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ESTIMATION OF GENETIC TRENDS IN YIELD AND AGRONOMIC TRAITS OF RECENT ROMANIAN WINTER WHEAT (*TRITICUM AESTIVUM* L.) CULTIVARS, USING DIRECT COMPARISONS IN MULTIYEAR, MULTI-LOCATION YIELD TRIALS

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ABSTRACT

Genetic trends in average, maximum and minimum grain yields and average values of yield components, drought resistance scores, *Septoria* scores, powdery mildew scores, days to heading, height, lodging score, test weight, protein concentration and protein yield of winter wheat cultivars released by NARDI Fundulea during the period 1993 to 2005 were estimated using data from direct comparisons in multiyear, multi-location trials in four regions of Romania.

Significant genetic gains of 30 to 82 kg ha^{-1} year^{-1} for grain yield were observed in South, West and East Romania. Maximum yields also showed significant gains, while minimum yields showed no trend. The increase in grain yield was entirely due to an increase in the number of kernels per unit area, while the grain weight showed a slight reduction trend. The increased number of kernels was mainly due to larger spikes (more kernels/spike), but also to more spikes per unit area in two of the regions.

Progress was noted in *Septoria tritici*, *Erysiphe graminis,* lodging and drought resistance, while no trend was evident in days to heading, height and test weight.

Despite the well known negative correlation between grain protein concentration and grain yield, the protein percentage showed no trend in two regions and decreased in the other two, but relatively less than the observed increase in grain yield.

Key words: Genetic progress, wheat, yield, grains m^{-2}.

INTRODUCTION

Periodical evaluation of genetic progress achieved by breeding programs is important for estimating the benefits of investments in genetics and breeding research and for identifying traits or target environments that may require increased efforts by breeders (Cox et al., 1988).

Many authors have compared the yield potential of wheat cultivars released over longer or shorter periods of time. The genetic gain in grain yield was estimated on the basis of data collected over a relatively long period from cultivar trials including check cultivars, or by direct comparisons of older and newer cultivars grown simultaneously in trials conducted for that specific purpose. This second approach usually provides more directly comparable information, while genetic gain estimated from the difference between checks and top-yielding cultivars are biased by the genotype by environment interactions, especially where crossover interactions occur and older cultivars are grown under modern cultural practices (Cox et al., 1988). Genotype by environment interactions can also introduce biases in direct comparisons, if the number of testing environments (locations and years) is small.

Brancourt-Hulmel et al. (2003) summarized the results of studies published in France, U.K., Germany, USA, Australia and Mexico, between 1951 and 1989 and found that genetic gains for grain yield varied from 5.8 kg ha^{-1} yr^{-1} to 59 kg ha^{-1} yr^{-1}.

Ortiz-Monasterio et al. (1997) demonstrated that genetic gains in grain yield tend to be larger under adequate fertilization than without applied N fertilizer. Testing cultivars released in Mexico during 1950 to 1985, they found that genetic gains in grain

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yield were 32, 43, 59, and 89 kg ha^{-1} yr^{-1} on an absolute basis, or 1.1, 1.0, 1.2, and 1.9% yr^{-1} on a relative basis when provided 0, 75, 150, and 300 kg ha^{-1} N, respectively.

More recently, Fufa et al. (2005) reported genetic gains for grain yield of 10.4 kg ha^{-1} yr^{-1} in Nebraska, Shearman et al. (2005) reported that grain yield increased linearly with year of release by 119 kg ha^{-1} yr^{-1} ($P < 0.001$) in UK, Zhou et al. (2007) found that average annual genetic gain in grain yield ranged from 32.07 to 72.11 kg $ha^{-1}yr^{-1}$ or from 0.48 to 1.23% annually in different provinces of China, while De Vita et al. (2007) found an annual genetic yield gain of 19.9 kg ha^{-1} yr^{-1} in durum wheat cultivars released in Italy in the last century.

In Romania, Săulescu (1983) reported that genetic progress for yield, estimated from the difference between check cultivar Bezostaya 1 and Romanian wheat cultivars released during 1971 to 1979 was 60 kg ha^{-1} yr^{-1} and later Săulescu et al. (1998), reported an annual genetic yield gain of 50 kg ha^{-1} yr^{-1}.

