seed material of the Italian varieties San Andrea and Opale, two commonly grown cultivars in North Macedonia was used. The most variable step of the production was the fertilization, which involved a variety of fertilizers and fertilizer dosage, depending on the available soil nutrients and the individual farmers' practices. The basic fertilization was performed before seeding and involved Nitrogen fertilizers (Urea N 46%) or combined NPK fertilizers (NPK 15:15:15; NPK 16:16:16; NPK 30:5:5; NPK Yara mila 32:5:5), while the split fertilization (1 to 3

Table 1. Characteristics of the examined farmer's parcels in the rice field production region of North Macedonia: years when investigation took place, location and area of the examined parcels and grown cultivar

Number of field parcels				Investigated area, ha			Cultivars
Localities	2017	2018	2019	2017	2018	2019	
Banja	ni	ni	1	ni	ni	0.5 0	Opale
Burilchevo	ni	2	2	ni	1.00	1.00	San Andrea
Cheshinovo	4	6	8	1.5	3.20	4.35	San Andrea
Chiflik	7	6	6	0.87	2.81	2.50	San Andrea
Krupishte	ni	1	1	ni	0.20	0.50	San Andrea
Kuchichino	ni	1	2	ni	0.47	0.96	San Andrea
Sokolarci	ni	ni	1	ni	ni	0.50	Opale
Spanchevo	ni	1	2	ni	0.50	1.00	Opale
Teranci	2	2	3	0.52	1.05	1.50	San Andrea
Ularci	1	3	4	0.25	1.50	2.00	San Andrea
Summary	14	22	30	3.14	10.73	14.81	

ni – not investigated.

Table 2. Common weeds found in the rice producing region and herbicides used for weed control in the study

Common weeds in the rice producing region of North Macedonia		
Algae: *Spirogira* spp., *Hydrodiction* spp., *Anabena* spp. Grasses and grass-like: Grasses (fam. Poaceae): barnyard grasses *Echinochloa* spp., rice cut-grass *Leersia oryzoides* (L.) Sw., Indian love-grass *Eragrostis pilosa* (L.) P.Beauv., common reed *Phragmites australis* (Cav.) Trin. **ex Steud.**, **finger grass** *Digitaria* spp., weedy rice *Oryza sativa* L.; Sedges (fam. Cyperaceae): sedges *Cyperus* spp., club-rushes *Scirpus* spp.; Cattails (fam Typhaceae): common (broadleaf) cattail *Typha latifolia* L.; Broadleaf emersed: water plantain *Alisma plantago-aguatica* L. (fam. Alismataceae); mud plantains: *Heterantera reniformis* Ruiz. & Pav. and *Heterantera limosa* (Sw.) Willd. (fam. Pontederiaceae), red stem *Ammannia coccinea* Rottb. Broadleaf submersed: *Potamogeton* sp. (fam Potamogetonaceae);		
Herbicides used in the study		
Herbicide	Active ingredient	Herbicide selectivity
Clincher	Cyhalofop butyil	Grass weeds (Poaceae)
MCPA	Dimethylamine salt	Broadleaf weeds
Roter	Metsulfurom methyl	Broadleaf weeds
Rainbow	Penoxulam	Grasses, sedges and broadleaf weeds
Basagran	Bentazon	Sedges and broadleaf weeds

split applications) included Urea N 46%, Ammonium nitrate 34% N, Calcium ammonium nitrate CAN, NPK 16:16:16 and Bio Star NPK 30:2:2 + 2MgO + 2 Zn.

The common weed management was performed, consisting of control of the water bed level in the field parcels combined with herbicides application against the most common weeds in the rice producing region (Table 2). It should be noted that these are ineffective in terms of weedy rice control, as weedy rice is conspecific with cultivated rice (*Oryza sativa* L.). The application and dosage of the herbicides was performed in compliance with the producer's instructions. Some common weeds in the rice production of North Macedonia are pictured on Figure 1.

