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IMPACTS OF DIFFERENT APPROVAL AGES AT SPRING WHEAT VARIETIES ON YIELD AND PLANT HEALTH

SUMMARY

Wheat is an important crop to meet the increasing demand for food and fodder. In Germany, it is the most common cereal crop, but only small area is cultivated with spring wheat. However, within the system of organic agriculture this acreage share is considerably higher. Diversified crop rotations with balanced proportions of summer and winter crops are an essential part of organic production systems. Thus, there is a need for varieties with potential under less intensive conditions.

In a field trial, breeding progress among 7 European spring wheat varieties with different ages of approval (1949-2011) was investigated at two study sites in Germany and Russia. Newer varieties showed at both sites significant better yields (2 to 4 times higher) than the oldest one. Better lodging resistance as well as lower vulnerability to powdery mildew was observed at significant level for varieties released in the 2000er compared to 1949. Furthermore, individual yield-forming components like 1000-kernel weight, grains/ear and ears/m² were significantly higher among the newer than at the oldest variety. Overall, these results confirm breeding progress for the observed varieties over the entire period for their region of origin (Germany) and under other climatic conditions in Siberia, respectively.

Keywords: spring wheat, organic agriculture, breeding progress.

INTRODUCTION

Wheat (*Triticum aestivum*) is one of the world's most widespread crop and important to meet the increasing demand for food and fodder (FAOSTAT, 2013). In Germany, it is the most common cereal crop with more than 3 million hectares, but only 2% are cultivated with spring wheat (DESTATIS, 2013). However, within the system of organic agriculture this acreage share is with 16% considerably higher (AMI, 2012).

Predictions suggest that the world will need about 50% more food by 2050, though to ensure future food security, agricultural production must grow in

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a sustainable way (Godfray et al., 2010; Foley et al., 2011). Sustainable agriculture requires in particular ecologically based management practices to maximize the net benefits from the whole system including production as well as ecosystem services (Tilman et al., 2002; The Royal Society, 2009). One alternative are organic farming systems (Maeder et al., 2002), which match these requirements and usually provide a better balance of all ecosystem services and disservices compared to conventional agriculture (Kühling and Trautz, 2013).

Diversified crop rotations with balanced proportions of summer and winter crops are an essential part of organic production systems. Thus, there is a need for varieties with potential under less intensive conditions, especially in the context of climate change (Lammerts van Bueren et al., 2011).

To look on the breeding progress of customary German spring wheat seeds, a field trial with 7 varieties of different approval ages was installed within the framework of the interdisciplinary German-Russian research project “SASCHA”. This paper presents results from two study sites with different climate conditions. Grain yield and plant health parameters are comparedamong the approval ages and between the study sites.

MATERIAL AND METHODS

The field trial was installed at the organic experimental farm “Waldhof” (52°19'19"N, 8°2'28"E), University of Applied Sciences Osnabrueck, Germany. An identically designed experiment took place at biological station “Kuchak” (57°20'56"N, 66°3'24"E), Tyumen State University in Russia (Figure 1).

