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STUDY OF GENOTYPE – ENVIRONMENT INTERACTION OF WINTER WHEAT VARIETIES WITH RESPECT TO GRAIN YIELD

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Abstract

Stability of 13 winter wheat varieties across 4 different environments and 2 years was tested with respect to grain yield. High significant genotype environment (GE) effects obtained in the experiment proved the necessity of testing wheat varieties at multiple locations. The joint regression analysis showed that the varieties ‘Zentos’,‘Compliment’, ‘LIA 3948’, ‘Elfas‘ and ‘Marshal’ were most acceptable for cultivation in a wide range of environments, while the varieties ‘Cubus’ and ‘Vergas’ were suitable for cultivation in favourable conditions. The variety ‘Meunier’ was found to be well-adapted to cultivation in poor environments. Kang’s stability statistics analysis confirmed that among the investigated varieties ‘Elfas’ was the best at combining yield stability and productivity. The grain yield of this variety was 7.459 t ha^{-1} with the lowest variance of stability (0.157). Cluster analysis revealed five groups of genotypes and four environments having similar response pattern, with respect to grain yield. The majority of the investigated varieties have similar response pattern (in matching with the mean yields) over all environments with small differences in separate environments. The genotypes from group 4 and Indiv.2 had different (extra-ordinary) response pattern, especially in B, C, and E environments groups.

Key words: yield stability and adaptability, winter wheat, varieties.

Introduction

Genotype – environment interaction (GEI) in winter wheat (*Triticum aestium* L.) varieties is the differential response of genotypes to changing environmental conditions. An ideal variety should have a high mean yield combined with a low degree of fluctuation when this variety is grown over diverse environments. Two main contrasting concepts of stability are distinguished: “static“ (Type 1) and “dynamic“ (Type 2) Becker and Leon, 1988; Lin at al., 1986. For static stability, best genotype tends to maintain a constant yield across environments. Dynamic stability implies for a stable genotype a yield response in each environment that is always parallel to be mean response of the tested genotypes, i.e. zero GEI /Annicchiarico, 2002/. Analysis of GEI of a particular variety can reduce the errors in the breeding process, as the selection in one environment cannot provide advantage in others. It is noteworthy, that the high yield stability can frequently be connected to its low level or, on the contrary, low stability with a high average yields, that too complicates the breeding process. Increase and stability of productivity of a wheat variety, representing a pure line, depend on its individual buffering, i.e. on its ability to exploit favourable conditions of environments. Several methods have been proposed to analyse genotype x environment interactions and phenotypic stability. Joint regression is the most popular calculation and application for them /Gonsalves at al., 2003/. Finlay and Wilkinson's (1963) b_i consider a cultivar stable if its response to environments is parallel to the mean response of all cultivars in the trial. Varieties with the coefficient of regression b_i=1.0 exhibit a full correspondence between the yield dynamics and environmental changes. Higher value of the coefficient (b_i > 1.0) indicates that the response of a variety to the changing environmental conditions is high, i.e. that the variety is less stable. In the case when (b_i < 1.0) a variety shows a weaker response to environmental conditions than the average pool of the varieties. Eberhart and Russell's (1966) $S^2{}_d$ consider a cultivar stable if the residual mean square from Finlay and Wilkinson's regression model is not significant. The less the sum of yield deviation squares is shown by a variety, the higher are its stability characteristics. A stable genotype has a regression coefficient (b_i) value close to 1 and deviations from regression are as small as possible ($S^2{}_d$ = 0). When Shukla's (1972) stability variance statistic (σ_i^2) is significant, this suggests that genotype is unstable across environments. Stability analysis, based on the criteria set forth in Kang & Magari (1995), examines the behaviour of each genotype using the location x year x genotype means. The first criteria used, is the distance a genotype is from the overall mean using its own variance to the LSD for all genotypes from the ANOVA at P = (not significant, 0.10, 0.05, 0.01) and assigns points (0, 1, 2, 3, + if above mean, - if below) to be added to the original ranking. The second criterion used is the relationship of each genotype's variance (σ_i^2) to the average variance (ANOVA error mean square). The further a variance is away from this average, the more negative points are assessed. Again, this is determined using P = (>0.10, > 0.05, >0.01, <0.01) from an F-test and assigning negative points (0, -2, -4, -8) that are subtracted from the adjusted ranking obtained from the first criteria. The higher the stability index (SI) value, the more stable the trait. This Kang's (1988) developed the rank-sum method (YS_i) that combines yield and Shukla's (1972) σ_i^2 statistic to rank genotypes for selection. This method is realized in a computer program 'STABLE' /Kang and Magari, 1995/.