Along with genetic gains in yield, many authors also reported genetic trends for other traits such as yield components, test weight, height, protein concentration etc. (Waddington et al., 1986; Cox et al., 1988; Austin, 1989; Perry and d'Antuono, 1989; Slafer and Andrade, 1989; McCaig and DePauw 1995, Sayre et al., 1997; Brancourt-Hulmel et al., 2003; Shearman et al. 2005, etc.)

This paper reports estimations of genetic progress in yield, yield components and several agronomic traits, based on direct comparisons of wheat cultivars released by the National Agricultural Research and Development Institute (NARDI) Fundulea during 1993 to 2005, grown simultaneously in trials conducted during 3-4 years in several locations in the main wheat growing regions of Romania.

MATERIAL AND METHODS

Yield trials intended to provide data for the list of recommended varieties included cultivars released by NARDI Fundulea in the last two decades: Dropia (released in 1993, authors N.N. Săulescu, G. Ittu, Mariana Ittu, P. Mustăţea), Boema 1 (released in 2000, authors N.N. Săulescu, G. Ittu, Mariana Ittu, P. Mustăţea), Crina (released in 2001, authors N.N. Saulescu, G. Ittu, Mariana Ittu, P. Mustăţea, Mihaela Tianu, Elena Petcu, Maria Balotă), Dor F and Delabrad 2 (released in 2002, authors N.N. Saulescu, G. Ittu, Mariana Ittu, P. Mustăţea, Mihaela Tianu, Elena Petcu, Maria Balotă), Faur F (released in 2004, authors N.N. Săulescu, G. Ittu, A. Giura, Mariana Ittu, P. Mustăţea, Mihaela Tianu, Elena Petcu, Maria Balotă), Gruia (released in 2005, authors N.N. Sãulescu, G. Ittu, P. Mustãţea, Mariana Ittu, Mihaela Tianu, Elena Petcu) and Glosa (released in 2005, authors N.N. Sãulescu, Gh. Ittu, A. Giura, Mariana Ittu, P. Mustãţea, Mihaela Tianu, Elena Petcu). All these cultivars were tested in the South region, while cultivars Crina and Dor were not tested in the West and East regions and cultivars Boema 1, Crina and Dor were not tested in Transylvania. All cultivars are semidwarf, carrying the *RhtB1-b* height reducing gene.

We used data from yield trials performed in 7 locations in the South region (Fundulea, Mărculeşti, Brăila, Dobrogea, Teleorman, Albota and Şimnic), 3 locations in the West region (Lovrin, Oradea and Livada), 2 locations in the East region (Secuieni and Suceava) and 3 locations in Transylvania (Tg. Mureş, Turda and Braşov). In 2007-2009 at all locations cultivars were tested both in trials fertilized with recommended doses of nitrogen (N) fertilizer and without additional N, while in 2010 only data from fertilized trials were available.

Data from 4 years of testing (only 3 years for Transylvania) were used. Weather conditions during the years of testing varied from less favorable (in 2007) to favorable (in 2010), as reflected by the average yields of all trials, which varied from 4660 to 5528 kg ha^{-1}.

Average, maximum and minimum grain yields for each region, and average values of yield components, drought resistance score, *Septoria* score, powdery mildew score, days to heading, height, lodging score, test weight, protein concentration and protein yield were regressed on the year of release of tested cultivars, regression coefficients being considered to estimate the genetic trend in the improvement of each trait.

RESULTS AND DISCUSSION

Grain yield

The difference between the lowest average yield, always recorded in the oldest cultivar (Dropia), and the highest average yield, always recorded in one of the newest cultivars (Glosa) varied between 497 and 1419 kg ha^{-1} and was significant in all regions. Grain yield showed an average increase varying between 30 and 82 kg ha^{-1} year^{-1}, or 0.59% to 1.53% yr^{-1} as compared to Dropia, released in 1993 and most widely grown cultivar in Romania from 2000 to 2009 (Figure 1). The regressions of average yield on the year of release were significant (P<0.05) in the South, West and East regions and not significant in Transylvania, which has different environmental conditions and is not a primary target area of the NARDI wheat breeding program.

