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IN SITU BREEDING FOR SOIL ABIOTIC STRESS TOLERANCE IN WHEAT

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Plant breeding programs are mainly settled in breeding institutions accompanied by experimental fields established nearby. Experimental fields are usually organized in favorable agro-technical conditions on a soil as best as possible. That is understandable, because the targets of breeding process, as well, as selection criteria are adjusted for intensive agricultural conditions. However, the increasing demand for food requires all the available resources to be put in good use. In that aspect, the land non-suitable for agricultural production, at the moment, become of certain interest for broadening agricultural potentials. More intensive agricultural use of less productive or degraded soil, involves novel genotypes obtained under adequate selection criteria in specialized breeding programs. The general debate is whether *ex situ* breeding programs were good enough to meet the challenge or *in situ* established breeding would be required? Experiences and results from parallel wheat breeding trials on chernozem, and solonetz soil are commented in the article.

Key words: wheat, breeding, abiotic stress, soil

Introduction

Wheat represents, in various forms, an essential food in the Western civilization. The run for the food production enhancement and agricultural industrialization started with the Green revolution in a second half of the past century. All the achievement in wheat breeding was sublimated in 1970, when Norman Borlaug was awarded the Nobel Peace Prize. The advent of semi-dwarf germplasm created primarily by Nazareno Strampelli in 1930s, as well as, considerable later by Norman Borlaug in CIMMYT wheat breeding program in the late 1960s, had a great impact on agriculture (Salvi et al., 2013., Phillips, 2013.). According to World Bank estimation, thirty years ago half of the developing world lived in extreme poverty. Today, that is a quarter. In today world, children malnutrition, and a risk of early death is quite diminished (World bank, 2010.). Whole wheat plant architecture has been changed, in order to ensure food security that has been a major challenge in 20th Century, and is going to be even a greater challenge in time to come. Due to globalization, and market integration, bread wheat is preferred over rice, sorghum and millet-based foods, in developing countries (Wrigley, 2009.). Furthermore, global food demand will increase, along with the population size increment. According to projection, 8 billion by 2030, and probably over 9 billion people by 2050 are going to put a heavy pressure on the global food system over the next 40 years (Foresight, 2011.).

There are, generally, two ways to responding to food production challenge. One is through wheat plant ideotype changes. In 1960s Donald (1968) appeared with wheat plant ideotype with improved sink to source ratio (harvest index) that was able to give higher grain yield due to more efficient assimilative translocation from vegetative to generative part of the plant. In the past 50 years the semi-dwarf plant stature (60-80cm), semi-erect leaves, large ear, harvest index of 50-60% was predominant in a wheat production. That kind of plant architecture has the yield potential above 10t/ha (Borojević, 1983.). However, to make a run for the new border of 20t/ha, wheat breeders have to make a qualitative step forward by establishing a new ideotype. Denčić (1994) reported promising effort that has been made for ten years to enhance sink capacity by creating branched and tetrastichon (two spikelets per node of the rachis) type of spike. Other researchers investigated the improvement of source capacity by changes in flag leaf angle, anatomy, chlorophyll content (Liu et al., 2009.). The other way is to enhance food production by converting non-arable to arable land, as well as, to put less productive soil in more intensive agricultural use. From the beginning of 1960s, the growth in food production has been based on genotype and agricultural practice improvements, while agricultural land mass stayed almost at the same level (fig. 1).

