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ASSESSMENT OF SPRING BARLEY POPULATIONS IN COMPARISON TO HOMOGENOUS VARIETIES

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Abstract

The necessity to increase genetic diversity in agriculture has been widely discussed during the last decades. Heterogeneous populations is one of the ways to increase genetic diversity in varieties of self-pollinating cereals. The aim of this research was to compare grain yield, its stability, foliar diseases severity and competitiveness against the weeds of spring barley (*Hordeum vulgare*) populations and homogenous varieties. Field trials consisting of three types of populations (simple, complex and composite cross populations – CCP) containing different levels of diversity and three check varieties were carried out during 2015-2018 under organic and conventional farming systems. No one of the populations had a significantly higher average yield than any of the check varieties. CCP1 showed a tendency to be more productive under organic growing conditions and can be characterized as widely adaptable to various growing conditions with a significantly higher yield as the average overall environments. One of the complex populations showed adaptability to favorable growing conditions and yield insignificantly higher than overall average. Other studied populations can be characterized with wide adaptability and various yield levels. For most of the populations under organic and conventional conditions, a significantly lower net blotch (caused by *Pyrenophora teres)* severity was observed in comparison with the most susceptible variety; infection with powdery mildew (caused by *Blumeria graminis)* lower than for check varieties was observed under organic growing conditions, whereas such trend was not observed under conventional conditions. All populations had a significantly lower crop ground cover and slightly lower competiveness against weeds than the variety with the best competitiveness.

Key words: populations, yield, yield stability, leaf diseases, competitiveness against weeds.

Introduction

Since the first half of the past century, the trends in agriculture, plant breeding and variety legislation have tended towards an increased use of genetically uniform varieties. The genotypes selected for good performance under high-input conditions do not necessarily perform very well in marginal environments or in organic farming systems (Murphy *et al.*, 2005). Such genetically uniform varieties are inappropriate to overcome unpredictable environmental changes because their response to environmental fluctuations is not buffered by genetic diversity. Increasing genetic diversity in crops can ensure yield stability, reduce spread of diseases, and improve competitive ability against weeds. For the self-pollinating cereals the solution is creation of composite cross populations (CCP) which include high levels of diversity if compared to pure line varieties (Döring *et al.*, 2011). They are created by crossing a group of varieties in all possible combinations, then growing over years as a bulk population and exposed to natural selection. The varieties with different useful characteristics having potential to dynamic adaptation to growing conditions are used in crossing. The diversity of the genotypes in the population is not permanent. The number of plants with good adaptability over time is increasing and resulting in a better overall performance of CCP (Suenson, 1956; Döring *et al.*, 2011). Due to changes in populations, there is no possibility to obtain and market constant seed material (Brown, Caligari, & Campos, 2014).

At the beginning of the 20th century, Harry Harlan began to make CCPs from many diverse barley (*Hordeum vulgare*) varieties originating from the whole world. These populations were planted under standard agronomic conditions over a period of 50 years. Results from numerous studies on these populations show steady increases over generations in grain yield, disease resistance and yield stability, however, in comparison with commercial or control varieties the yield was only 78 – 85% (Soliman & Allard, 1991; Danquah & Barrett, 2002). CCPs based on 20 diverse winter wheat (*Triticum aestivum*) parents were developed in the UK starting from 2002, and they are researched in a number of studies in different countries now (Kassie, 2013; Döring *et al.*, 2015; Brumlop, Pfeiffer, & Finckh, 2017). CCP's are created and investigated also in Italy (Raggi *et al.*, 2017). The results of these studies suggest that populations can ensure better yield stability, but there are different results regarding to disease control and competitiveness against weeds. However, in comparison with other topics on agriculture, there are only a few published research results on CCPs.

The aim of the study was to evaluate the yield, yield stability, foliar diseases severity and competitiveness against weeds of three types of barley populations: simple (cross of two parents), complex (more than two parents crossed step by step) and composite cross populations (CCPs) if compared with homogeneous varieties currently grown in organic farming in Latvia.