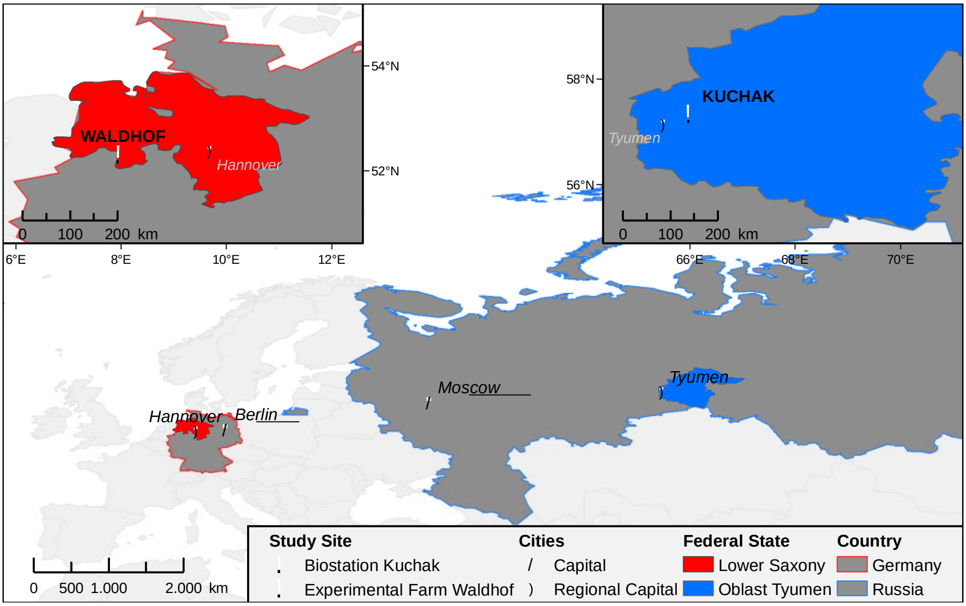

Figure 1: Location of the two study sites in Germany and Russia

Osnabrueck (Lower Saxony, Northern Germany) is located in the warm temperate climate zone (847 mm mean yearly precipitation, 8.9° C average temperature with variation of 16° C, Climate Data, 2014a). The soil type is planosol with loamy sand texture. Climate at the Russian site (Oblast Tyumen, Western Siberia) is continental (490 mm mean yearly precipitation, 0.7° C average temperature with variation of 36° C, Climate Data, 2014b) and sandy podzolic soil.

The experiments were set up in a completely randomized block design with 4 replications. Each plot had a size of 0.45 m² with 200 sown seeds. Table 1 lists the used spring wheat varieties with their year of approval in Germany and the breeding company.

Table 1: Names of the used varieties with year of approval in Germany and breeding company

Variety	Approval year	Name	Breeder
1	2011	Granus	Saaten Union
2	2010	Sonett	Latmännen SW Seed
3	2003	Eminent	SaatzuchtSchweiger
4	2003	Taifun	LochowPetkus
5	1994	Thasos	Saaten Union
6	1992	Naxos	Saaten Union
7	1949	Tschermarks Blaukörniger	Anonymous (Czech Republic)

For statistical analysis we used the software SPSS (IBM, 2012) and R(R Core Team, 2010), differences among means were analysed by multiple comparisons (Tukey-HSD-test, α=0.05).

RESULTS AND DISCUSSION

In Germany, vegetation period started on April 17th and lasted 111 days until harvest. Growing season in Russia began on May 9thand was overall 12% shorter with only 98 days (Figure 2). In the beginning, time spans were nearly equal at both study sites (germination until stem elongation) but during later growth stages (heading, floweringand fruitdevelopment), Russian plants developed 27-35% faster than in Germany. Differences between varieties were little at both locations.

According to the site-specific phenological development, yields in Germany were overall higher than in Russia. At both experimental sites, the year of approval of the varieties significantly affected observed grain yields.

In Germany the maximum yield was recorded for second youngest variety 2 (2010) with 122% relative to overall average, the oldest variety 8 (1949) showed with 53% lowest relative yield (Figure 3 A). Statistically significant differences in grain yield could be observed for varieties 2, 4 and 6 (2010, 2003, 1992) in comparison to variety 8 (1949). Among the 6 varieties released between 1992 and 2011 differences in yield were not statistically significant.

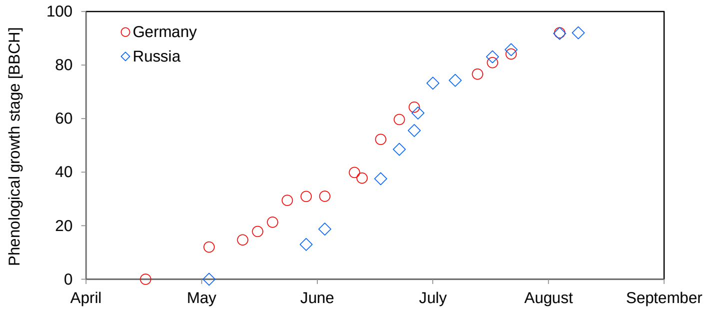

Figure 2: Phenological plant development stages in Russia and Germany (Average over all varieties at each location)

At the Russian site variety 5 (1994) got the highest relative yield (158%), the minimum value with 33% compared to overall mean was also seen at the oldest variety from 1949 (Figure 3 B). Yields of the younger varieties 2, 3 and 5 (2010, 2003, 1994) were significant higher than the lowest level of old variety 8 (1949). Similar to the German situation, yields did not distinguish at significant level between varieties introduced from 1994 to 2011.