At harvest, 3 samples (bundles of whole plants – 1 m^2 above ground biomass) from each field parcel were taken to access the weed infestation and some productive rice properties (Figure 2). The weed tillers were separated in two groups based on the efficacy of herbicide application on their control. Group 1 included the weedy rice morphotypes (*Oryza sativa* L.) which are difficult to control with herbicides,

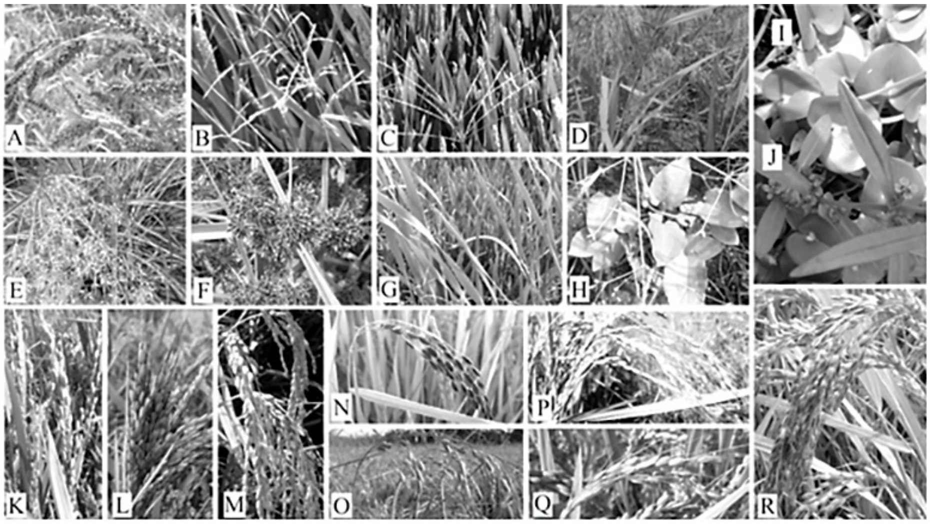

Fig. 1. Common weeds in the rice fields of North Macedonia: A: *Echinochloa* sp., B: *Leersia oryzoides* (L.) Sw., C: *Digitaria* sp., D: *Phragmites australis* (Cav.) Trin. ex Steud., E: and F: *Cyperus* spp., G: *Typha latifolia* L., H: *Alisma plantago-aguatica* L., I: *Heterantera reniformis* Ruiz. & Pav., J: *Ammannia coccinea* Rottb., K to R: the weedy rice complex: WR1200234 (K), WR1323232 (L), WR1311234 (M), WR1313632 (N), WR3311234 (O), WR3321232 (P), WR1321232 (Q), WR1300632(R).

while group 2 included weeds manageable with herbicides, mainly grasses and grass like weeds (members of the Poaceae and Cyperaceae family). The infestation of the weed flora and its components were calculated as follows:

$$TWT/m^2 = WRP/m^2 + OWT/m^2;$$
$$TWI\ (\%) = (WRP/m^2 + OWT/m^2)/\ (WRP/m^2 + OWT/m^2 + NPP/m^2 + NNP/m^2) \times 100$$
$$WRI\ (\%) = (WRP/m^2)/\ (WRP/m^2 + OWT/m^2 + NPP/m^2 + NNP/m^2) \times 100$$
$$OWI\ (\%) = (OWT/m^2)/\ (WRP/m^2 + OWT/m^2 + NPP/m^2 + NNP/m^2) \times 100,$$

where $TWT/m^2$is the total number of weed tillers, $WRP/m^2$is the number of weedy rice panicles while OWT/m^2 is the number of tillers from other weeds found in each 1m^2 crop sample; TWI total weed infestation, WRI weedy rice infestation and OWI – infestation with other weed species; NPP/m^2 – number of productive rice panicles/m^2, NNP/m^2 – number of non-productive rice panicles/m^2.

Fig. 2. Aboveground plant samples of 1 m^2

The following productive properties of the crop were evaluated: total number of rice crop panicles/m^2 (TNP) as sum of the number of productive (ripen) panicles/m^2 (NPP) and number of non-productive (sterile and unripe) panicles/m^2 (NNP), biological yield (BY), paddy rice yield (PRY), straw yield (SY), harvest index (HI) and head rice yield (HRI). The biological, straw and paddy rice yield were calculated as kg/ha. The paddy rice yield was calculated at 14% grain moisture. The head rice yield was determined by milling 100 g paddy rice sample on laboratory milling machine during 1.40 min.