Magari and Kang (1993), Upadnya and Cabello (1996), Pazdernik at al. (1997) Kenneth and Bernhardt (2000), Rao et al., (2002) found that the YS_i statistic was useful in selecting high-yielding, stable corn, potato, rice and soybean genotypes, respectively.

Pattern analysis using cluster classification techniques for grouping genotypes and locations based on similarity GEI effects and main effects /Annicchiarico, 2002/. A squared Euclidean distance as the dissimilarity measure and Ward's clustering method are normally recommended /DeLacy et al., 1996/. It was successfully used for analysis of GE interaction in multi location trials with wheat Robert, 1997, sorghum /Haussmann et al., 2001/, sunflower /Ghafoor at. al. 2005/ and other crops.

The present study was initiated to achieve the following objectives:

– to observe genotypic stability (with respect to grain yield) of 13 winter wheat varieties tested across 4 environments (locations) and 2 years,

– to select varieties combining high level of grain yield and its stability,

– to group the genotypes having similar response pattern over all environments,

– to provide recommendations about wheat varieties in well adapted environments.

Materials and Methods

Plant material and field condition. Thirteen winter wheat varieties ‘Zentos’, ‘Aristos’, ‘Compliment’, ‘Cubus’, ‘Elfas’, LP.562.4.99, LP.790.1.98, LIA 3937, LIA 3948, ‘Marshal’, ‘Meunier’, ‘Residence’ and ‘Vergas’ were tested at the State Variety Testing Stations (SVTS) in Plunge, Kaunas, Pasvalys and Utena, located in contrasting soil and climatic zones during the period 2003 - 2004. At each location the 13 genotypes were planted in 18–20 m^2 test plots using a randomized complete block design with four replications. The seeding rate for all varieties was 450 seeds m^2. Soil pH value in Kaunas SVTS was 7.1–7.3, Pasvalys 6.1–6.5, Plunge 5.7–6.1, Utena 5.9–6.9, mobile P_2O_5 208,319, 267 and 73; K_2O 178, 374. 235 and 161 mg kg^{-1} soil, respectively. Percentage of organic matter was 2.0–2.4, 2.2–3.0, 1.8–2.1 and 1.9–2.2, respectively. Fertilizer application was 90 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}. Analysis of variance was done for the combined analyses of variance across the test environments of location and years.

Statistical analyses: The following linear regression model /Eberhart, Russel, 1966/ was used:

$$Y_{ij} = \mathrm{m} + \mathrm{b}_i \mathrm{I}_j + \mathrm{d}_{ij} + \overline{\varepsilon}_{ij}$$

where Y_{ij} is the mean of the variety i^{th} at the location j; m is the general mean of clone i; b_i is the regression coefficient of the i^{th} variety at the location index which measures the response of this clone to varying location; I_j is the environmental index which is defined as the mean deviation of all varieties at a given location from the overall mean; d_{ij} is the deviation from regression of the i^{th} variety in the j^{th} location; $\overline{\varepsilon}_{ij}$ is the mean of experimental error.

The stability analysis computer program STABLE developed in BASICA by Kang & Magari (1995) was converted to run in the VBA macro program YIELDSTAB of the EXCEL. This was necessary because the version of STABLE could not be run in the BASIC version available. The data furnished with STABLE program were used to test the accuracy of the converted in VBA macro program by comparing the results with those given by Kang & Magari (1995). The program YIELDSTAB has also joint regression analysis in details described by Brewbaker (1996). Cluster analysis was performed using the software IRRISTAT. Pattern analysis module for program IRRISTAT has been adapted from program GEBEI developed by dr. Jan Delasy from University of Queensland, Australia.

Results and discussion

Analysis of variance: The analyses of variance are presented in Table 1. Genotype, location, genotype x location (GxL), crop-year, crop-year x genotype, crop-year x location and crop-year x location x genotype were significant ($P < 0.01$) for wheat grain yield. Such statistical interaction resulted from the changes in the relative ranking of the genotypes or changes in the magnitudes of differences between genotypes from one environment to another. The significant GxL effects ($P < 0.01$) demonstrated that genotypes responded differently to the variation in environmental conditions of the location and indicated the necessity of testing wheat varieties at multiple locations. This shows the difficulties encountered by breeders in selecting new genotypes for release; these difficulties arise mainly from the masking effects of variable environments /Gonsales, 2003/. Thus, it is important to study adaptation patterns, genotypes response and their stability in multi location trials. The factors explained (%) show that winter wheat grain yield was most markedly affected by crop-years (38.7), locations (16.2) and their interaction (15.9) (Table 1).

