THE INFLUENCE OF ENVIRONMENT ON YIELD AND YIELD COMPONENTS IN TWO ROW WINTER BARLEY VARIETIES

Short title: THE ENVIRONMENTAL INFLUENCE ON YIELD IN BARLEY VARIETIES

NATALIJA MARKOVA RUZDIK[1], DARINA VALCHEVA[2], LJUPCHO MIHAJLOV[1], SASA MITREV[1], ILIJA KAROV[1], VERICA ILIEVA[1]

[1] *"Goce Delchev" University, Faculty of Agriculture, "Krste Misirkov" 10-A, 2000 Shtip, Republic of Macedonia; e-mail: natalija.markova@ugd.edu.mk*

[2] *Institute of Agriculture, 8400 Karnobat, Republic of Bulgaria*

Abstract

The aim of this paper is to analyze the environmental influence over the yield and yield components in two row winter barley varieties. The experiment work was conducted during the period of 2012-2014 on the research fields of the Faculty of Agriculture, in two different locations in the Republic of Macedonia, as follows: Ovche Pole and Strumica. As far as material is concerned 21 genotypes were used with Macedonian, Serbian, Croatian and Bulgarian origin. Generally, genotype *NS 525* indicated highest yield (5549 kg/ha) as compared to the rest of the genotypes while the lowest grain yield was obtained by genotypes *Obzor* (3443 kg/ha) and *Imeon* (3272 kg/ha) for the period of study and for the both locations together. The research had proved that the influence of year i.e. weather conditions in the period of study is the strongest over yield. By yield and yield components, most distant, form one hand, are genotypes *Hit* and *Izvor* compare to genotypes *Ladreya* and *Odisej*. For Ovche Pole location, the highest influence to the grain yield has the traits: number of productive tillers per plant and grain weight per plant, while for Strumica location these are the grain weight per plant and plant height. Genotypes *Emon, Lardeya*, *Kuber*, *Odisej* and *Asparuh* stand out as the most suitable genotypes for growing in conditions in Ovche Pole location, while for Strumica location the genotypes *NS 525, NS 565, Asparuh, Sajra*, *Rex* and *Zlatko,* are most appropriate. Mentioned genotypes can be introduced in the production of barley or to be chosen as the most suitable varieties for new parents in any future breeding process, in order to get the new high yielding varieties suitable for cultivation in the regions examined.

Key words: yield, yield components, genotypes, cluster, environment, PCA

Abbreviations: PCA-Principal Components Analysis; NSm^2-Number of spikes per m^2; PH-Plant height; TTNP-Total tillers number per plant; NPTP-Number of productive tillers per plant; SL-Spike length; NGS-Number of grains per spike; NSSS-Number of sterile spikelets per spike; GWS-Grain weight per spike; GWP-Grain weight per plant; 1000 GW-1000 grain weight; Y-Yield; A-factor genotype**;** B-factor year**;** C-factor location; OP-Ovce Pole; S-Strumica.

Introduction

Barley is one of the most important crops because it's used as raw material in beer production and animal feed, cultivated successfully in a wide range of climate environments. The primary goal in the breeding process is the crop yield, whose significance is valuated through the economic benefit for the producers. The yield is a function of genetic potential of the variety, external conditions in which the crop is grown, applied technology and the interaction of all these factors (Abad et al., 2013). Increasing the yield is a basic task of breeding program of barley and aim in improving the existing genetic potential through creating more favourable conditions for optimum realization of existing potential or creation of new varieties whose yield will be higher than the yield of the existing varieties (Johnson and Aksel, 1959; Yau and Hamblin, 1994; Mersinkov, 2000). At the same time, directions in breeding process are aimed at improving productivity through obtaining stable yields over years and improving resistance on biotic and abiotic factors (Valcheva et al., 2010).

The greatest effects on the crops yield have components: the number of spikes per m^2, the number of grains per spike, the weight of whole plant and 1000 grain weight (Fathi and Rezaie, 2000).

In order to see how changes of environmental conditions influence the genetic potential of a variety, it is necessary to assess the interaction between genotype and the environmental conditions. Today, there are many papers in which it is explained about the interaction between the environmental conditions and grain yield (Valcheva et al., 1996; Penchev et al., 2002; Tsenov et al., 2006).

Baring in mind that barley is a crop with wide adaptive growing possibilities, it is to be expected that each variety reacts differently on the environmental conditions (Dimova et al., 2006, Valcheva et al., 2010).