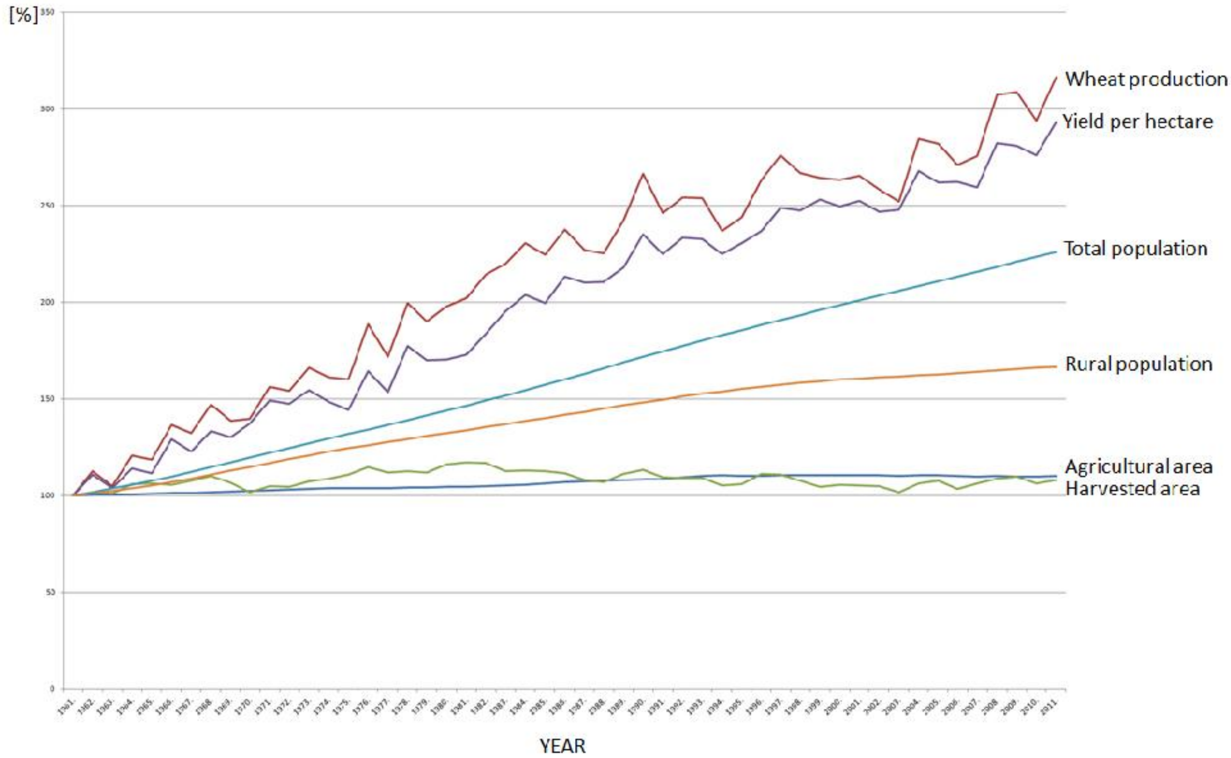

Figure 1. Agricultural area vs. wheat production and human population from 1961 (indexed 100) to 2011. (Data source: FAO)

Less productive soil could be an interesting source of broadening agricultural area by using suitable crop and ameliorative measures. Solonetz soil occupies about 1% of the land in the World, and about 0.5% in Europe. (Encyclopedia Britannica, 2013.). That soil type is characterized by alkaline pH reaction, sodium accumulation, and strong clay sub arable layer. In natural form, commonly occurs in dry, flat continental areas and could be used as a pasture. In Serbia, solonetz covers about 80000ha in the northern part of the country in Banat, mostly (Belić, 1999).

The aim of the article is to estimate the possibility of utilizing solonetz for wheat production, and to investigate the possibilities of creating novel genetic variability acceptable adapted to solonetz abiotic stress contiditons in an *in situ* established wheat breeding program.

Materials and methods

Five parental varieties of bread wheat (*Triticum aestivum ssp. vulgare* L.), Pobeda, Renesansa, Sara, Partizanka and Pesma, and seven of their F_2 progenies, from an *in situ* established wheat breeding program, were studied. The experiment has been conducted in vegetation periods (2009/2010, 2010/2011, and 2011/2012), at two localities Kumane village (45.521994^0N, 20.194919^0E, pH = 9.86) on solonetz soil, and Rimski Šančevi experimental field of the Institute of Field and Vegetable Crops in Novi Sad (45.324936^0N, 19.842883^0E, pH=6.86) on chernozem, parallel. All the wheat cultivars have been created at the Institute of Field and Vegetable Crops in Novi Sad. Three wheat plant traits were followed: plant height (cm), grain number and grain weight (g) per spike. According to the results of Denčić *et al.* (2000), individual plant traits are closely correlated to grain yield in abiotic stress conditions. Moreover, phenotypic expression of individual plant traits is the only usable selection criteria for desirable genotype selection in F_2. Each variety, as well as, progeny was sawn, spike per row, in eight 12.5cm spaced rows one meter long with 20cm space between plots. Fifty kilograms of NPK 15:15:15 fertilizer was applied along with sowing, and 150kg of KAN was additionally applied in spring. The whole *in situ* breeding program covers about 2ha. Elementary statistics has been calculated for quantifying and describing studied traits. The mode of inheritance has been established using t-test.