Table 1. Analyses of variance of grain yield for winter wheat genotipes grown in four locations in 2003 and 2004.
1 lentelė*. Žieminių kviečių veislių, išaugintų keturiose vietovėse 2003 ir 2004 m. grūdų derliaus variantų analizė*

Source / *Šaltinis*	DF	SS	MS	(%)
Total / *Iš viso*	415	1001.658		
Replications / *Pakartojimai*	3	0.519		
Year / *Metai* (Y)	1	387.776	387.776**	38.713
Location / *Vieta* (L)	3	162.805	54.268**	16.253
Genotype / *Genotipai* (G)	12	65.700	5.475**	6.559
Y x L	3	159.447	53.149**	15.918
Y x G	12	42.621	3.552**	4.255
L x G	36	60.171	1.671**	6.007
Y x L x G	36	46.618	1.184**	4.654
Errors / *Paklaidos*	309	80.001	0.259	

** - significance at the 0.01 probability level / *patikimumo lygis* 0,01

The data in Table 2 show that better conditions for shaping high grain yield were in 2004 than in 2003. Across four locations, the best growing conditions were in Kaunas in both testing years. The highest grain yield was observed for the variety ‘Cubus’ (10.33 t ha^{-1}) in Kaunas in 2004 and the lowest yield for ‘Meunier’ (3.28 t ha^{-1}) in Utena in 2003. Across location and years, however, only ‘Vergas’ surpassed all other genotypes with a mean grain yield of 7.48 t ha^{-1}.

Table 2. Mean grain yield performance (t ha^{-1}) for different locations in 2003 and 2004
2 lentelė*. Grūdų derliaus vidurkis (t ha^{-1}) skirtingose vietovėse 2003 ir 2004 m.*

Location / *Vieta*	Grain yield 2003 (t ha^{-1}) *Grūdų derlius 2003 (t ha^{-1})*	Grain of yield 2004 (t ha^{-1}) *Grūdų derlius 2004 (t ha^{-1})*
Plungė	6.662**	6.553
Kaunas	7.035**	9.051**
Pasvalys	5.729	8.798**
Utena	5.089	7.836
Average / *Vidurkis* (LSD01 / *R01* = 0.065)	6.128	8.059**
LSD05 / *R05*	0.152	0.059
LSD01 / *R01*	0.207	0.082

*, ** the highest differences from the average data significance at the 0.05 and 0.01 probability levels, respectively
*, ** *didžiausi skirtumai nuo vidurkio 0,05 ir 0,001 patikimumo lygiams*

When grain yield varies due to the GxE effect, wheat breeders have the alternatives of either developing specific varieties for different environments or broadly adapted varieties that can perform well under variable conditions. It is noteworthy that yield stability is the most important socio economic aim to minimize crop failure, especially in marginal environments.

Joint regression analysis. The joint regression analysis is widely used by researchers to study the genotype x environment interaction and main stability parameters. The stability parameters for all varieties are given in Table 3. The regression coefficient (b_i) measures the increase in the mean yield of a genotype per unit of increase in the environmental index. The mean squared deviation from regression (S^2_d) measures how well the predicted response agrees with that actually observed and includes GE analysis. A genotype with a regression coefficient > 1.0 is responsive to increasingly favourable conditions with respect to site mean yield; a genotype with a regression coefficient < 1.0 is considered not responsive. Small values S^2_d indicate higher stability of a variety. High values of the coefficient of determination (R^2) suggest that the variety is more stable.

In the present study the regression coefficients of the varieties 'Zentos', 'Cubus', LIA 3948 and 'Meunier' were significantly different from $b_i = 1$. The varieties 'Zentos', 'Compliment', 'Cubus', 'Elfas', LIA 3948, 'Marshal' and 'Vergas' significantly exceed an average grain yield among the tested varieties.

The simultaneous consideration of the three parameters of stability (Table 3) for the individual genotype revealed that genotypes 'Elfas' and 'Marshal' produced significant highest yield (7.459 and 7.279 t ha^{-1}) with the regression values of 0.915 and 1.161 respectively, low standard deviation from regression (0.061 and 0.106) and high significant determination coefficient (0.967 and 0.969).