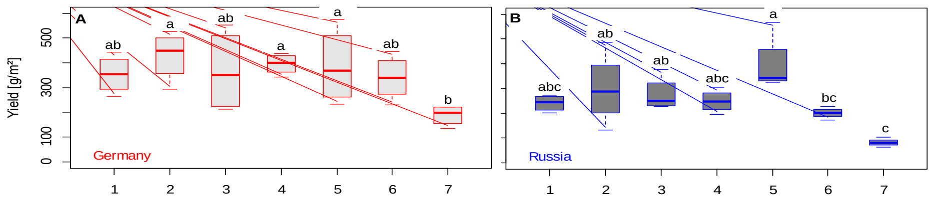

Figure 3: Observed grain yields for varieties 1-7 at the German (A) and Russian (B) study site. Different small letters indicate statistically significant differences (Tukey-test, α=0.05)

Differences in individual yield-forming components were not as obviously as contrasts in grain yield (Table 2). In Germany ears/m² and 1000-kernel weight did not differ on significant level. Only differences in grains/ear could be statistically secured for variety 1 and 5 (2011, 1994) towards variety 7 (1949). At the Russian experimental site, components ears/m² and grains/ear showed the same significant gradation between variety 5 and 7 as grain yield. All observed significant differences in individual yield-forming components occurred among newer varieties in comparison to the oldest from 1949 at both locations.

Table 2: Yields, yield-forming components and plant health parameters at both study sites. Mean values ± standard deviation, different small letters indicate statistically significant differences (Tukey-test, α=0.05)

Variety (Year)	**Grainyield [g/m²]**		**Ears/m²**		**Grains/Ear**		**1000-kernel weight [g]**		**Mildew infestation [1=low, 9=high]**		**Lodging resistance [1=low, 10=high]**	
Germany												
1 (2011)	354.94 ± 66.67	ab	390.56 ± 32.90	a	33.25 ± 3.47	a	39.75 ±3.14	a	5.50 ± 0.87	ab	9.75 ± 0.43	a
2 (2010)	430.00 ± 87.09	a	449.44 ± 15.90	a	29.45 ± 1.80	ab	37.50 ±2.91	a	2.50 ± 0.50	a	9.50 ± 0.50	ab
3 (2003)	367.00 ± 146.09	ab	366.67 ± 89.14	a	27.30 ± 2.22	ab	38.40 ±2.09	a	2.75 ± 0.43	a	9.50 ± 0.50	ab
4 (2003)	395.50 ± 36.77	a	379.44 ± 58.00	a	32.80 ± 1.64	ab	37.35 ±2.29	a	4.25 ± 1.09	ab	7.75 ± 0.43	ab
5 (1994)	385.67 ± 133.49	a	431.11 ± 78.54	a	33.40 ± 4.27	a	38.63 ±0.75	a	4.50 ± 0.50	ab	9.50 ± 0.50	ab
6 (1992)	340.17 ± 79.01	ab	402.78 ± 26.17	a	31.00 ± 3.75	ab	40.20 ±1.32	a	4.50 ± 0.50	ab	9.00 ± 0.00	ab
7 (1949)	188.89 ± 36.20	b	325.56 ± 12.42	a	22.20 3.54	b	39.75 1.78	a	9.00 ± 0.00	b	5.75 ± 0.43	b
Russia												
1 (2011)	240.90 ± 27.95	abc	288.89 ± 23.47	ab	24.85 ± 4.53	ab	30.61 ± 2.34	ab	1.75 ± 0.43	a	8.50 ± 0.50	a
2 (2010)	298.57 ± 125.95	ab	346.11 ± 77.45	a	25.05 ± 6.36	ab	31.65 ± 0.94	ab	1.75 ± 0.83	a	9.25 ± 0.43	a
3 (2003)	276.44 ± 60.30	ab	326.67 ± 47.89	ab	22.75 ± 1.63	ab	32.21 ± 1.53	ab	1.25 ± 0.43	a	9.25 ± 0.83	a
4 (2003)	249.42 ± 39.27	abc	310.00 ± 17.60	ab	23.93 ± 7.03	ab	33.78 ± 1.95	a	1.50 ± 0.50	a	8.75 ± 0.43	a
5 (1994)	394.61 ± 99.55	a	361.67 ± 35.78	a	36.90 ± 5.40	a	31.48 ± 2.40	ab	2.25 ± 0.83	a	9.00 ± 1.00	a
6 (1992)	201.71 ± 19.50	bc	293.89 ± 16.13	ab	20.93 ± 0.87	ab	32.28 ± 1.09	ab	1.75 ± 0.43	a	9.50 ± 0.50	a
7 (1949)	83.04 ± 14.06	c	196.67 ± 17.25	b	13.01 ± 2.50	b	27.20 ± 1.37	b	8.00 ± 0.00	b	8.00 ± 0.71	a