Results and discussion

The specific soil conditions of solonetz could be considered as abiotically stressful environment (Dimitrijević *et al*., 2011). The cultivar of choice for that surrounding should fulfill the following criteria: to be durable, to have at least moderate tolerance to salinity, to be of higher economic interest, to be of low input production and to be usable as ameliorator of the soil. Wheat (*Triticum aestivum*) is a moderately salt-tolerant of low input production crop, as well as, essential and valuable source of nutrition providing social secutrity for the farmer and society (Farooq and Azam, 2001, Munns *et al.*, 2006). After the crop selection, the next step was to test the existing and available genetic variability (Petrović *et al*., 2010). During a decade of investigation several wheat varieties have been selected as promising parents in crosses (Dimitrijević *et al*., 2009, Petrović *et al*., 2009). A parallel breeding program has been established on solonetz (*in situ*) and chernozem (*ex situ*). Having two part of the experiment geographically close, environmental variation due to meteorological conditions is considerable diminished. The same goes for agricultural practice which was the same, as well as, genetic material in study. That way the main differences are caused by soil variation. The following results illustrate advantages and disadvantages of an *in situ* breeding program for abiotic stress tolerance that is halomorphic soil in this experiment. According to previous results, selection criteria have been built. Since, F2 is compared, phenotypic markers are followed. The general approach has been to reach wheat plant habitus of normal environmental condition chernozem provides. According to the results, novel genetic variability has to compensate about 30% of plant height loss due to solonetz soil conditions. Predominant heterotic effect that appears in F_2 in two of three examioned vegetation periods, gives a space to work in that direction in progenies that follows, and to get that heterotic effect fixed (tab.1). Overdominance that is denoted in F_2 progenies for the grain number and grain weight per spike looks promising for further selection that should catch up about 20-25% off solonetz to chernozem differences (tab. 2, tab. 3, respectively). The problem is that unfavorable meteorological conditions make greater pressure on plants in solonetz soil environment, comparing to one on chernozem soil. The loss of some progenies at the locality of Kumane had been just from that reason, because weather conditions caused hard crust formation on the surface of solonetz soil, but not on chernozem (tab. 1, tab. 2, and tab. 3). However, hush conditions of solonetz in an *in situ* breeding program put the genetic material in a real situation. Phenotypic variability appears not only because of soil type, but also due to complex genotype by environment interactions that are quite different in abiotic stress, comparing to normal growth conditions. Unfavorable conditions generally diminish the cultivar differences and enhance genotype by environment interaction.

Table 1. Mean values of number of plant height (cm) on black soil ($\bar{x}_{Ch}$) and solonetz ($\bar{x}_{So}$) over three wheat growing seasons. The differences (d) and environmental means ($\bar{X}_{E}$) are given