Table 3. Means and estimates of stability statistics for grain yield of wheat varieties in four locations and two years

3 lentelė . *Kviečių veislių grūdų derliaus vidurkiai ir stabilumo statistika keturiose vietovėse tiriant dvejus metus*

Variety *Veislė*	Means (t ha^{-1}) *Vidurkiai (t ha^{-1})*	b_i *regresijos koef.*	S^2_D *regresijos paklaida*	R^2 *determinacijos koeficientas*
'Zentos'	7.301*	0.603*	0.169	0.831**
'Aristos'	7.152	1.209	0.313	0.914**
'Compliment'	7.387*	0.796	0.520	0.735**
'Cubus'	7.315*	1.356*	0.442	0.904**
'Elfas'	7.459*	0.915	0.061	0.969**
LP.562.4.99	6.782	1.035	0.211	0.920**
LP.790.1.98	7.216	0.970	0.207	0.912**
LIA 3937	6.894	0.845	0.189	0.896**
LIA 3948	7.323*	0.762*	0.338	0.796**
'Marshal'	7.279*	1.161	0.106	0.967**
'Meunier'	6.028	1.482*	0.624	0.889**
'Residence'	6.625	1.016	0.548	0.811**
'Vergas'	7.480*	0.847	0.641	0.718**

*,** significant at the 0.05 and 0.01 levels, respectively

, patikimumo lygis atitinkamai 0,05 ir 0,01*

Figure 1 shows that the best stability parameters were exhibited by the varieties 'Zentos', 'Compliment' and LIA 3948. These genotypes significantly differed in regression coefficient ($b_i < 1$) and had grain yield > grand mean. Therefore, they appeared to be the best varieties with regard to stability. These three varieties exhibited wide adaptability and may be recommended for cultivation in different environments across the country. A slightly higher regression coefficient (but not significantly differing from 1.0) was identified for the varieties 'Elfas' and 'Marshal'. These varieties can be cultivated in diverse environments too. However, the variety 'Vergas' was best yielding in the experiment, and the standard deviation of its yield from linear regression was the greatest in the experiment. As a result, it may be characterized as suitable for specific adaptation in favourable environments. The variety 'Cubus' had yield significantly over grand mean grain yield, and had regression coefficients greater than the unity, therefore it may be characterized as and 'Vergas' for specific adaptation in favourable environments. The variety 'Meunier' had inferior grain yield, but regression coefficient ($b_i > 1$) suggests that this variety is well adapted to poor environments. To select a superior variety to others, it is necessary to test them widely /Troyer, 1996/ and select for both: average yield and stability /Lin and Binns, 1994; Kang, 1997/. In addition to agronomic traits, resistance to various diseases and winter hardiness should continue to be top priorities in Lithuanian winter wheat breeding.

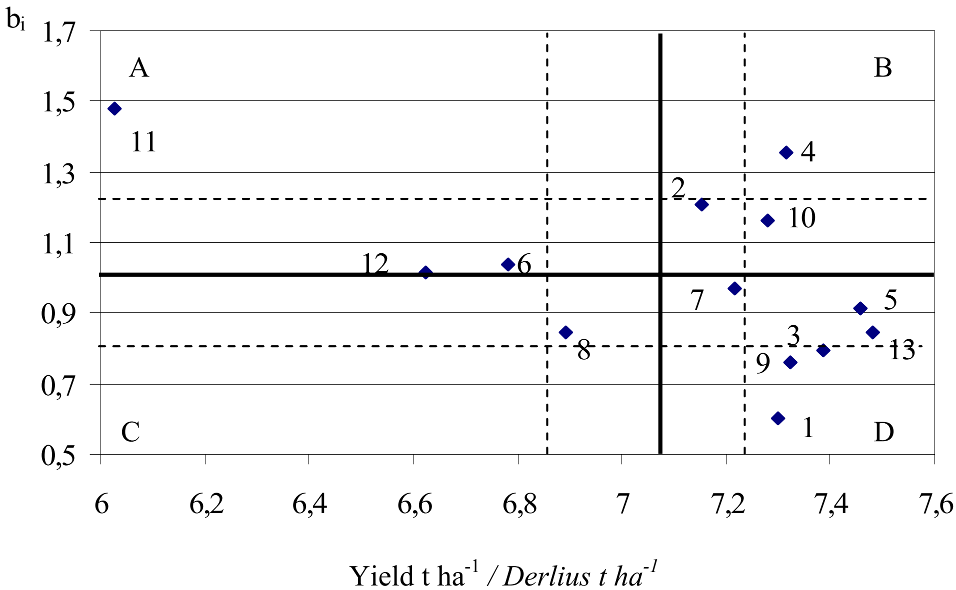

Figure 1. Scattered diagram for mean grain yield and regression coefficient. 1 – 'Zentos', 2 – 'Aristos', 3 – 'Compliment', 4 – 'Cubus;', 5 – 'Elfas', 6 – LP.562.4.99, 7 – LP.790.1.98, 8 – LIA 3937, 9 – LIA 3948, 10 – 'Marshal', 11 – 'Meunier', 12 – 'Residence', 13 – 'Vergas'