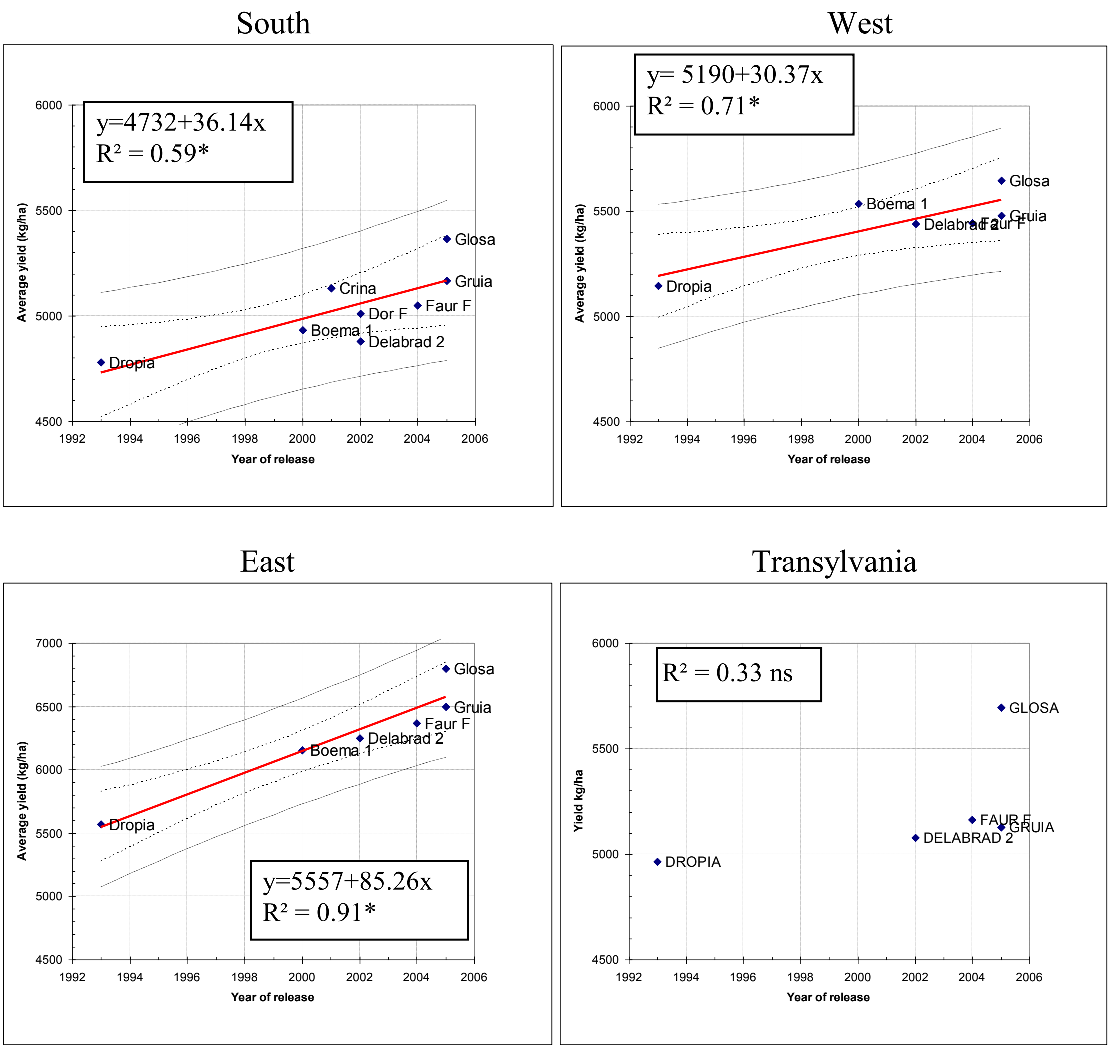

Figure 1. Relationship between the year of release and average grain yield of NARDI wheat cultivars in four regions of Romania

The achieved genetic progress between 30 and 82 kg ha^{-1} year^{-1} is comparable with that achieved in other breeding programs, being higher than the progress achieved in drier areas of US and smaller than that achieved in more favorable conditions of UK. It should be noted that the estimations presented here are based on data obtained in 6 (in Transylvania) to 28 (in the South region) locations*years, include fertilized and not fertilized trials and do not include the progress usually associated with the change from tall to semidwarf wheat. However, progress should be accelerated to meet the challenge of doubling wheat yields by 2050.