Materials and Methods

The study covers 11 populations of spring barley (*Hordeum vulgare*), including four simple (SPs), five complex (CPs) and two composite cross populations (CCPs), containing different levels of diversity (Table 1). To compare the yield, yield stability, foliar diseases severity, as well as competitiveness against weeds, three commercial check varieties bred in Latvia were used: 'Rubiola' – released for growing under organic conditions, 'Rasa' – control variety in official trials for testing of value for cultivation and use (VCU) under organic growing conditions, and 'Abava' – characterized as variety with good adaptability to various environments.

The field trials were carried out at Institute of Agricultural Resources and Economics in Priekuli (latitude 57.3148 ° N, longitude 25.3388 ° E) and Stende (latitude 57.1412 ° N, longitude 22.5367 ° E) during 2015-2018 under both conventional (C) and organic (O) growing conditions. Lattice experimental design with four replications was applied. Plot size was 12.3 m^2 in Priekuli and 5.2 m^2 in Stende, seed rate 400 untreated germinable seeds per m^2. The field trial in Stende under O growing conditions in 2015 was significantly damaged by heavy rainfall after sowing, but under C conditions in 2018 was not established. In overall, the data of seven C and seven O environments were obtained. The soil in all locations was sod-podzolic loamy sand (Kārkliņš, 2008). The agrochemical properties of the soil during investigations under C conditions were in range: pH KCL 5.3-6.1, organic matter content 1.8 – 2.3%, K_2O 136-167 mg kg^{-1}, P_2O_5 120-143 mg kg^{-1}; and under O conditions: pH KCL 5.7-6.3, organic matter content 1.9 – 2.4%, K_2O 111-167 mg kg^{-1}, P_2O_5 163-177 mg kg^{-1}. Pre-crop in all C environments had been potatoes (*Solanum tuberosum*); in O locations pre-crop in Priekuli had been grain legumes and in Stende – buckwheat (*Fagopyrum esculentum*) with one exception in 2015, when the pre-crop had been spring wheat (*T. aestivum*). Before sowing, in C sites complex mineral fertilizer was applied ensuring the following amounts of pure elements: in Priekuli N 95-108, P_2O_5 55-70, K_2O 45-93, in Stende N 75-80, P_2O_5 75-80, K_2O 75-80 kg ha^{-1}. In the plant tillering stage (GS 21-29), harrowing was performed in O growing sites with an aim to restrict weeds, but in C growing sites herbicide was applied. In Priekuli, in natural infection background during the vegetation period, the infection with foliar diseases was visually assessed as follows: powdery mildew caused by *Blumeria graminis* and net blotch caused by *Pyrenophora teres* in scores from 0 to 9, where 0 – no visible symptoms of disease, 9 – no green tissues of plants observed. The progress of the disease was described by the size of area under the disease progress curve (AUDPC) (Tratwal *et al.*, 2007). The assessment was started at the occurrence of the first disease symptoms with an interval of 7 to 9 days. To evaluate competitiveness against weeds under O growing conditions in Priekuli, in two barley development stages (GS 25-29, GS 29-31) the visual assessment of crop ground cover and in three barley development stages (GS 31-39, GS 59-65, GS 87-92) the visual assessment of weed ground cover was carried out. The weed suppression ability for each genotype was calculated as a difference between the weed ground cover in plots and maximum growth of weed in plots without crop, expressed in percentage (Hoad, Topp, & Davies, 2008).

The obtained data was processed by using analysis of variance ANOVA and General Linear Model. The data processing was performed using the software SPSS Statistic 17. The methodology used to evaluate the yield stability is based on Eberhart & Russel (1966) and Fox *et al.* (1990), and has been described in detail in our previous paper (Ločmele *et al.*, 2017b).

