# Effects of testing environments and crop density on winter wheat yield

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## ABSTRACT

Stability of genotypes across different environments is one of the main goals in winter wheat breeding programs. Attention has been devoted to analysing genotype by environment interactions (GEI) to improve crop breeding success. Usually, strategy for selection of winter wheat is that selection should be made on several locations different in climatic and soil conditions. The objectives of this paper were to examine influence of different testing environments and sowing rates on formation of winter wheat kernel yield and, after the stability analysis, to identify most stabile genotypes and locations. Research work was conducted on 14 winter wheat genotypes and four testing locations in East Croatia. On each location genotypes were sown in two sowing rates – 300 and 600 germinable seeds $m^2$. Examined genotypes included registrated cultivars (new and older one) and new breeding lines. Testing locations differs in average amount of rainfalls, average temperature and soil type. Combined analysis of variance showed highly significant ($p \leq 0.01$) influence of genotypes, environments (sowing rate and location) and GEI on kernel yield. AMMI 1 model biplot showed that the most yielding location, in commbination with higher sowing rate, was one with the best soil conditions (black soil-chernozem). Higher sowing rate at all locations showed higher yield than lower sowing rate at the same location. Biplot also showed that locations were spread from lower yielding to high yielding. Examined genotypes differed in yield and in stability accross environments. Genotype Lucija has the highest yield, but it was unstable and adapted to higher yielding environments. Best combination of high yield and good stability was in recognized cultivar Pipi and breeding line OSK 89/05.

## INTRODUCTION

Selection of stable genotype with broad adaptation to various environments is one of the main goals in winter wheat breeding. Genotype x environment interaction (GEI) hinders selection of the best genotypes due to confounding results for the genetic differences between wheat genotypes. Therefore, much attention has been made to analysing GEI (Haile et al. 2007; Gunjača et al., 2007; Thomason and Philips, 2006; Mardeh et al., 2006; Hoffman et al., 2005; Pepo and Györi, 2005; Yan et al., 2002). Wheat breeders try to select genotypes responsive to favourable environments for grain yield and other important wheat traits (Fufa et al., 2005). Therefore, strategy is that selection should be made on several locations and testing sites (Rodriguez-Perez et al., 2005) with variability in agroecological conditions. Therefore the aim of this study was (i) to examine influence of different testing environments and sowing rates on winter wheat kernel yield and (ii) to identify most stable genotypes and locations.

## MATERIALS AND METHODS

Research work was conducted during 2006/07 growing season on four test locations with four different soil types: Nova Gradiška – fluvisol; Osijek – eutric cambisol; Požega – pseudogley; Tovarnik – chernozem. Research work included 14 winter wheat genotypes (Table 1); genotype Žitarka was the standard cultivar. Genotypes were chosen due to their high yielding performance and good quality. The examined genotypes were sowed with two sowing rates: 330 and 600 germinable seeds $m^{-2}$. The experimental design was a randomised block design with four repetitions for each genotype and sowing rate. Therefore, for each location experiment was consisted of 112 plots with the basic plot of 7.56 $m^2$. Common agricultural practice for winter wheat in east Croatia was used. Plots were harvested separately and kernel yield was estimated in kilograms for each plot.

It should be stressed that environmental factors were relatively the same for all locations in vegetation year, characterised with above the average temperatures during winter (2006/07) and with drought during June and July 2007.

Combined analysis of variance (ANOVA) was carried out for estimation of genotypes, locations and sowing rates effects on kernel yield using the SAS GLM procedure SAS software 9.1 (2003). Stability estimates for locations and genotypes were performed with Additive Main Effects and Multiplicative Interaction Analysis model (AMMI) using the CropStat software Ver. 7.2. To graphically explain GEI and stability of genotypes and locations AMMI model 1 biplot was used where the IPCA 1 scores were plotted against mean kernel yield (Figure 1).