Year	2009/2010			2010/2011			2011/2012		
Genotype	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*
Parents									
Pobeda (P1)	83.7	55.6	67	73.3	61.0	83	65.9	71.6	109
Renesansa (P2)	87.7	59.0	67	76.3	61.8	81	67.4	67.7	100
Sara (P3)	87.2	51.3	59	72.8	61.3	84	64.2	57.1	89
Partizanka (P4)	90.5	62.9	70	79.0	64.1	81	68.2	60.0	88
Pesma (P5)	88.4	54.4	62	83.5	58.1	70	63.0	73.3	116
$\bar{x}_{EP}$	*87.5*	*56.7*	*65*	*77.0*	*61.2*	*80*	*65.7*	*65.9*	*100*
F_2 progenies									
P1 X P3	$^{+h}$ 107.2	$^{+h}$ 79.6	74	$^{+h}$ 85.8	$^{+h}$ 91.2	106	$^{+d}$ 67.2	-	-
P1 X P5	$^{+h}$ 96.2	$^{+h}$ 80.5	84	$^{-d}$ 76.5	$^{+h}$ 85.1	111	$^{-d}$ 63.7	-	-
P2 X P3	$^{+h}$ 93.5	$^{+h}$ 76.3	82	$^{-d}$ 73.3	$^{+h}$ 76.4	104	$^{+d}$ 68.1	-	-
P2 X P5	$^{-}$92.0	$^{+h}$ 78.3	85	$^{-h}$ 66.7	$^{+h}$ 80.7	121	$^{-d}$ 63.1	$^{+d}$ 71.3	113
P3 X P4	$^{+h}$ 100.6	$^{+h}$ 70.9	71	$^{+h}$ 91.6	$^{+h}$ 91.5	100	$^{+h}$ 78.0	$^{+d}$ 71.2	91
P3 X P5	$^{-}$90.9	$^{+h}$ 76.0	84	$^{-d}$ 76.4	$^{+h}$ 88.6	115	$^{+h}$ 70.6	$^{+h}$ 71.3	101
P4 X P5	$^{+d}$92.7	$^{+h}$ 82.9	89	$^{-}$ 78.5	$^{+h}$ 88.3	112	$^{+d}$ 67.8	$^{+d}$ 71.6	106
$\bar{x}_{Ek}$	*94.5*	*78.1*	83	*78.4*	*86.0*	*110*	*68.4*	*71.3*	*104*
$\bar{x}_{E}$	92.0	70.4	77	77.8	75.7	98	67.0	68.6	102
LSD $_{0.05}$=4.382 LSD $_{0.01}$=5.320		LSD $_{0.05}$=5.928 LSD $_{0.01}$=7.931			LSD $_{0.05}$=1.756 LSD $_{0.01}$=2.312				

Table 2. Mean values of number of grain number per spike on black soil ($\bar{x}_{Ch}$) and solonetz ($\bar{x}_{So}$) over three wheat growing seasons. The differences (*d*) and environmental means ($\bar{X}_E$) are given

Year	2009/2010			2010/2011			2011/2012		
Genotype	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*
Parents									
Pobeda (P1)	43	29	68	45	30	66	33	37	112
Renesansa (P2)	47	32	67	44	31	70	30	43	145
Sara (P3)	45	34	76	37	36	99	37	34	90
Partizanka (P4)	38	34	87	36	34	95	30	28	94
Pesma (P5)	46	39	84	37	36	98	32	42	130
$\bar{x}_{EP}$	*44*	*34*	*76*	*40*	*33*	*84*	*32*	*37*	*113*
F_2 progenies									
P1 X P3	$^{-}$42	$^{+h}$44	106	$^{-d}$37	$^{+h}$46	126	$^{-d}$31	-	92
P1 X P5	$^{-h}$36	$^{+d}$40	112	$^{-h}$36	$^{+h}$49	134	$^{+h}$38	-	104
P2 X P3	$^{-}$44	$^{+d}$40	92	$^{-d}$39	$^{+h}$45	117	$^{+h}$39	-	105
P2 X P5	$^{-}$50	$^{+h}$47	94	$^{-}$40	$^{+d}$37	91	$^{+d}$33	$^{-h}$30	104
P3 X P4	$^{-}$42	$^{+h}$45	108	$^{-}$36	$^{+h}$41	114	$^{-h}$30	$^{-h}$31	*95*
P3 X P5	$^{-}$47	$^{-}$40	85	$^{+h}$45	$^{-}$40	90	$^{-d}$31	$^{-d}$32	104
P4 X P5	$^{-}$43	$^{-}$37	86	$^{-}$35	$^{+h}$48	136	$^{-d}$32	$^{-d}$33	92
$\bar{x}_{EF}$	*44*	*43*	*97*	*38*	*44*	*114*	*34*	*32*	104
$\bar{x}_{E}$	44	40	90	39	39	101	33	34	105

LSD $_{0.05}$=5.354 LSD $_{0.01}$=7.121 LSD $_{0.05}$=4.268 LSD $_{0.01}$=5.71 LSD $_{0.05}$=1.505 LSD $_{0.01}$=1.981

Table 3. Mean values of number of grain weight per spike (g) on black soil ($\bar{x}_{Ch}$) and solonetz ($\bar{x}_{So}$) over three wheat growing seasons. The differences (*d*) and environmental means ($\bar{X}_E$) are given