Meteorological conditions during the investigation differed not only between the years, but also between the field trial locations. Conditions in 2015 and 2016 were described in the previous study (Ločmele *et al.*, 2017b). In 2017, cold and wet weather conditions in the last decade of April delayed sowing both in Priekuli and Stende, and it was started only in the early May. In Priekuli, there was an increased precipitation

Table 1

Characteristics of populations

Population	Type of population	Number of parents and generation (F) in 2015-2018
SP1; SP2	simple	Two parents, $F_{12} – F_{15}$
SP3; SP4	simple	Two parents, $F_5 – F_8$
CP1; CP4	complex	Three parents, $F_6 – F_9$ and $F_5 – F_8$
CP2; CP3	complex	Seven and six parents, $F_6 – F_9$
CP5	complex	Eight parents consecutively crossed to male sterile sample, $F_4 – F_7$
CCP1	composite	Dialell crosses among group of 10 parents, bulked, $F_3 – F_6$
CCP3	composite	10 parents crossed to 5 male sterile samples, bulked, F_3 – F6

during the whole vegetation period (11 – 153% above the long-term data (norm)), as well as lower average air temperature than the norm (by 0.1 – 3.3 °C). In July, the precipitation was in the form of several heavy rainfalls that caused early lodging of cereals. In general, the conditions prolonged the plant vegetation period, as well as made it more difficult to determine the actual occurrence of maturity. In Stende, over the vegetation period, the temperature deviations by decades were close to the norm. The precipitation was lower than norm, only in June it was at the level of long-term data. In 2018, the meteorological conditions had a significantly negative impact on the plant development. Both locations were characterized by low precipitation, reaching on average 64% of the norm in Priekuli and 35% in Stende over the growing season, causing drought stress to the plants. The air temperature was above the long-term observations on average by 3.6 °C in Priekuli and 2.7 °C in Stende.

Results and Discussion

Yield and yield stability

Significant differences were observed in yield levels between the growing sites ($p<0.05$); therefore the evaluation of population yield in comparison with check varieties has been analysed separately in each site. The yield of check varieties in both locations under O growing conditions was without significant differences, but under C growing conditions 'Rubiola' significantly out-yielded the others, with the exception in 2018, when the yield of 'Abava' was significantly higher.

Simple populations (SPs) under O growing conditions only in some cases slightly exceeded the yield of check varieties. In most cases they had lower yields than checks. For example, in Priekuli, SPs yield slightly exceeded the yield of variety 'Rasa' in nine cases out of 16 (4 sites × 4 populations = 16), but in comparison with the varieties 'Rubiola' and 'Abava' – in none of the cases (Table 2).

Under C growing conditions, the yield of SPs varied to a greater extent, showing in some cases a significant increase, but this was found in comparison with only one or rarely two check varieties, as well as in one particular site. Also under C conditions, in most cases the yield of SPs was lower than that of check varieties; it was particularly expressed in Stende, where SPs yield was significantly lower than that of the best yielding variety 'Rubiola' in all cases (Table 2). We have not found information in literature that such type of populations have been created and investigated. Two of the populations included in this study along with eight simple wheat populations were investigated by V. Strazdina with colleagues (Strazdiņa *et al.*, 2012), and she came to a conclusion that their yield varied between the yield of parent

Table 2

Range of barley population yield, t ha^{-1}, and comparison with check varieties during 2015-2018

Growing site	Type of population	Yield*	Comparison with check variety					
			Abava		Rasa		Rubiola	
			yield*	+/-**	yield*	+/-**	yield*	+/-**
Priekuli O$^{\&\&}$ n=4	simple n=4	2.23-3.34	2.78 – 3.25	-16	2.19 – 3.07	-7; +9	2.20 – 3.59	-16
	complex n=5	2.21-3.53		-18(**4**)$^{\&}$;+2		-4;+16(**2**)		-13(**1**);+7
	CCP1	2.79-3.87		+4		+4(**1**)		+4(**1**)
	CCP3	2.36-3.30		-3;+1		-2;+2(**1**)		-3;+(**1**)
Stende O n=3	simple n=4	2.23-4.01	2.25 – 4.12	-8;+4	2.25 – 4.15	-11;+1	2.46 – 4.71	-11(**4**);+1
	complex n=5	2.18-4.37		-8(**1**);+7		-8;+7(**1**)		-10(**3**);+5
	CCP1	2.71-4.58		-1;+2		-1;+2		-2;+1
	CCP3	2.54-4.22		-2;+1		-2;+1		-2;+1
Priekuli C$^{\&\&}$ n=4	simple n=4	3.13-5.48	3.88 – 5.52	-11(**1**);+5(**4**)	3.57 – 5.39	-9(**4**);+7(**2**)	3.34 – 5.93	-15(**11**);+1
	complex n=5	3.15-5.54		-12(**3**);+8(**5**)		-6;+14(**5**)		-18(4);+(**2**)
	CCP1	4.39-5.78		+4(**1**)		+4(**1**)		-2(**1**);+2(**1**)
	CCP3	3.47-5.43		-2(**1**);+2(**1**)		-2;+2(**1**)		-3(**1**);+1
Stende C n=3	simple n=4	5.09-7.00	5.16 – 6.28	-6;+6	5.57 – 6.40	-7(**4**);+5(**1**)	6.47 – 8.26	-12(**12**)
	complex n=5	5.37-6.53		-2;+13(**6**)		-7(**4**);+8(**2**)		-13(**12**);+2
	CCP1	6.04-6.81		+3(**2**)		-1;+2		-3(**1**)
	CCP3	5.86-6.56		+3(**1**)		-1;+2		-3(**1**)