The field parcels results obtained during the 3 years were pooled in 5 groups based on the level of total weed infestation: 0% (weed free parcels), 0.01% to 1.00%, 1.01% to 5.00%, 5.01% to 15.00% and 15.01 to 25.00%. The average results obtained in each group were statistically analyzed in Microsoft Excel by performing correlation analysis. The Pearson correlation coefficient (r) was calculated in order to investigate the correlation of total weed infestation and its components with the productive rice properties, as well the relation between the total weed infestation and its components (weedy rice and other weeds managed with herbicides).

The weedy rice codes were given according to Dimitrovski et al. (2018b), by evaluating the panicle and grain morphology. The codes were given based on the following characteristics: attitude of branches (compactness of the panicle), main axis attitude, awns presence, awns color, lemma and palea color, caryopsis shape and caryopsis color at late observation. Each trait was given a number corresponding to the rating scale given in the Descriptors for wild and cultivated rice (*Oryza* spp.) by Bioversity International, IRRI and WARDA (2007).

The weedy rice morphotypes were evaluated for their recognizability based on the possibility to distinguish the weedy rice morhotypes from cultivated rice by observation of the plant and panicle morpghology in field conditions. A rating scale of 0 to 3 at both early stage (athesis) and late stage (full maturity) was given as follows: 0- the morphotype is hard to distinguish from cultivated rice based only on panicle observation. For exact confirmation the caryopsis color needs to be examined; 1- the morphotype can be recognized after close examination of the panicle morphology in comparison to the rice cultivar; 2- the morhotype is easily distinguished based on 1 panicle trait; 3- easily distinguished based on 2 or more panicle traits.

Results and Discussion

Table 3 presents the average weed infestation and density for the 2017–2019 period. The average weed infestation in 2017 was 5.45% with 21.90 tillers/m^2 (16.05 weedy rice panicles/ m^2 and 5.85 tillers/m^2 from other weeds). The minimum and maximum weed density across all field parcels ranged from 0.33 to 78.00 tillers/ m^2. In 2018, the average weed infestation was 4.75% with density of 26.20 tillers/m^2. 1 of the 22 parcels was weed free, while 2 were free from weedy rice. The highest recorded weed density was 135.66 tillers/m^2. In 2019, 4 out of the 30 field parcels were completely free from weeds and 13 were free from weedy rice. The average weed infestation in the third year was 1.53%

Table 3. Average weed infestation and weed density for the 2017- 2019 period

	2017	min/max	2018	min/max	2019	min/max
TWI (%)	5.45 6.95	0.08 21.88	4.75 6.39	0.00 23.19	1.53 2.39	0.00 10.65
WRI (%)	4.04 5.82	0.08 17.54	3.04 6.00	0.00 22.62	0.73 1.35	0.00 5.08
OWI (%)	1.42 1.54	0.00 4.33	1.71 2.27	0.00 7.87	0.80 1.67	0.00 6.94
TWT/ m^2	21.90 26.30	0.33 78.00	26.20 35.78	0.00 135.66	7.96 13.16	0.00 61.67
WRP/ m^2	16.05 22.43	0.33 69.00	17.05 34.06	0.00 132.33	3.86 7.15	0.00 24.33
OWT/ m^2	5.85 6.01	0.00 14.33	9.15 11.87	0.00 38.33	4.10 9.03	0.00 38.00

Results are yearly average results standard deviation between the field parcels. TWI – total weed infestation, WRI – weedy rice infestation, OWI – infestation with other weed species, TWT/m^2 – total number of weed tillers/m^2, WRP/m^2 – weedy rice panicles/m^2, OWT- tillers/m^2 of other weeds species.

with density of 7.96 tillers/m^2(3.86 weedy rice panicles/m^2 + 4.10 tillers from other weeds). The highest recorded density in 2019 was 61.67 tillers/m^2. Regarding the weed flora components, the average weedy rice density ranged from 3.86 panicles/m^2 in 2019 to 17.05 panicles/m^2 in 2018, while the density of other weeds ranged from 4.10 tillers/m^2 in 2019 to 9.15 tillers/m^2 in 2018. By regions, during all of the 3 years the highest weedy rice infestation was found in the area of Cheshinovo, where rice is extensively cultivated in monoculture, with densities of up to 69.00 panicles/m^2 in 2017, 150 panicles/m^2 in 2018 and 24.33 panicles/m^2 in 2019.