1 paveikslas*. Vidutinis grūdų derlius ir regresijos koeficientas. 1 – 'Zentos', 2 – 'Aristos', 3 – 'Compliment', 4 – 'Cubus', 5 – 'Elfas', 6 – LP.562.4.99, 7 – LP.790.1.98, 8 – LIA 3937, 9 – LIA 3948, 10 – 'Marshal', 11 – 'Meunier', 12 – 'Residence', 13 – 'Vergas'*

Kang's stability statistics: The main task of the state variety testing is to select varieties combining a high level of grain yield and yield stability. The results of yield stability analysis for the period 2003 – 2004 are provided in Table 4.

Final result of this analysis is the integral parameter YS_i based on the sum of ranks of grain yield and its stability. When the sum of ranks is higher, the variety has better economic value. The sign (+) means that the given variety exceeds an average YS evaluation in an experiment. During 2003-2004 the variety 'Elfas' showed the highest integrated evaluation YS (14+). It combined a high grain yield (7.459 t ha^{-1}) with the lowest (not significant) variance of stability (0.157). All the other varieties had significant stability variance and therefore had negative stability rating from -4 to -8. The varieties 'Aristos' and 'Vergas' had integral evaluation YS 5+ and 7+ , respectively. These varieties had high grain yield (7.387–7.480 t ha^{-1}), but low stability. The varieties 'Meunier' and 'Residense' had the lowest integral evaluation YS_i (-10 and -8, respectively). The low grain yield (6.028–6.629 t ha^{-1}) and high variances of stability

(4.512–2.068) are characteristic of them. Most of the varieties studied showed crossover interaction (differential response in different location), indicating specific adaptation. Only the variety 'Elfas' showed significant grain yield stability across years within a location. This suggests the possibility of simultaneous selection for high grain yield and broad adaptability to diverse environments. In conclusion, we found that Shukla's stability variance statistics and Kang's YS_i were practical, informative and useful.

Table 4. Selection of wheat varieties for yield and stability in 2003–2004.
4 lentelė. *Kviečių veislių atranka derliui ir stabilumo įvertinimas 2003–2004 m.*

Variety *Veislė*	Yield means t ha^{-1} *Derlius t ha^{-1}*	Yield rank *Derliaus rūšiavimas*	Adjustment to rank *Korekcija*	Adjusted *Pataisyta korekcija*	Stability variance *Stabilumo pokyčiai*	Stability rating *Stabilumo įvertinimas*	YS(i) *Integralinis rodiklis*
'Zentos', check	7.301	8	1	9	1.977	-8	1+
'Aristos'	7.152	5	1	6	1.518	-8	-2
'Compliment'	7.387*	11	2	13	2.332	-8	5+
'Cubus'	7.315	10	1	11	2.806	-8	3+
'Elfas'	7.459*	12	2	14	0.157	0	14+
LP 562.4.99	6.782	3	-2	1	0.710	-8	-7
LP 790.1.98	7.216	6	1	7	0.693	-8	-1
LIA 3937	6.894	4	-1	3	0.828	-8	-5
LIA 3948	7.313*	9	1	10	1.735	-8	2+
'Marshal'	7.279	7	1	8	0.510	-4	4+
'Meunier'	6.028	1	-3	-2	4.512	-8	-10
'Residence'	6.625	2	-2	0	2.068	-8	-8
'Vergas'	7.480*	13	2	15	2.656	-8	7+

Grand mean / *Generalinis vidurkis* 7.095 $\overline{YS} = 0.231$
LSD $_{05}$/ *R $_{05}$* 0.239
* - indicates the highest differences from the average data significance at the 0.05 probability level
** - rodo, kad aukščiausi skirtumai nuo vidurkio patikimi, 0,05 patikimumo lygio*

Cluster analysis. Cluster analysis or numerical classification Sneath & Sokal, 1973 is one of the techniques used to simplify the data set by grouping individuals with similar responses for all attributes. In the case of genotype x environment interaction analysis, clustering is used to simplify the data set by grouping the genotypes over all environments, with similar response patterns for yield. The second grouping is grouping for environments, over all genotypes, with similar response patterns in respect to grain yield /Williams, 1976/. Ward's fusion strategy of hierarchical clustering technique was used on winter wheat G x E data of grain yield (t ha^{-1}) in 2003 and 2004. Segmentation into separate bunches is a very important moment in a cluster analysis /Ghafoor at al., 2005/. We were guided by the principle that interaction within group must be less than 20 % of the total interaction /Robert, 1997/. Therefore we cut the genotype dendrogram at fusion level 1.14. Thirteen genotypes were re-grouped into five clusters (Table 5 and Figure 2). The eight environments were re-grouped into five by cutting the dendrogram at fusion level 0.66. (Table 5 and Figure 4).