*min and max values; ** number of cases when yield was lower (-)/higher (+) than that of check variety; $^{\&}$ in brackets in bold – number of cases when differences are significant ($p<0.05$); $^{\&\&}$O – organic, C – conventional.

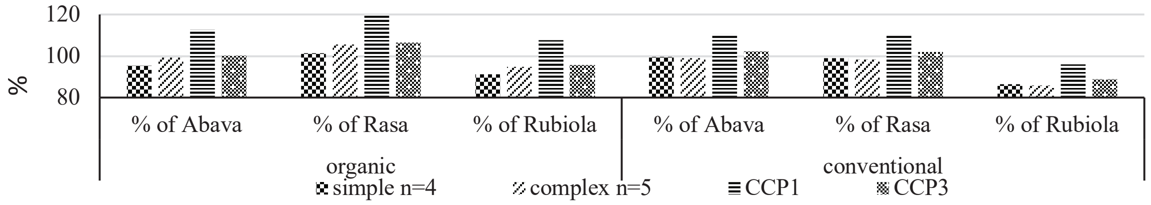

Figure 1. Comparison (in %) of average yield between populations and check varieties over organic (n=7) and conventional (n=7) sites during 2015-2018.

varieties, rarely insignificantly exceeding the yield of the best yielding parent variety. It could be explained with the relatively low diversity of these populations (Ločmele *et al.*, 2017a).

The yield of the complex populations (CPs) varied both in O and C growing conditions, showing some significant differences in comparison with the checks, but, the same as with SPs, differences were significant in comparison with one or rarely two varieties in one site of the trial. Only CP1 was significantly higher yielding than 'Abava' under C conditions in Stende in all three years, and if compared with 'Rasa' – in two years. In Priekuli, this population had a significantly higher yield than mentioned varieties in one out of four years of the trial. No information on creation and investigation of such type of populations has been found in literature.

Raggi *et al.* (2017) reported that two winter barley CCPs significantly out-yielded check varieties under O conditions, while no significant differences were observed under C conditions. In our investigation in Priekuli, CCP1 yielded more than all check varieties under O growing conditions, showing some significant differences ($p<0.05$) (Table 2). In Stende, its yield in some cases was insignificantly lower than the yield of check varieties under O conditions. Under C conditions, the yield of this population was higher than that of check varieties in most cases, showing some significant advantages (Table 2). Differences of CCP1 performance between both O locations can probably be explained by the fact mentioned in literature that growing the population under the particular growing conditions year by year leads to its adaptation to these conditions (Döring *et al.*, 2011). In Stende, this effect could not be observed because the seed for trial was prepared from the material grown in Priekuli. The yield of CCP3, like CPs, under O and C conditions varied in comparison with checks, showing some significant differences if compared to one or two check varieties. Döring *et al.* (2015) reported an average yield increase of wheat CCPs by 2.4% over 12 sites in comparison with the average yield of parent varieties. In our investigations, the average yield of SPs, CPs and CCP3 over seven O sites exceeded only the variety with the lowest yield – 'Rasa' by 1 – 7%. Whereas CCP1 exceeded all check varieties by 8 – 20% (Figure 1). Under C conditions, the average yield of SPs and CPs over seven environments was lower than that of all check varieties, but the average yield of CCP3 exceeded varieties 'Abava' and 'Rasa' by 2%. CCP1 also out-yielded 'Abava' and 'Rasa' under C conditions by 11% and 10%, respectively, but was slightly behind the variety 'Rubiola'.