Year	2009/2010			2010/2011			2011/2012		
Genotype	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*	$\bar{x}_{Ch}$	$\bar{x}_{So}$	*d (%)*
Parents									
Pobeda (P1)	1.70	1.22	72	2.05	1.31	64	1.7	1.6	97
Renesansa (P2)	1.83	1.37	75	1.89	1.31	69	1.9	1.9	99
Sara (P3)	1.65	1.13	68	1.60	1.49	93	1.8	1.1	63
Partizanka (P4)	1.42	1.33	94	1.77	1.31	74	1.4	0.7	55
Pesma (P5)	1.68	1.32	79	1.59	1.43	90	1.2	1.5	122
$\bar{x}_{EP}$	*1.66*	*1.27*	*76*	*1.78*	*1.37*	*77*	*1.6*	*1.4*	*86*
F_2 progenies									
P1 X P3	$^{-}$1.58	$^{+h}$1.75	111	$^{+d}$2.04	$^{+h}$1.97	97	$^{-}$1.7	-	-
P1 X P5	$^{-h}$1.33	$^{-}$1.56	117	$^{-d}$1.59	$^{+h}$1.99	125	$^{+h}$1.9	-	-
P2 X P3	$^{-}$1.70	$^{-}$1.49	88	$^{-h}$1.55	$^{+h}$1.85	119	$^{+h}$2.0	-	-
P2 X P5	$^{-}$1.86	$^{+h}$1.90	102	$^{-d}$1.40	$^{-}$1.53	110	$^{-d}$1.7	$^{-h}$1.1	64
P3 X P4	$^{-d}$1.78	$^{+h}$1.75	98	$^{-}$1.70	$^{+d}$1.58	93	$^{-d}$1.5	$^{+d}$1.1	74
P3 X P5	$^{-}$1.84	$^{+h}$1.71	92	$^{+h}$1.96	$^{-}$1.57	80	$^{+d}$1.7	$^{+d}$1.2	68
P4 X P5	$^{-}$1.44	$^{-}$1.47	102	$^{-}$1.59	$^{+h}$1.90	119	$^{+d}$1.4	$^{+d}$1.2	87
$\bar{x}_{EF}$	*1.67*	*1.69*	101	*1.69*	*1.77*	*105*	*1.7*	*1.1*	*67*
$\bar{x}_{E}$	1.66	1.54	*93*	1.73	1.60	93	1.6	1.3	76.7

LSD $_{0.05}$=2.256 LSD $_{0.01}$=3.000 LSD $_{0.05}$=0.244 LSD $_{0.01}$=0.327 LSD $_{0.05}$=0.126 LSD $_{0.01}$=0.166

In *ex situ* breeding program targeted for special purposes that is abiotic stress tolerance in this experiment, there is an undeniable cosines of more secure environment giving considerable certainty. Commonly, the *ex situ* breeding approach is combined with physiological or molecular studies conducted in order to find certain gene(s) for salinity tolerance, high Na^+ content, etc. However, in rencounter of complex and interactive genetic background and high selection pressure of complex environmental influence of solonetz soil conditions combined with meteorological and climate change influences, the eventual satisfactory result depends on more factors than Na^+ or salinity introduced tolerance could be. The experiments that include *in situ* vs. *ex situ* breeding comparison are to be continued….

Conclusion

Comparison of *in situ* and *ex situ* wheat breeding program for getting genotypes capable to withstand hush conditions of solonetz field production, reveals some potential advantages and disadvantages of these two approaches. However, the program of genetic variability creation exhibiting higher level of tolerance to stressful growing conditions of alkaline soil in wheat breeding *in situ* gave some promising results for yield components considered in the article as phenotypic markers in early generations of crosses. Induced genetic variability obtained in an *in situ* breeding program on solonetz soil, by crossing parents selected in the previous years of experiments, open a perspective of superior genotypes selection in F_2 populations. That gives the possibility of desirable variation creation by the selection in consequent progenies to obtain varieties that could give an economically sound result maximizing the use value of halomorphic, alkaline solonetz soil.

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