First component which directly affects the barley yield and on other cereals is the number of spikes per m^2 (Grafius, 1964; Dofing and Knight, 1994; Sinebo, 2002; Ataei, 2006). The second component is the number of grains per spike and the third component is 1000 grain weight (Evans and Wardlaw, 1976; Reid Wiebe, 1979). According to Rasmussen and Chanel (1970), increasing the number of grains per spike means reducing the grain weight per spike.

Our research goal is to explore the influence of the environmental conditions over the yield and its components in two row winter barley varieties.

Material and methods

The experiment was conducted during the period 2012-2014 in the research fields of Faculty of Agriculture, "Goce Delchev" University in two locations in Republic of Macedonia. The first one was Ovche Pole with altitude between 200-400 m, longitude 41°49'21.9" and latitude 21°59'03.9" with soil type smolnica. The other one was Strumica with 280 m altitude, longitude 41°26'32.0" and latitude 22°39'54.5" with alluvial soil type.

In total 21 two row winter barley genotypes were used in this study. Five of them are Macedonian (*Hit, Izvor, Egej, Line 1* and *Line 2*), two varieties are Serbian (*NS 525* and *NS 565),* two varieties are Croatian (*Zlatko* and *Rex*) and the other 12 varieties are with Bulgarian origin (*Obzor, Perun, Emon, Lardeya, Orfej, Imeon, Zagorec, Asparuh, Kuber, Sajra, Devinija* and *Odisej*).

The experiment was conducted in a randomized block design with three replications. Each replication plot has 1 m^2, consisted of 10 rows and the amount of cultivated seed was evaluated on 500 seeds per m^2. Seeds were sown by hand at 3 to 5 cm deep on the same date in both localities. The method of setting up the experiment was the same in both locations. The standard growing measures were applied during the vegetation.

Then plant samples were randomly chosen from middle part of each replication plot from both locations. Plants were evaluated for traits including: number of spikes per m^2, plant height (cm), total tillers number per plant, number of productive tillers per plant, spike length (cm), number of grains per spike, number of sterile spikelets per spike, grain weight per spike (g), grain weight per plant (g), 1000 grain weight (g) and yield (kg/ha).

Figure 1 shows the average values of the temperature during the period of study and lond-term period for both locations. The average monthly temperature values for OP and S locations do not differ significantly as compared to the long-term averages (Figure 1). Namely, Figure 1 clearly shows that higher average monthly temperatures in the period of study are registered only in January and February, as compared to the long-term monthly average values in both locations.

Figure 2 shows the monthly amount of precipitations for a period of study and long-term period for both locations. As far as monthly precipitations value is concerned, Figures 2 clearly point that generally OP location is characterized by lower monthly precipitation values, compared to S location except in November, April and May in the period of study. Total precipitation values for OP location is 475.5 mm or 57.3 mm higher as compared to the total long-term annual precipitation. As far as S location is concerned, total precipitation value is 569.4 mm, or 47.6 mm less than the total long-term annual precipitation.

Fig. 1.

Fig. 2.

The obtained results of yield and yield components are statistically processed with variance analysis, cluster and principle component analysis using statistical programs JMP version 5.0 1a (2002), SPSS Statistics 19 (2010) and Stat graph.

Results and discussion

Figure 3 illustrate average, lowest and highest values of grain yield of tested genotypes in period of study average for both locations. Furthermore, Figure 3 illustrates that genotype *NS 525* has highest grain yield (5549 kg/ha), but at the same time and highest range of variation, followed by genotypes *Kuber* (5407 kg/ha) and *NS 565* (5233 kg/ha). The lowest grain yield have genotypes *Obzo*r (3443 kg/ha) and *Imeon* (3272 kg/ha).

Fig. 3.

In order to check the influence of genotype, year conditions and location and their interaction on the grain yield, variance analysis is performed (Table 1). The yield variance analysis points that highest influence is by the factor (B) 'year' i.e. weather. Not to be neglected in the phase of yield composition is the role of the genotype too. In this research it is shown that the effect of factor (C) i.e. location is the lowest.

Out of the interaction of the three factors (genotype, year and location) the strongest is the interaction between the genotype and year. Knowing that factor year has the highest influence over the yield and knowing that the influence of genotype is strong, it leads to a conclusion that suitable for production and future breeding in that year can be considered the genotypes which are in high productivity.

Table 1.

In Table 2 are given the values for average, minimum, maximum values and coefficient of variation for all examined traits in barley varieties in both locations separately. Average values for number of spikes per m^2, number of productive tillers per plant, spike length and grain weight per plant for S location are higher than OP location. That is probably consequence to the favourable climatic conditions in the S location. The highest coefficient of variation in both locations has the number of sterile spikelets per spike while the lowest coefficient of variation has 1000 grain weight (1.82%) in OP location and number of grains per spike (2.55%) in S location.