The check varieties used in the study can be described as diverse regarding their adaptability: 'Rubiola' – with adaptability to high yielding sites (coefficient of regression $b>1$), 'Rasa' – with wide adaptability ($b=1$) and 'Abava' – with adaptability to low yielding sites ($b<1$), according to the data from 14 sites. The average yield of variety 'Rubiola' was significantly higher than average per 14 sites (4.16 t ha^{-1}), but that of varieties 'Rasa' and 'Abava' – at a level of average (Table 3). The significantly higher yield than overall average and a wide adaptability was found for CCP1. The results of other investigations demonstrate that barley and wheat CCPs can achieve more stable yield than pure line varieties (Soliman & Allard, 1991; Döring *et al.*, 2015; Raggi *et al.*, 2017). Most of CPs and CCP3 also showed yield above the average and wide adaptability, whereas CP1 can be characterized as suitable for high yielding sites ($b>1$). The yield of other populations was below the average yield per 14 sites; SP1 and CP3 provided a significantly lower yield level (Table 3). When evaluating the yield stability by ranking method, 'Rubiola' and CP1 ranked at the top of genotype range in most of the C sites (Table 3), while being lower ranked in O sites; this is according to the previously described adaptability of these genotypes to high yielding sites. Under O growing conditions, 'Rubiola' in most of the cases was at the upper third of genotype range, but the population CCP1 was in the top range in all O sites; this demonstrates the specific adaptation of this population to O growing conditions. In general, comparing the types of populations, most of SPs and CPs rarely rank at the upper third of genotype range. The differences in the yield of the populations can probably be explained by different genetic material applied. In creation of CCP1, 10 parent genotypes were diallely crossed in all possible combinations, and it contains a greater genetic diversity than SPs and CPs (Mežaka & Legzdiņa, 2018). CCP3 theoretically can contain the greatest diversity in comparison with other populations included in this study because parent

Table 3

Average yield of populations and check varieties over 14 sites, and the yield stability indicators

Genotype	Average yield, t ha^{-1}	Coefficient of regression (b)	Deviation from regression (s^2 dj)	Number of rankings					
				Organic (n=7)			Conventional (n=7)		
				I***	II***	III***	I	II	III
CCP 1	4.52**	0.93	0.08	7	–	–	5	2	–
Rubiola	4.51**	1.22*	0.14	5	1	1	5	2	–
CP4	4.37	0.91	0.07	6	1	–	4	2	1
CP1	4.34	1.19*	0.09	2	5	–	5	1	1
CP5	4.20	1.07	0.10	3	1	3	5	1	1
CCP 3	4.17	1.01	0.03	2	4	1	2	5	–
Abava	4.17	0.84*	0.10	5	1	1	2	2	3
CP2	4.15	0.99	0.03	2	4	1	1	5	1
Rasa	4.11	1.01	0.10	1	4	2	3	2	2
SP3	4.08	0.99	0.04	–	3	4	1	3	3
SP4	4.07	1.01	0.05	–	6	1	2	3	2
SP2	3.98	0.89*	0.04	2	1	4	–	2	5
SP1	3.82**	0.89*	0.05	–	3	4	–	–	7
CP3	3.81**	1.01	0.07	–	1	6	–	3	4

*significantly different from 1 ($p<0.05$); ** significantly different from average yield (4.16 t ha^{-1}) over 14 sites ($p<0.05$) ($LSD_{0.05}=0.23$); ***ranked in the upper (I), middle (II) and lower (III) third.

plants with male sterility possessing larger diversity themselves were used in crossings; during the first generations of population growing, thanks to the male sterility the cross-pollination was also possible (Ločmele *et al.*, 2017a). Differences in yields of both CCPs were probably influenced by the presence of low yielding male sterile plants and greater diversity of CCP3; in literature it is mentioned that a very large diversity causes competition between different plants that may negatively affect the yield (Döring *et al.*, 2011). The important factor is also the possible differences between the yield potential of parents used for creation of populations that can be greater for CCP1 (Ločmele *et al.*, 2017a). It is due to the fact that choice of parent plants for creation of populations determines their performance to a much greater extent than growing conditions to which these populations are subjected (Brumlop, Pfeiffer, & Finckh, 2017). Comparing the types of populations (simple, complex and CCPs) mutually, it was concluded that the average yield over 14 sites was significantly lower for SPs than for CPs and CCPs. Population types have different levels of genetic diversity, therefore we can conclude that greater genetic diversity in combination with appropriate parent yield potential can ensure better yield performance of the population.