## RESULTS

Mean values of kernel yield for examined genotypes at all locations, main values for the examined locations and IPCA scores are presented in Table 1. The highest yield of all examined genotypes was achieved with genotype Lucija (6.24 kg). On the second place was genotype Osk 241/04 (6.00 kg) and on the third was genotype Srpanjka (5.97 kg). Regarding locations the highest kernel yield was achieved at location Tovarnik (5.97 kg) with sowing rate 600 germinable seeds $m^{-2}$. On the second place was location Nova Gradiška (5.81 kg) also with sowing rate of 600 germinable seeds m$^{-2}$. If we calculate average yield from both sowing density the best yielding location is Tovarnik. The lowest yield was achieved at location Osijek (4.64 kg) with sowing rate of 300 germinable seeds m$^{-2}$. If we compare lower and higher sowing density, higher kernel yield at all locations was achieved with higher sowing density.

Table 1 Mean values and IPCA 1 scores for examined genotypes and environments

| Genotype | Mean | IPCA score1 | Genotype | Mean | IPCA |
|---|---|---|---|---|---|
| AIDA | 5.66 | -11.44 | OSK.64/05 | 5.35 | -10.31 |
| ALKA | 5.92 | -23.82 | OSK.67/05 | 5.13 | 4.50 |
| DIVANA | 3.54 | -1.81 | OSK.89/05 | 5.78 | -3.95 |
| LUCIJA | 6.24 | 23.82 | PIPI | 5.52 | 2.69 |
| OSK.108/04 | 5.86 | 17.12 | SANA | 5.67 | -15.24 |
| OSK.241/04 | 6.00 | 12.02 | SRPANJKA | 5.97 | 8.9 |
| OSK.63/05 | 5.27 | -5.65 | ŽITARKA | 4.12 | 2.67 |

| Environment | Mean | IPCA |
|---|---|---|
| Nova Gradiška – low density (A/R) | 5.07 | -9.2 |
| Nova Gradiška – high density (A/G) | 5.81 | -10.71 |
| Osijek – low density (B/R) | 4.64 | 23.9 |
| Osijek – high density (B/G) | 5.19 | 19.27 |
| Požega – low density (C/R) | 5.47 | 12.66 |
| Požega – high density (C/G) | 5.48 | 4 |
| Tovarnik – low density (D/R) | 5.51 | -23.75 |
| Tovarnik – high density (D/G) | 5.97 | -16.98 |

Combined analysis of variance (Table 2) showed highly significant ($p \leq 0.01$) influence of genotypes, environments (sowing rate and location) and GEI on kernel weight.

Table 2 Combined analysis of variance (ANOVA)

| Source | df | SS | MS | Sign .F |
|---|---|---|---|---|
| Genotype | 13 | 234.108 | 18.008 | ** |
| Environments | 7 | 48.902 | 6.986 | ** |
| Sowing rate | 1 | 15.164 | 15.164 | ** |
| Location | 3 | 25.886 | 8.628 | ** |
| GEI | 91 | 37.053 | 0.407 | ** |
| IPCA1 | 19 | 19.559 | 1.029 | ** |
| IPCA2 | 17 | 7.734 | 0.454 | ** |
| Residual GEI | 55 | 9.76 | 0.177 | |
| Residual | 312 | 45.25 | 0.145 | |

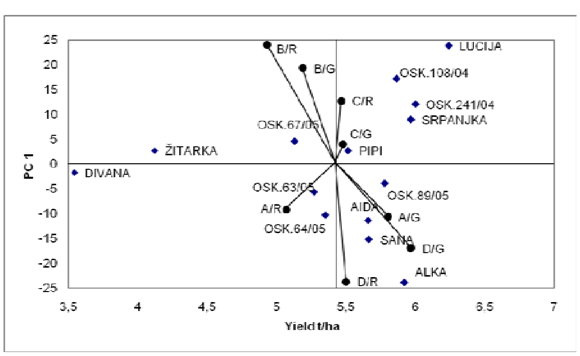


Figure 1 AMMI 1 model biplot for yield of 14 winter wheat genotypes in eight environments

In Figure 1 IPCA 1 scores for the genotypes and the environments were plotted against the mean kernel yield for the genotypes and environments. Regarding the environments high yielding ones were Tovarnik (D/R, D/G) and Požega (C/R, C/G). Low yielding environment was Osijek. Higher sowing density showed more stability that lower density except at location Nova Gradiška where lower sowing rate was more stable thatnhigher sowing rate, but with lower sowing rate kernel yield was considerably lower. Regarding genotypes highest yield was achieved with genotype Lucija. This genotype also was unstable. High yielding genotypes adapted to high yielding environments were Alka, Sana, Aida, Srpanjka, Osk 241/04 and Osk 108/04. Divana and Žitarka were stable genotypes with lower yield.