Table 4 presents the results for the infestation level, weed density and productive rice properties obtained during 2017 to 2019 pooled in 5 groups based on the infestation level: 0%, 0.01% to 1.00%, 1.01% to 5.00%, 5.01% to 15.00% and 15.01 to 25.00%. Table 5 presents the correlation among these characteristics. The total weed and weedy rice infestation and density were in significant negative correlation with most of the productive properties of rice, namely the total number of rice crop panicles, the number of productive panicles, the biological yield, harvest index and paddy rice yields.

With the increase of infestation level and total weed density, the crop density decreased (total number of panicles/m^2 and number of productive panicles/m^2), along with the biological yield, harvest index and the paddy rice yield. According to Xu et al. (2017), the net photosynthetic rate, net

Table 4. Weed infestation and density and rice productive properties at different infestation levels

Infestation level	0%	0.01 to 1.00%	1.01 to 5.00%	5.01 to 15.00%	15.01 to 25.00%
TWI (%)	0.00	0.48	2.77	7.99	20.85
WRI (%)	0.00	0.24	1.52	3.48	18.63
OWI (%)	0.00	0.25	1.24	4.51	2.22
TWT/m^2	0.00	2.49	14.19	40.00	100.08
WRP/m^2	0.00	1.23	7.98	16.70	90.75
OWT/m^2	0.00	1.26	6.21	23.30	9.33
NPP/m^2	542.60	512.05	497.37	458.89	381.75
NNP/m^2	3.60	3.76	3.93	4.52	1.67
TRP/m^2	546.20	515.81	501.30	463.41	383.42
BY (kg/ha)	17400.00	16170.00	16684.74	16443.33	13815.00
SY (kg/ha)	7352.00	6737.14	7830.00	7557.78	7275.00
PRY (kg/ha)	10454.44	9750.36	9410.27	9178.55	6763.55
HRY (kg/ha)	64.89	63.84	62.80	64.17	64.58
HI (%)	59.22	59.20	55.28	54.41	47.46
f	5.00	29.00	19.00	9.00	4.00

TWI – total weed infestation, WRI – weedy rice infestation, OWI – infestation with other weed species, TWT/m^2 – total number of weed tillers/m^2, WRP/m^2 – weedy rice panicles/m^2, OWT/ m^2 tillers/m^2 of other weeds species, NPP/ m^2 – number of productive rice panicles/ m^2, NNP/ m^2 – number of non-productive rice panicles/m^2, TRP/m^2 – total number of rice panicles/ m^2. BY – biological yield, SY – straw yield, PRY – paddy rice yield, HRY – head rice yield, Hi – harvest index, f – frequency (number of pooled results in each infestation level group, obtained by three replications per field parcel).

Table 5. Correlation analysis for the examined properties

	TWI	WRI	OWI	TWP	WR	OWS	NPP	NFP	TRP	BY	SY	PRY	HRY
WRI	0.980	1											
OWI	0.523	0.344	1										
TWT	1.000	0.977	0.537	1									
WRP	0.979	1.000	0.341	0.976	1								
OWT	0.436	0.249	0.995	0.451	0.246	1							
NPP	-0.981	-0.942	-0.601	-0.983	-0.941	-0.520	1						
NNP	-0.765	-0.877	0.146	-0.754	-0.878	0.243	0.676	1					
TRP	-0.983	-0.946	-0.591	-0.985	-0.945	-0.510	1.000	0.686	1				
BY	-0.920	-0.948	-0.282	-0.916	-0.949	-0.192	0.925	0.842	0.929	1			
SY	0.080	-0.008	0.410	0.090	-0.005	0.419	-0.082	0.226	-0.077	0.220	1		
PRY	-0.975	-0.975	-0.429	-0.974	-0.976	-0.339	0.979	0.796	0.981	0.968	-0.024	1	
HRY	0.292	0.320	0.008	0.285	0.315	-0.020	-0.149	-0.388	-0.154	-0.186	-0.372	-0.134	1
HI	-0.975	-0.949	-0.539	-0.977	-0.950	-0.454	0.971	0.716	0.972	0.879	-0.255	0.970	-0.110