Foliar diseases

The highest severity of net blotch was observed in 2015, when the average AUDPC value was 232 under C conditions, and 170 – under O conditions. During the other three years of investigation, it was on average 56 – 134 under C conditions and 31 – 53 under O conditions. The variety 'Abava' in most cases was infected significantly more than 'Rasa' and 'Rubiola'. Despite the differences in disease level between the years, populations were significantly less ($p<0.05$) infected in most cases if compared with check varieties, demonstrating a number of significant differences (Table 4).

Similarly, Maroof *et al.* (1983), while investigating barley CCPs created in the 20th century regarding thenet blotch and powdery mildew, has concluded that they can achieve higher resistance than the parent varieties. In contrast, for wheat CCPs, it was not found that the spread of foliar diseases decreases in populations in comparison with checks and mixture of parent varieties (Döring *et al.*, 2015).

Infection with powdery mildew under O conditions in Priekuli was observed only in 2015. The disease severity was not significantly different between check varieties. Infection of the populations was insignificantly lower in most cases (data not shown), but, since the results were obtained only in one year, convincing conclusions cannot be made. Under C conditions, powdery mildew was observed in small amounts in three years out of four. In 2018, it was not observed due to warm and rainless weather conditions. In 2015, significant differences between the powdery mildew severity of check varieties were not observed under C conditions, but in 2016 and 2017, the variety 'Abava' was infected significantly more. Only SP2 was infected significantly higher than all

Table 4

Range of population infection with foliar diseases and comparison with check varieties during 2015-2018

Growing site, Disease	Type of population	Range of AUDPC*^	Comparison with check					
			Abava		Rasa		Rubiola	
			AUDPC*	+/-**	AUDPC	+/-	AUDPC	+/-
Priekuli O[&&] n=4 net blotch	simple n=4	21–178	67 – 220	-16(**15**)[&]	39 – 197	-16(**8**)	32 – 184	-16(**6**)
	complex n=5	23–176		-20(**19**)		-19(**5**);+1		-18(**6**);+1
	CCP1	13–160		-4(**3**)		-4(**3**)		-4(**3**)
	CCP3	28–184		-4(**2**)		-4(**2**)		-4(**1**)
Priekuli C[&&] n=4 net blotch	simple n=4	45–247	117 – 296	-16(**16**)	81 – 263	-15(**10**);+1	67 – 220	-7(**3**);+9
	complex n=5	41–238		-20(**20**)		-20(**10**)		-11(**3**);+9
	CCP1	53–214		-4(**4**)		-4(**4**)		-3(**1**);+1
	CCP3	47–214		-4(**4**)		-4(**4**)		-4(**1**)
Priekuli C n=3 powdery mildew	simple n=4	3–151	11 – 61	-6(**3**);+6(**2**)	1 – 88	-5;+7(**3**)	0 – 82	-5;+7(**2**)
	complex n=5	0–116		-12(**7**);+3		-9;+6(**1**)		-9;+6(**1**)
	CCP1	6–118		-2;+1(**1**)		+4(**1**)		+3
	CCP3	8–119		-2;+1(**1**)		+3(**1**)		+3

*min and max values; **number of cases when infection level was lower (–)/higher (+) than that of check variety; [&] in brackets in bold – number of cases when differences are significant ($p<0.05$); [&&]O – organic, C – conventional; ^ area under disease progress curve.

check varieties in all C growing sites. Obtained results for other populations varied, and the trend that any of populations is more resistant against powdery mildew was not observed (Table 4). Despite the different levels of genetic diversity of population types, we did not get any evidence that severity with net blotch and powdery mildew was affected by the types.