Linear regression of maximum yields on years of release showed increases of 73 to 168 kg ha^{-1} year^{-1}, being significant in all regions, except West (Table 1), suggesting a trend for higher yielding potential. In contrast, the change in minimum yields was small and not significant. Increased efforts in breeding for resistance or tolerance to the main limiting factors, mainly drought, unfavorable conditions for stand establishment or diseases are necessary to increase the minimum yields.

Table 1. Regression slopes and coefficients of determination for the relationship between the year of release, grain yield and yield components of NARDI wheat cultivars in four regions of Romania

Region	South		West		East		Transylvania	
Number of cultivars	8		6		6		5	
	b	R^2	b	R^2	b	R^2	b	R^2
Average yield	36	**0.586**	30	**0.708**	82	**0.908**	32	0.330
Maximum yield	114	**0.516**	73	0.304	168	**0.706**	130	**0.863**
Minimum yield	43	0.431	-23	0.400	15	0.035	43	0.734
Kernels m^{-2}	190	**0.692**	156	**0.814**	314	**0.982**	112	**0.911**
Spikes m^{-2}	2.10	**0.540**	-0.16	0.003	7.29	**0.969**	0.04	0.000
Kernels/spike	0.28	**0.548**	0.36	**0.972**	0.25	**0.960**	0.18	**0.884**
TKW	-0.38	**0.410**	-0.30	**0.483**	-0.44	**0.793**	-0.19	**0.252**

Bolded values of R^2 indicate correlations significant at $P<0.05$

Yield components

The superiority of new cultivars was associated with higher number of kernels per square meter, which increased linearly with year of release by 112 to 314 grains m^{-2} yr^{-1} (Table 1). Our findings correspond to the results of Slafer and Andrade (1989) who concluded that the genetic improvement of grain yield potential in Argentina, among other wheat growing countries of the world, has been achieved mainly through an increase in kernel number. Shearman et al. (2005) also found that genetic progress in yield was associated with the number of grains per square meter, which increased linearly with year of release by 217 m^{-2} yr^{-1}. McCaig and DePauw (1995) reported similar results, showing that the increase in mean yield over time was primarily due to an increase in kernel number rather than an increase in kernel weight. Genetic improvement associated with new spring wheat cultivars in Australia was also achieved through substantial increases in kernel number (Perry and D'Antuono, 1989), and in northwest Mexico, bread wheat cultivars released during the l950-1982 period increased yield potential entirely through an increase in kernel number (Waddington et al. 1986). Calderini et al. (1995) and Sayre et al. (1997) also found that genetic progress in yield was due mainly to larger numbers of kernels per square meter.

Our results showed that the increase in the number of kernels per square meter was associated in all regions with a significant linear increase in number of grains per spike of 0.18 to 0.36 yr^{-1} and in South and East also by a significant linear increase of the number of spikes per square meter (Table 1 and Figure 2). Previously reported results also showed that the increase in kernel number was mostly due to an increase in the number of kernels per spike (Slafer and Andrade, 1989), or due to increases in both kernels per spike and number of spikes per unit area (Perry and d'Antuono, 1989).

The increase in the number of kernels per square meter observed in our trials was accompanied by a significant decrease in kernel weight, from -0.19 to -0.44 g 1000 grains^{-1} year^{-1} (Table 1 and Figure 3). It should be noted however that in relative terms the decrease in kernel weight was much smaller than the increase in the number of kernels m^{-2} (-0.39 to -0.90 % yr^{-1} for TKW and +1.09 to 2.75% yr^{-1} for kernels m^{-2} yr^{-1}.

Previous studies have shown either an increase in 1000-kernel weight (Cox et al., 1988, Fufa et al., 2005), a decrease (Waddington et al., 1986; Perry and d'Antuono, 1989), or no change (McCaig and DePauw 1995). Feil (1992) suggested that the stagnation or decrease of the mean TKW may be due to the fact that kernels added by breeding occur at sites in the spikelets that normally develop below average TKW values.