Plant health in terms of powdery mildew (*Blumeriagraminis*) infestation and lodging resistance showed the same tendencies as yields and yield-forming components: If differences on significant level occurred, newer varieties showed advantages towards the oldest one (Table 2). At the German location varieties 2 and 3 were less affected by mildew and variety 1 had significant better stability in comparison to variety 8. Due to continental climate, vulnerability to diseases was lower in Russia; only variety 7 was significantly more affected with powdery mildew than all other ones.

The significant trend of increasing grain yield over time is parallel for both location, but on a higher level for Germany compared to Russia (Figure 4 A). The tendency of significant lower mildew infestation among later introduced varieties was also observed at both locations, because of different climate conditions with less susceptibility in Russia (Figure 4 B). The stem stability in terms of lodging resistance showed significant improvement over time for the German site but no clear trend for the Russian location (Figure 4 C).

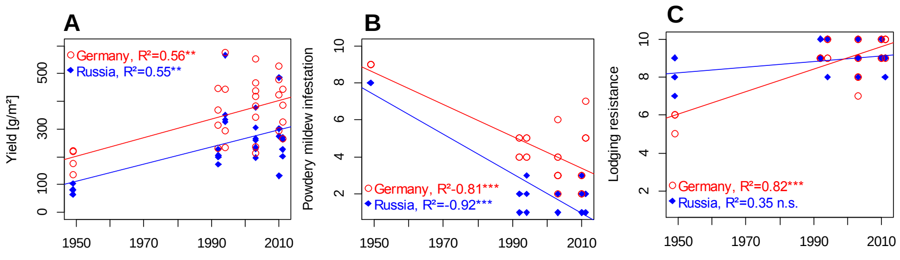

Figure 4: Relationship between grain yield, powdery mildew infestation and lodging resistance subject to the year of approval for all varieties at the Russian and German experimental site

Similar results to our trials were reported from other experiments, which also confirm poorer quality of older varieties (De Vita et al., 2007). Some studies showed decreasing trend in 1000-kernel weight according to improvement in grain yield (Slafer and Andrade, 1989; Guarda et al., 2004) but our data did not show a clear trend in 1000-kernel weight over time.

Especially in organic farming systems increases in yield among newer varieties seems to be limited by poorly adaption to low input conditions (Murphy et al., 2007). Lammerts van Bueren et al. (2002) also see great potential for special breeding programs with explicit selection under organic conditions. As the main problem they identify the limited area of organic agriculture as the bottleneck for commercial activities but also suppose future benefits for conventional production systems (Lammerts van Bueren et al., 2002).

Summarized there are generally advantages of later released varieties but there is also great potential for improving these advantages under the special conditions of organic farming systems.

CONCLUSIONS

Overall, these results confirm breeding progress for the observed varieties over the entire period for their region of origin (Germany) and under different climatic conditions in Siberia, respectively. If only varieties from the last 2 decades are taken into consideration, fewer differences at significant level were detectable in this experiment. For more reliable conclusions further experiments are needed including additional analysis like protein content and quality.

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