Crop ground cover and weed suppression ability

At the beginning of plant development, the crop ground cover is one of the most essential indicators related to good competitive ability against weeds (Hoad, Topp, & Davies, 2008). Significantly greater four-year-average crop ground cover among check varieties was observed for 'Abava' in GS 25-29 and GS 29-31: 15 and 22%, respectively. All populations in both growth stages, except CP4 in GS 25-29, showed a significantly lower crop ground cover if compared with 'Abava'. Crop ground cover of populations varied, either slightly exceeding or not reaching indicators of 'Rasa' and 'Rubiola' (data not shown). Kassie (2013) also has found a better crop ground cover for check varieties than for wheat CCPs. The weed suppression ability in GS 31-39 and GS 59-65 did not differ significantly between the check varieties, but in GS 87-92 it was significantly higher for the check variety 'Abava'. In GS 31-39 for all populations, insignificantly lower average weed suppression ability than that of 'Abava' and 'Rubiola' was observed, but in GS 59-65 and GS 87-92, it was slightly lower than that of variety 'Abava' (data not shown). It is possible that over generations of the populations their competiveness may improve, because Bertholdsson *et al.* (2016) concluded that traits of early vigour of plants were improved after five years. However, this contradicts another study where this parameter decreased over generations (Kassie, 2013).

There were no differences between types of populations regarding the crop ground cover and weed suppression ability, indicating that these traits were not affected by the level of diversity.

Conclusions

1. No population significantly out-yielded all check varieties in any of 14 sites. Significant differences were observed in some cases in comparison with one, or rarely two, check varieties within site. For CCP1 a trend was observed to out-yield the check varieties under organic growing conditions in location Priekuli.
2. CCP1was the most stable of 11 populations and ranked highest under organic growing conditions. The trend to produce above average and wide adaptability were observed also for two complex populations (CP4, CP5) and CCP3, whereas CP1 was characterized by an adaptability to high yielding environments.
3. For most of populations under both growing conditions a significantly lower severity of net blotch was observed in comparison with the most infected variety 'Abava', and in most cases it was insignificantly lower than that of 'Rasa'

and ‘Rubiola’; severity of powdery mildew of one SP was significantly higher than that of all check varieties in C growing sites, but varied for other populations, not indicating that some of the populations would be more resistant against powdery mildew.

4. The crop ground cover of all populations was significantly lower, but the weed suppression ability – slightly lower if compared with the variety ‘Abava’.
5. Populations containing a greater genetic diversity (CPs and CCPs) could ensure a better yield performance than populations with lower diversity level (SPs). Evidence that severity of foliar diseases and competiveness against weeds would be affected by population types was not observed.