Table 5. The group members at the specified group level for genotypes and environments grain yields in 2003 and 2004
5 lentelė. *Specifinių grupių narių lygis pagal genotipų ir grūdų derlių 2003 ir 2004 m.*

Genotypes / *Genotipai*		
Group *Grupės*	No	Group members/ *Grupių nariai*
Group 1	2	'Elfas', 'Marshal' (high – yielding / *didelio derlingumo*)
Group 2	2	LP.562.4.99, LP.790.1.98 (middle – yielding / *vidutinio derlingumo*)
Group 3	3	LIA 3937, 'Zentos', LIA 3948 (middle – yielding / *vidutinio derlingumo*)
Group 4	2	'Compliment', 'Vergas' (high – yielding / *didelio derlingumo*)
Group 5	2	'Aristos', 'Cubus' (middle – yielding / *vidutinio derlingumo*)
Indiv. 1	1	'Residence' (low – yielding / *nedidelio derlingumo*)
Indiv. 2	1	'Meunnier' (low – yielding / *nedidelio derlingumo*)
Environments / *Vietovės*		
Croup A	2	Kaunas 2004, Utena 04 (high – yielding / *didelio derlingumo*)
Group B	2	Utena 2003, Pasvalys 2003 (middle – yielding / *vidutinio derlingumo*)
Group C	2	Kaunas 2003, Pasvalys 2003 (low – yielding / *nedidelio derlingumo*)
Indiv. D	1	Plungė 2003 (middle – yielding / *vidutinio derlingumo*)
Indiv. E	1	Plungė 2004 (middle – yielding / *vidutinio derlingumo*)

Figure 2 and Table 5 clearly indicate that genotypes 12 – 'Residense' and especially 11 – 'Meunier' are different from the test of the genotypes over all environments. The group -1, group - 2, group - 3, group - 5 and Indiv. 1 have similar response pattern (in matching with mean yields) over all environments with small differences in separate environments (Figure 3). As it is clear from Figure 2 the circumscribed above bunches envelop the majority of the investigated genotypes.

The genotypes from group 4 and Indiv. 2 as shown in Figure 5 have different (extra-ordinary) response pattern, especially in B, C, and E environments groups.

If genotypes group 4 had tendency to augmentation of grain yield, that Indiv. 2 have tendency its drop (Figure 5).

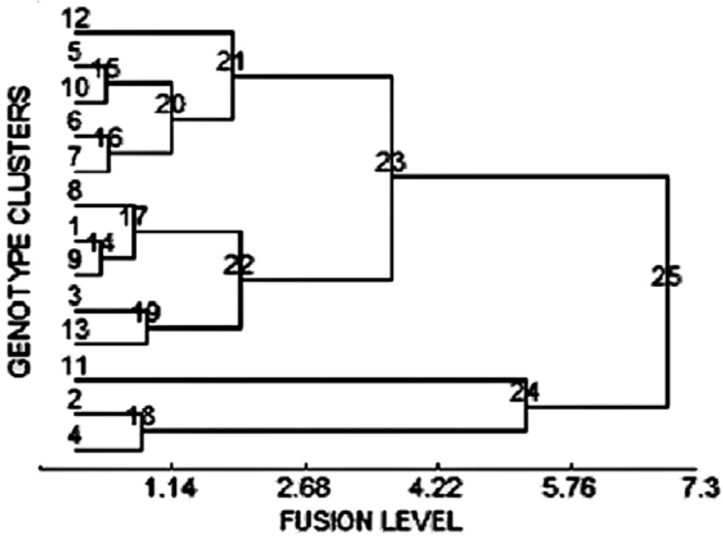

Figure 2. Cluster dendrogram for genotypes: 1 – 'Zentos', 2 – 'Aristos', 3 – 'Compliment', 4 – 'Cubus', 5 – 'Elfas', 6 – LP.562.4.99, 7– LP.790.1.98, 8- LIA 3937, 9 – LIA 3948, 10 – 'Marshal', 11 – 'Meunier', 12 – 'Residence', 13 – 'Vergas'

2 paveikslas. *Klasterinė dendrograma genotipams. 1 – 'Zentos', 2 – 'Aristos', 3 – 'Compliment', 4 – 'Cubus', 5 – 'Elfas', 6 – LP.562.4.99, 7 – LP.790.1.98, 8 – LIA 3937, 9 – LIA 3948, 10 – 'Marshal', 11 – 'Meunier', 12 – 'Residence', 13 – 'Vergas'*