## DISCUSSION

Combined analysis of variance showed highly significant ($p \leq 0.01$) influence of genotypes, environments (sowing rate and location) and GEI on kernel yield. Similar results were reported by De Vita et al. (2006), El-Khayat et al. (2006), and Yan et al. (2005). Research results showed that selection for high quality and yield in winter wheat should be conducted through multi-location trials. Tested environments had high influence on kernel yield. This is expected due to the differences especially in soil type. Tovarnik as a location with highest yield had the best soil type (chernozem). Differences between tested locations were also reported by Yan et al. (2005), Thomason and Philips (2006) and Marić et al. (2007). Biplot also showed that locations were spread from lower yielding to high yielding which is very good for selection of stable wheat genotypes. Examined genotypes differed in yield and in stability accross environments. Genotype Lucija has the highest yield, but it was unstabie and adapted to higher yielding environments. Best combination of high yield and good stability was in recognized cultivar Pipi and breeding line OSK 89/05.

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## REFERENCES

De Vita, P., Riefolo, C., Codianni, P., Cattivelli, L., Fares, C. (2006): Agronomic and qualitative traits of T. turgidum ssp. dicoccum genotypes cultivated in Italy. Euphytica 150: 195–205.

El-Khayat, G.H., Samaan, J., Manthey, F. A., Fuller, M.P., Brennan, C.S. (2006): Durum wheat quality I: some physical and chemical characteristics of Syrian durum wheat genotypes. International

Journal of Food Science & Technology, 41: 2. 22-29.
Fufa, H., Baenziger, B.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.
Gunjača, J., Knezović, Z., Pecina, M. (2007): Genotype by environment interaction in variety trials. Cereal Research Communications 35: 2. 425-428.
Haile, J.K., Sarial, A.K., Assefa, S. (2007): AMMI analysis for stability and locations effect on grain protein content of durum wheat genotypes. Cereal Research Communications **35**: 4. 1661-1673.
Hoffmann, B., Burucs, Z. (2005): Adaptation of wheat (*Triticum aestivum* L.) genotypes and related species to water deficiency. Cereal Research Communications, **33**: 4. 681-687.
Mardeh A.S.S., Ahmadi, A., Poustin, K., Mohammadi, V. (2006): Evaluation of drought resistance indices under various environmental conditions. Fields Crops Research 98: 222-229.
Marić, S., Čupić, T., Jukić, G., Varnica, I., Dunković, D. (2007): Selection of testing environments for winter wheat breeding. Cereal Research Communications 35: 2. 749-752.
Pepó, P., Győri, Z. (2005): A study of the yield stability of winter wheat varieties. Cereal Research Communications, 33: 4. 769-776.
Rodriguez-Perez, J.E., Sahagun-Castellanos, J., Villasenor-Mir, H.E., Molina-Galan, J.D., Martinez-Garza, A. (2005): Interaction genotype x environment in the characterization of reinfed areas for wheat. Agrociencia, 39: 1. 51-64.
Thomason, W.E., Philips, S.B. (2006): Methods to evaluate wheat cultivar testing environments and improve cultivar selection protocols. Field Crops Research, 99: 87-95.
Yan, W., Hunt, L.A., Johnson, P., Stewart, G., Lu, X. (2002): On-farm strip trials vs. replicated performance trials for cultivar evaluation. Crop Sci, 42: 385-392.
Yan, Z., Yong, Z., He, Z., Guoyou Y. (2005): Milling quality and protein properties of autumn-sown Chinese wheat's evaluated through multi-location trials. Euphytica 143: 209–222.