TWI – total weed infestation, WRI – weedy rice infestation, OWI – infestation with other weed species, TWT – total number of weed tillers/m^2, WRP – weedy rice panicles/m^2, OWT- tillers/m^2 of other weeds species, NPP – number of productive rice panicles/ m^2, NNP – number of non-productive rice panicles/m^2, TRP – total number of rice panicles/ m^2, BY – biological yield, SY– straw yield, PRY – paddy rice yield, HRY – head rice yield, Hi – harvest index. Italicized and bolded results: significant correlation at α0.05. Bolded results: significant correlation at α0.01. R critical: 0.878 (α0.05) and 0.959 (α0.01) at 3 dF. α – level of probability.

assimilation rate, grain filling rate and the grain yield of cultivated rice decreased with increasing weedy rice density.

The weed free conditions (0% infestation) had the highest crop density (546.20 total number of panicles/ m^2 and 542.60 number of productive rice panicles /m^2), the highest biological yield (17400.00 kg/ha), the highest harvest index (59.22%) and highest paddy rice yield of 10454.44 kg/ha.

The negative impact of weed flora on rice productive properties was already detected in the group with the lowest infestation level of 0.01% to 1.00%. The average weed infestation was 0.48% with average density of 1.23 weedy rice panicles/m^2 and 1.26 tillers/m^2 of other weed species. This resulted in a crop density reduction of 30.55 productive panicles/m^2 and drops in paddy rice yield of 1230.00 kg/ha compared to weed free conditions. These results are in accordance with the study by Ottis at al. (2005), who reported white rice yield reductions between 100 and 755 kg/ha for every red rice plant/m^2.

At higher infestation levels (1.01% to 5.00% and 5.01% to 15.00%), the crop density progressively decreased with 497.37 and 458.89 productive panicles/m^2 accordingly, as well as the harvest index (55.28% and 54.41%) and paddy rice yield (9410.27 kg/ha and 9178.55 kg/ha).

The lowest values for the productive rice properties were found in the group of heaviest weed infestation (15.01 to 25.00%): 383.42 total panicles/m^2, 381.75 productive panicles/m^2, 13815.00 kg/ha biological yield, 6763.55 kg/ha paddy rice yield and harvest index of 47.46%. Regarding the weed flora components, the total weed infestation and density were significantly correlated only with the weedy rice infestation and density. The correlation between weeds managed with herbicides and total weeds was not significant. Also, the density and infestation of the weeds managed with herbicides were not significantly correlated to the productive rice properties. Therefore, it can be argued that the weedy rice complex was the main component of the weed flora with significant impact on the productive properties of rice, while the weeds managed with herbicides affected the same traits indirectly, as a contributing component of the weed flora.

These results can be explained by the cultural practices of the region and biology of weedy rice and weed flora. The regulation of water bed depth and application of herbicides was effective in suppression of the common weed flora (grass and grass-like weeds, broadleaf weeds), but they were ineffective against weedy rice. In fact, in the most severe cases of 15.01% to 25.00% infestation the main weed component was weedy rice with density of 90.75 panicles/m^2 or 90.68% of the total weed density, against 9.33 panicles/m^2 of all other weed species. This group consisted of pooled results from field parcels in the Cheshinovo area with extensive rice monoculture. Due to the use of certified seed material free of weedy rice, the seed was excluded as potential source. It may be argued that the main cause of the high weedy rice density was the accumulated soil seedbank from previous years.

Even though the common weed practices performed by the farmers were successful in suppressing the common weed flora, the monoculture led to widespread of weedy rice and caused the highest crop loss with decrease of up to 29.64% productive panicles, 20.60% biological yield, 35.30% paddy rice yield and 19.86% harvest index.