A) Kernels m^{-2} B) kernels/spike

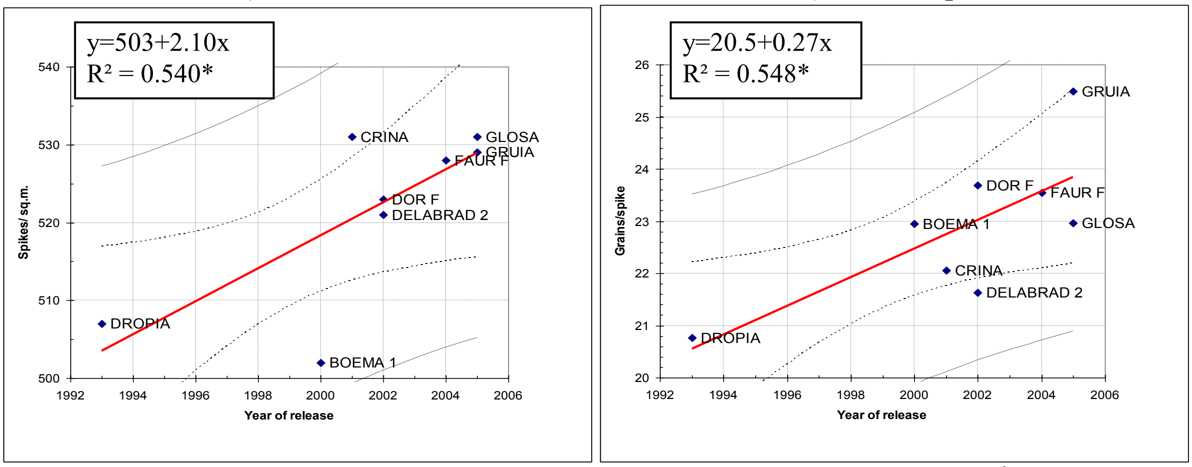

Figure 2. Relationship between the year of release and components of the number of kernels m^{-2} in NARDI wheat cultivars in the South region of Romania

A) kernels m^{-2} yr^{-1} B) 1000 kernels weight

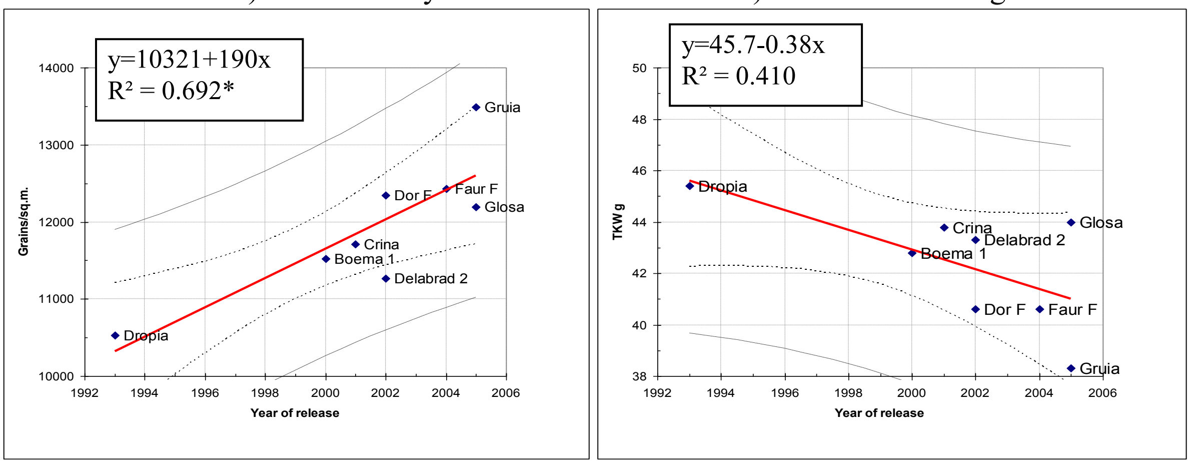

Figure 3. Relationship between the year of release and yield components of NARDI wheat cultivars in the South region of Romania

Drought resistance score

A trend towards better response to drought, as assessed visually during the vegetation period was observed in all regions where differences between cultivars were visible. However the trend was significant only in the Western part of the country (Table 2).

Disease resistance

Significant differences among cultivars were observed on average for powdery mildew (*Erysiphe graminis*) and *Septoria tritici* response. A significant linear trend for lower scores of both diseases was observed in the South region (Table 2), but not in the other regions.

This could be due to Genotype* Environment interactions and possibly different races, which caused some cultivars to have different reaction to diseases in different regions.

Days to heading

Differences among studied cultivars in heading date were small, and no significant trend of earliness in relation with the year of release was observed, meaning that the yield increase was not due to longer vegetation period (Table 2).