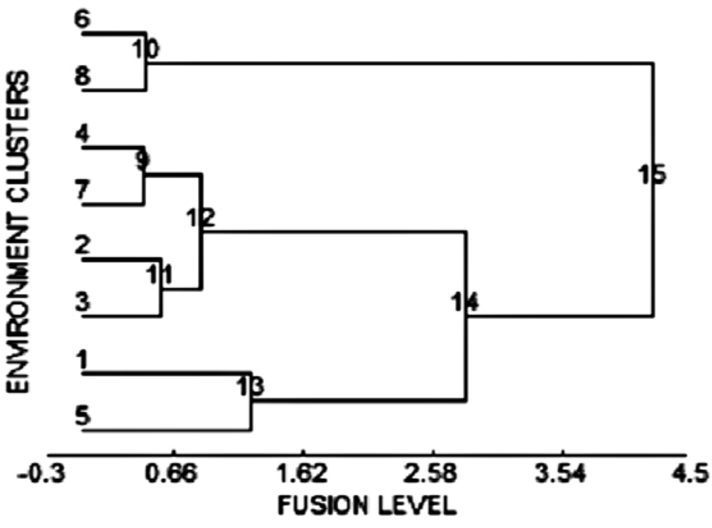

Figure 3. Cluster dendrogram for environments: 1 – Plunge 2003, 2 – Kaunas 2003, 3 – Pasvalis 2003, 4 – Utena 2003, 5 – Plunge 2004, 6 – Kaunas 2004, 7 – Pasvalis 2004, 8 – Utena 2004

3 paveikslas. *Klasterine dendrograma pagal vietoves : 1 – Plungė 2003, 2 – Kaunas 2003, 3 – Pasvalys 2003, 4 – Utena 2003, 5 – Plungė 2004, 6 – Kaunas 2004, 7 – Pasvalys 2004, 8 – Utena 2004*

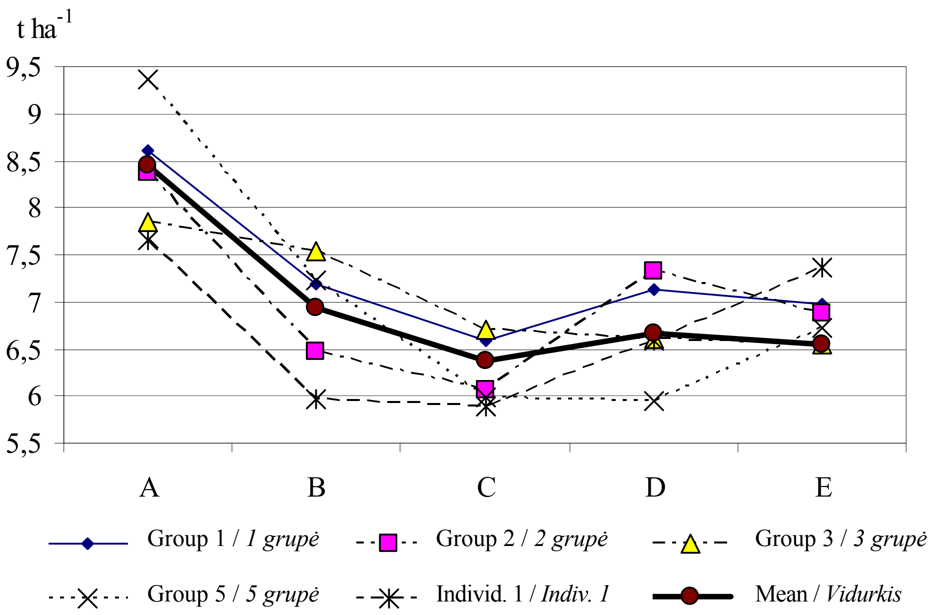

Figure 4. Performance of genotypes groups 1, 2 , 3, 5 and Indiv. 1 versus environments group. Grain yield

4 paveikslas*. Genotipų grupių 1, 2, 3, 5 ir Indiv. 1 grupės grūdų derlius pagal vietoves*