Table 6. Weedy rice recognizability in comparison to cultivated rice

Weedy rice moprhotype	PC	MAA	APC	LPC	Recognizability
WR1200234	Compact	Semi-upright	Awnless	Green (EO) Straw (LO)	EO: 0 LO: 2 (maa)
WR1311234	Compact	Slightly drooping	Partly awned; whitish (EO); straw (LO)	Green (EO) Straw (LO)	EO: 0 LO: 0
WR1313632	Compact	Slightly drooping	Partly awned; black (EO); brown (LO)	Green with purple apex (EO) Brown furrows (LO)	EO: 2 (apc) LO: 3 (apc; lpc)
WR3311234	Semi-compact	Slightly drooping	Partly awned; whitish (EO); straw (LO)	Green (EO) Straw (LO)	EO: 1 (pc) LO: 1 (pc)
WR1321232	Compact	Slightly drooping	Fully awned; whitish (EO); straw (LO)	Green (EO) Straw (LO)	EO: 2 (apc) LO: 2 (apc)
WR1323232	Compact	Slightly drooping	Fully awned; red (EO); brown (LO)	Green (EO) Straw (LO)	EO: 2 (apc) LO: 2 (apc)
WR1300632	Compact	Slightly drooping	Awnless	Green with purple apex (EO) Brown furrows (LO)	EO: 1 (lpc) LO: 2 (lpc)
WR3321232	Semi-compact	Slightly drooping	Fully awned; whitish (EO); straw (LO)	Green (EO) Straw (LO)	EO: 3 (pc; apc) LO: 3 (pc; apc)
San Andrea	Compact	Slightly drooping	Awnless to partly awned; whitish (EO); straw (LO)	Green (EO) Gold (LO)	
Onice	Compact	Slightly drooping	Awnless	Green (EO) Gold (LO)	

The weedy rice codes were given according to Dimitrovski et al. (2018). PC – panicle compactness; MAA – main axis attitude; APC –awns presence and color; LPC – lemma and palea color; EO – early observation; LO – late observation. Rating scale: 0: the morphotype is hard to distinguish from cultivated rice based only on panicle observation (caryopsis color must be observed for confirmation); 1: distinguished after close panicle observation in comparison to cultivated rice; 2: easily distinguished based on 1 trait; 3: easily distinguished based on 2 or more traits.

Some key morphological traits of the weedy rice complex are presented in Table 6. The recognizability varied depending on the morphotype morphology. Four types were readily distinguished from cultivated rice as early as anthesis due to the awning characteristics. While the cultivar Onice is awnless and San Ansrea is awnless to partly awned with very short awns 1 to 10 mm long appearing rarely and randomly, the weedy types WR1321232, WR1323232 and WR332123 were fully awned, with longer awns of about 10 to 50 mm. WR1313632 which is partly awned was also easily distinguished at early observation by the black awns and green hulls with purple apex.

As the grain matures the color changed to black furrows on green base, black-brown color to brown stripes at full maturity. WR1300632 an awnless type with a similar hull color progression as WR1313632 was distinguished at anthesis after close examination of the panicle, while in the later stages was easily recognized as the hull color changed. WR3311234 was identified only after close inspection, by the semi-compact panicle and lower number of grains compared to cultivated rice. WR1200234, an awnless morphotype was difficult to distinguish from cultivated rice at athesis. At maturity, this type was easily observed due to the panicle main axis attitude while cultivated rice had slightly drooping panicles, the main panicle of this morphotype was semi-upright and the secondary panicles were upright to semi upright. The most difficult morphotype to recognize even with close inspection was WR1311234, which was most similar in appearance to cultivated rice. The most distinct feature in comparison to cultivated rice was the pigmented pericarp, which could only be observed after pealing the hulls of the grain to expose the caryopsis.

Conclusions

The common weed management practice in North Macedonia- combination of the water level regulation with herbicides application is effective against the common weeds species found in the region. However, it does not take into consideration the biology of weedy rice moprhotypes present in the region, which in combination with the extensive monoculture and abandonment of hand weeding as a cultural practice has led to widespread of weedy rice. This weed was widespread across all inspected villages from the rice producing region. The weed flora and weedy rice infestation negatively affected most of the productive properties, ultimately causing grain yield loss of up to 35.30% in the most severe cases were weedy rice was the dominant weed component with density of 90.75 weedy rice panicles per m^2. Some of the weedy rice morphotypes were easily recognized from cultivated rice in field conditions as early as anthesis, while others were more difficult to distinguish. This study confirms that weedy rice represents a major threat for the rice production in this region if not properly managed. For effective management of weedy rice in this region, further studies should be undertaken in order to study the biology of weedy rice populations inhabiting the region, and the most suitable practices for its management.

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