It seems that earliness of present cultivars is already in the optimal range, and more breeding efforts are necessary in order to reduce the vegetation period without sacrificing yield.

Cox et al. (1988) reported that, in hard red winter wheat cultivars released in US from 1919 to 1987, days to heading decreased at rate of -0.1 days yr^{-1}, and similar changes happened in Romania during longer periods than that included in this study.

Height and lodging score

No significant trend was observed for plant height, as expected from the fact that all studied cultivars are semidwarf, carriers of the same height reducing gene (Table 2). The small difference observed in height due to modifying genes did not show a trend related with the year of release. This is in contrast with previous studies, which included old taller cultivars along with new short or semidwarf cultivars. For example, Cox et al. (1988) found that plant height decreased at rate of -0.5 cm yr^{-1} in hard red winter wheat cultivars released in US from 1919 to 1987. A significant progress in lodging resistance, not related with changes in plant height was observed in the South region, the only region where significant differences in lodging scores were noted.

Table 2. Regression slopes and coefficients of determination for the relationship between the year of release and various traits of NARDI wheat cultivars in four regions of Romania

Region	South		West		East		Transylvania	
Number of cultivars	8		6		6		5	
	b	R^2	b	R^2	b	R^2	b	R^2
Drought resistance score	-0.18	0.358	-0,18	**0.746**	-0.12	0.306		
Septoria score	-0.38	**0.503**	0.36	0.622	0,02	0,010	-0,07	0,443
Powdery mildew score	-0.31	**0.774**	-0.06	0.046	-0.07	0.031		
Days to heading	0,017	0.020	-0.217	0.209	-0.066	0.116	-0,024	0,009
Height	-0.166	0.141	0.163	0.111	-0.315	0.250	-0.336	0.302
Lodging score	-0.27	**0.588**						
Test weight	0.03	0.091	-0.28	0.241	0.071	0.516	0.098	0.126
Protein concentration	0.007	0.004	-0.022	0.259	-0.026	**0.796**	-0.048	**0.783**
Protein yield	5.47	**0.577**	2.98	0.525	9.75	**0.872**	2.04	0.086

Bolded values of R^2 indicate correlations significant at $P<0.05$

Test weight

Test weight variation among the studied cultivars was small and therefore no trend was detectable (Table 2). This corresponds with the results of Fufa et al. (2005), who explained the non-significant genetic gain observed for grain volume weight by the fact that all cultivars must meet a minimum standard. Based on the 12 hard red winter wheat cultivars evaluated in Oklahoma, Khalil et al. (2002) also observed no linear trend of grain volume weight with the year of release.

Protein concentration

No significant trend of grain protein content was observed in the South and West regions, which is remarkable in view of the significant trend of increase in grain yield. A significant trend towards lower grain protein concentration was however observed in the East and Transylvania (Table 2), but even here, in relative terms the decrease in protein concentration (-0.20 to -0.33% year^{-1}) was smaller than the increase in grain yield (0.65 to 1.53% year^{-1}). Protein yield per unit area showed an increasing trend in all regions, significant in the South and East, suggesting that the trend in protein concentration was most likely due higher accumulation of starch in the grain, related to higher yield. Most previous reports noted that newer cultivars generally had lower N concentrations in the grain than the older ones, due to dilution (Shearman et al., 2005; Fufa et al., 2005).

CONCLUSIONS

Estimations of genetic progress in recent hard red winter wheat cultivars released by NARDI Fundulea from 1993 to 2005, based on data from direct comparisons in multiyear, multi-location trials in four regions of Romania, showed significant gains for average grain yields, similar to those estimated from the difference between check cultivar Bezostaya 1 and Romanian wheat cultivars released during 1971 to 1979, and higher than gains reported by many studies performed under continental climate. Maximum yields also showed significant gains, while minimum yields showed no trend, suggesting that more breeding effort should be directed towards resistance or tolerance to the main yield-limiting factors.

The increase in grain yield was entirely due to an increase in the number of kernels per unit area, while the grain weight showed a negative, but relatively smaller, trend.

An increasing trend was observed for grain protein yield per unit area, while grain protein concentration showed no trend in two regions and a slight negative trend in the other two.

REFERENCES

Austin, R.B., 1989. *Genetic improvement in the yield of winter: A further evaluation*. J. Agric. Sci., (Cambridge), 112: 295-301.