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References

1. Bertholdsson, N.O., Weedon, O., Brumlop, S., & Finckh, M.R. (2016). Evolutionary changes of weed competitive traits in winter wheat composite cross populations in organic and conventional farming systems. *European Journal of Agranomy,* 79, 23–30. DOI: 10.1016/j.eja.2016.05.004.
2. Brown, J., Caligari, P., & Campos, H. (2014). Plant Breeding (2nd ed.). United Kingdom: Wiley Blacwell.
3. Brumlop, S., Pfeiffer, T., & Finckh, M.R. (2017). Evolutionary effects on morphology and agronomic performance of three winter wheat composite cross populations maintained for six year under organic and conventional conditions. *Organic Farming*, 3 (1), 34–50. DOI: 10.12924/of2017.03010034.
4. Danquah, E.Y., & Barrett, J.A. (2002). Grain yield in Composite Cross Five of barley: effects of natural selection. *Journal of Agricultural Science*, 138(Ccv), 171–176. DOI: 10.1017/s0021859601001678.
5. Döring, T.F., Annicchiarico, P., Clarke, S., Haigh, Z., Jones, H.E., Pearce, H., … Wolfe, M.S. (2015). Comparative analysis of performance and stability among composite cross populations, variety mixtures and pure lines of winter wheat in organic and conventional cropping systems. *Field Crops Research*, 183, 235–245. DOI: 10.1016/j.fcr.2015.08.009.
6. Döring, T.F., Knapp, S., Kovacs, G., Murphy, K., & Wolfe, M.S. (2011). Evolutionary plant breeding in cereals – into a new era. *Sustainability*, 3(10), 1944–1971. DOI: 10.3390/su3101944.
7. Eberhart, S.A., & Russel, W.A. (1966). Stability parameters for comparing varieties. *Crop Science*, 6(1), 36–40. DOI: 10.2135/cropsci1966.0011183X000600010011x.
8. Fox, P.N., Skovmand, B., Thompson, B.K., Braun, H.J., & Cormier, R. (1990). Yield and adaptation of hexaploid spring triticale. *Euphytica,* 47, 57–64.
9. Hoad, S., Topp, C., & Davies, K. (2008). Selection of cereals for weed suppression in organic agriculture: A method based on cultivar sensitivity to weed growth. *Euphytica,* 163(3), 355–366. DOI: 10.1007/s10681-008-9710-9.
10. Kassie, M.M. (2013). *Comparison of several generations of winter wheat composite cross populations with modern cultivar under organic farming*. Doctoral dissertation, Wageningen University, Wageningen, The Netherlands.
11. Kārkliņš, A. (2008). *Augsnes diagnostika un apraksts* (*Guidelines for soil diagnosis and description*). Jelgava: LLU. (in Latvian)
12. Ločmele, I., Legzdiņa, L., Gaile, Z., & Kronberga, A. (2017a). Vasaras miežu populāciju un viendabīgu šķirņu ražas salīdzinājums (Yield comparison of spring barley populations and homogeneous varieties). In Proceedings of the Scientific and Practical Conference ‘Harmonious Agriculture – 2017’, 23 February 2017 (pp. 64–68). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. (in Latvian)
13. Ločmele, I., Legzdiņa, L, Gaile, Z., & Kronberga, A. (2017b). Estimation yield and yield stability of spring barley genotype mixtures. In Annual 23nd International Scientific Conference proceedings ‘Research for Rural Development 2017’, 17-19 May 2017 (pp. 19–25). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/rrd.23.2017.044.
14. Maroof, M.A.S., Webster, R.K., & Allard, R.W. (1983). Evolution of resistance to scald, powdery mildew, and net blotch in barley composite cross II populations. *Theoretical and Applied Genetics*, 66, 279–283. DOI: 10.1007/BF00251159.
15. Mežaka, I., & Legzdiņa, L. (2018). Effect of farming system on genetic diversity of spring barley populations. In Environmental and Experimental Biology Abstracts of the 7th Baltic Genetics Congress, 24-27 October 2018 (pp. 231). Riga, Latvia: University of Latvia.

16. Murphy, K., Lammer, D., Lyon, S., Carter, B., & Jones, S.S. (2005). Breeding for organic and low-input systems: an evolutionary – participatory breeding method for inbred cereal grains. *Renewable Agriculture and Food Systems.* 20(1), 48–45. DOI: 10.1079/RAF200486.
17. Raggi, L., Ciancaleoni, S., Torricelli, R., Terzi, V., Ceccarelli, S., & Negri, V. (2017). Evolutionary breeding for sustainable agriculture: Selection and multi-environmental evaluation of barley populations and lines. *Field Crops Research,* 204, 76–88. DOI: 10.1016/j.fcr.2017.01.011.
18. Soliman, K.M., & Allard, R.W. (1991). Grain yield of composite cross populations of barley: effects of natural selection. *Crop Science,* 31(3), 705–708. DOI: 10.2135/cropsci1991.0011183X003100030032x.
19. Strazdiņa, V., Beinaroviča, I., Legzdiņa, L., & Kronberga, A. (2012). Are there any advantage of genetically diverse material in cereal breeding programmes for organic farming? *Proceedings of The Latvian Academy of Science,* 66(4/5), 152–162. DOI: 10.2478/v10046-012-0022-z.
20. Suenson, C.A. (1956). An evolutionary plant breeding method. *Agronomy Journal,* 48, 188–191. DOI: 10.2134/agronj1956.00021962004800040012x.
21. Tratwal, A., Law, J., Philpott, H., Horwell, A., & Garner, J. (2007). The possibilities of reduction of winter barley chemical protection by growing variety mixtures. Part II. Effect on yield. *Journal of Plant Protection Research,* 47(1), 79–86.