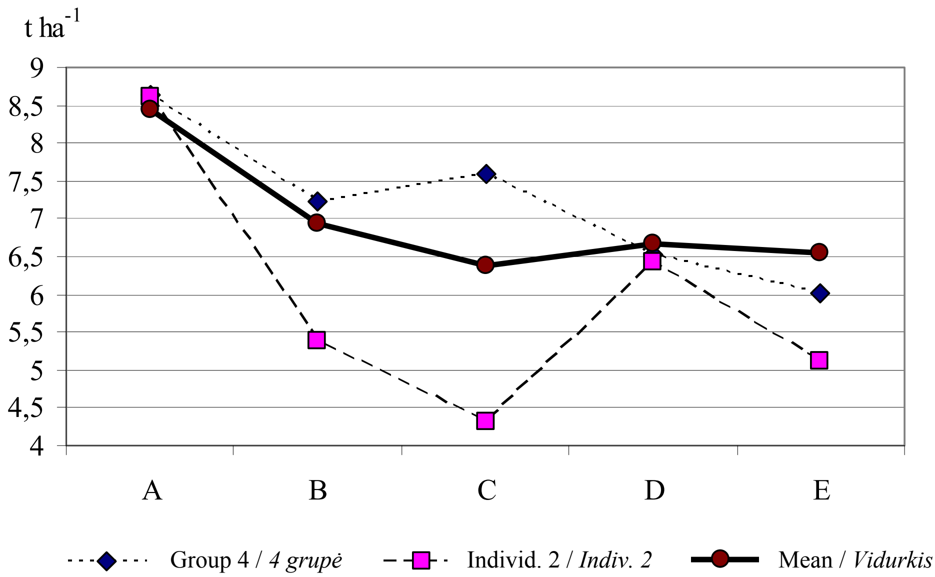

Figure 5. Performance of genotypes groups 4 and Indiv. 2 in different environments groups

5 paveikslas*. Ketvirtos grupės ir Indiv. 2 genotipų įvertinimas skirtingose vietovėse*

Conclusion

1. The analysis of variance for 13 varieties in 8 environments suggests that genotype (G), location (L), crop-year (Y) and their interaction were significant ($P < 0.01$) for wheat grain yield. High significant G x L effects indicated the necessity of testing wheat varieties at multiple locations.

2. Joint regression analysis has shown that the varieties 'Zentos', 'Compliment', LIA 3948, 'Elfas' and 'Marshal' are best-suited for cultivation in a wide range of environments, while the varieties 'Cubus', 'Vergas' are best suited for cultivation in favourable conditions. The variety 'Meunier' is well-adapted for cultivation in poor environments.

3. Kang's stability statistic analysis has confirmed that the variety 'Elfas' combined the best parameters of stability and productivity compared with the other varieties tested. It combined a high grain yield (7.459 t ha^{-1}) with the lowest (not significant) variance of stability (0,157). All the other varieties had a significant stability variance and therefore had negative stability rating from -4 to -8.

4. Cluster analysis revealed 5 groups of genotypes and 4 – environments having similar response pattern, with respect to grain yield. The majority of the investigated varieties have a similar response pattern (in matching with mean yields) over all environments with small differences in separate environments. The genotypes from group 4 and Indiv.2 had different (unusual) response pattern, especially in B, C, and E environments groups.

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ŽIEMINIŲ KVIEČIŲ VEISLIŲ APLINKOS IR GENOTIPO SĄVEIKOS ANALIZĖ PAGAL GRŪDŲ DERLIŲ

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Santrauka

2003–2004 metais buvo tirta 13-kos žieminių kviečių veislių, augintų keturiose skirtingose augimvietėse, genotipo ir aplinkos sąveika. Tyrimuose buvo nagrinėjamas šių veislių grudų derlius, taikant įvairius statistinius metodus.

Analizė parodė, kad veislių 'Zentos', 'Compliment', LIA 3948, 'Elfas' ir 'Marshal' kviečiai gali būti auginami įvairiose aplinkose. Veislės 'Cubas' ir 'Vergas' turi būti auginamos tik geriausiomis sąlygomis. Nustatyta, kad veislės 'Meunier' kviečiai geriau prisitaiko ir auga kad ir prastesnėse dirvose. Kauno rajone augintų veislių stabilumo analizė parodė, kad tarp tirtų veislių geriausia buvo veislė 'Elfas'. Šios veislės grūdų derlingumas buvo 7,459 t/ha^{-1} esant pačiam žemiausiam stabilumo įvairavimui (0,157). Klasterinė analizė parodė, kad visus genotipus galima suskirstyti į penkias grupes, kurių grūdų derlingumas keturiose augimvietėse yra panašus, remiantis vidutinio derlingumo duomenims. Dauguma tirtų veislių turėjo panašią genotipo ir aplinkos sąveiką visose aplinkose. Skyrėsi tik ketvirta ir Indiv 2 grupė. Atlikus tyrimus, šių grupių genotipų rezultatai gerokai skyrėsi, ypač B, C, ir E aplinkose.

Reikšminiai žodžiai: derlius, stabilumas, žieminiai kviečiai, veislės.