Brancourt-Hulmel, M., Doussinault, G., Lecomte, C., Bérard, P., Le Buanec, B. and Trottet, M., 2003. *Genetic Improvement of Agronomic Traits of Winter Wheat Cultivars Released in France from 1946 to 1992*. Crop Sci., 43 (1): 37-45.

Calderini, D.F., Dreccer, M.F. and Slafer, G.A., 1995. *Genetic improvement in wheat yield and associated traits. A reexamination of previous results and the last trends*. Plant Breed. 114: 108-112.

Cox, T.S., Shroyer, J.P., Ben-Hui, L., Sears, R.G., Martin, T.J., 1988. *Genetic improvement in agronomic traits of hard red winter wheat cultivars from 1919 to 1987*. Crop Sci., 28 (5): 756-760.

De Vita, P., Li Destri Nicosia, O., Nigro, F., Platani, C., Riefolo, C., Di Fonzo, N. and Cattivelli, L, 2007. *Breeding progress in morpho-physiological, agronomical and qualitative traits of durum wheat cultivars released in Italy during the 20th century*. European Journal of Agronomy, 26 (1): 39-53.

Feil, B.,1992. *Breeding Progress in Small Grain Cereals – A Comparison of Old and Modern Cultivars*. Plant Breeding,108: 1-11.

Fufa, H., Baenziger, P.S., Beecher, B.S., Graybosch, R.A., Eskridge, K.M., Nelson, L.A., 2005. *Genetic Improvement Trends in Agronomic Performances and End-Use Quality Characteristics Among Hard Red Winter Wheat Cultivars in Nebraska.* Euphytica, 144: 187-198

Khalil, I.H., Carver, B.F., Krenzer, E.G., MacKown, C.T., Horn, G.W. and Rayas-Duarte, P. 2002. *Genetic Trends in Winter Wheat Grain Quality with Dual-Purpose and Grain-Only Management Systems.* Crop Sci., 42: 1112-1116

McCaig, T.N. and DePauw, R.M., 1995. Breeding hard red spring wheat in western Canada: Historical trends in yield and related variables. Can. J. Plant Sci., 75: 387-393.

Ortiz-Monasterio, R.J.I., Sayre K.D., Rajaram, S., McMahon, M., 1997. *Genetic progress in wheat yield and nitrogen use efficiency under four nitrogen rates.* Crop Sci, 37 (3): 898-904

Perry, M.W. and D'Antuono, M.F., 1989. *Yield improvement and associated characteristics of some Australian spring wheat cultivars introduced between 1860 and 1982*. Aust. J. Agric. Res., 40: 457-472.

Sayre, K.D., Rajaram, S. and Fischer, R.A., 1997. *Yield potential progress in short bread wheats in northern Mexico*. Crop Sci., 37: 36-42.

Săulescu, N.N., 1983. *Évaluation des progrès réalisés au cours des dernières 25 années dans l'amélioration du blé tendre d'hiver en Roumanie*. Bulletin de l'Académie des Sciences Agricoles et Forestières,13: 13-22.

Săulescu, N.N., Ittu, G., Balotă, M., Ittu, M., Mustățea, P., 1998. *Breeding wheat for lodging resistance, earliness and tolerance to abiotic stresses.* In: "Wheat: Prospects for Global Improvement", H.J.

Braun et al. (Eds.), Kluwer Academic Publishers, Netherlands: 181-188.

Shearman, V.J., Sylvester-Bradley, R., Scott, R.K., Foulkes, M.J., 2005. *Physiological Processes Associated with Wheat Yield Progress in the UK.* Crop Sci., 45 (1): 175-185.

Slafer, G.A. and. Andrade, F.H., 1989. *Genetic improvement in bread wheat (Triticum aestivum) yield in Argentina.* Field Crops Res., 21: 289-296.

Waddington, S.R., Ransom, J.K., Osmanzai, M., Saunders, D.A., 1986. *Improvement in the yield potential of bread wheat adapted to northwest Mexico*. Crop Sci., 26: 698-703.

Zhou Y., He Z. H., Sui X.X., Xia X.C., Zhang X.K., Zhang G.S., 2007. *Genetic Improvement of Grain Yield and Associated Traits in the Northern China Winter Wheat Region from 1960 to 2000*. Crop Sci., 47 (1): 245-253.