Table 2.

In order to determine the similarity or distance between the tested genotypes on yield and its components, cluster analysis had been performed (Figure 4). The dendogram illustrates that by yield and yield components the genotypes are clearly grouped in three clusters. The first cluster is the biggest one and is consisted of 14 genotypes i.e. *Hit, Izvor, Line 1, Orfej, Zagorec, Zlatko, Rex, NS 565, Egej, Kuber, Devinija, Sajra, Perun* and *NS 52*5, and could be divided into groups and subgroups. Within the frame of this cluster, genotypes *Zlatko* and *Rex* are genetically most similar, they are linked in a subgroup and have least distant unit (difference). Their similarity is linked with the following productivity components: plant height, number of productive tillers per plant, spike length, number of grains per spike, number of sterile spikelets per spike and 1000 grain weight. Within the first cluster, the following genotypes are very similar to the tested yield components, *Orfej* and *Zagorec* on one, and genotypes *Kuber and Devinija* from the other side. Yield components, close to the genotypes *Orfej* and *Zagorec* from one, and genotypes *Kuber* and *Devinija* from the other side are: total tillers numbers per plant, number of productive tillers per plant, number of grains per spike, grain weight per spike and grain weight per plant. Genotypes *Hit* and *NS 525* are most distant within the first cluster.

The second cluster is the least populated, consisted by three genotypes: *Line 2, Obzor* and *Imeon.* The three genotypes are close to the following yield components: number of sterile spikelets per spike, spike length and 1000 grain weight.

The third cluster is composed of 4 genotypes, the ones with Bulgarian origin. Within the cluster there are two subgroups. The first one is between the genotypes *Emon* and A*asparuh* while the second is between genotypes *Lardeya* and *Odisej*. Genotypes from the first subgroup are close by yield components: total tillers number per plant, grain weight per spike and grain weight per plant. The second subgroup of genotypes *Lardeya* and *Odisej* are genetically close by trait 1000 grain weight.

Fig. 4.

In order to obtain more thorough explanation for yield variation and yield components for both locations a Principle component analysis had been performed. Table 3 illustrates the PCA analysis for main components for both locations. For OP location the first component is related with 28.77% of the total variation, the second with 23.60%, the third with 15.19% and the fourth component with 11.59% of the total variation. The cumulative variation coefficient is 79.14% from the total yield variation (Table 3). For S location, the first main component relates with 24.57% of the total variation, the second main component 23.30%, the third with 18.10% and the fourth one is related with 11.52% of the total variation. The cumulative variation coefficient is 77.52% of the total yield variation (Table 3).

Table 3.

Values of yield components by main components, from both locations are presented in Table 4.

For OP location it is visible that the first main component is linked with the following yield components: number of spikes per m^2, number of productive tillers per plant, grain weight per plant, plant height and yield. Negative value for trait number of grains per spike shows that cannot always be expected to provide high yielding varieties with larger number of grains per spike.

The second main component is linked with the following yield components: grain weight per spike, number of productive tillers per plant, total tillers number per plant, grain weight per plant, number of grains per spike and 1000 grain weight. Negative values for traits number of spikes per m^2 and spike length indicates it should be careful for these properties selected genotypes whit high productivity.

The third main component is related to the following yield components: yield, number of sterile spikelets per spike, plant height, grain weight per spike and number of spikes per m^2, which indicates that it is with high probability to expect genotypes with high yield to have greater number of sterile spikelets per spike.

The fourth main component is related to the following yield components: number of grains per spike and number of sterile spikelets per spike, which means as bigger is the number of grains per spike there is high level of probability to expect higher number of sterile spikelets per spike as well. The negative values for the traits: 1000 grain weight and total tillers number per plant by the fourth main component indicates that the total tillers number per plant is quite important traits for the yield, but for higher yield values, the number of productive tillers per plant should be considered and that 1000 grain weight is not always firm element for selection of genotypes with high productivity.

For S location Table 4 clearly illustrates that the first main component is linked to the following yield components: grain weight per plant, total tillers number per plant, 1000 grain weight and yield. Negative value for the trait spike length illustrates that it would be hard to choose genotype with high productivity based on this trait.

The second main component is linked to the following yield components: number of spikes per m^2 and yield. Negative value for the traits: grain weight per spike and number of grains per spike illustrates that the yield depends much more of the number of spikes per m^2 rather than the number and weight of grain per spike.

The third main component is linked to the following yield components: number of productive tillers per plant and spike length. Negative high value of the trait plant height illustrates that it is not always to expect the higher plants should obtain high yields.

The fourth component is linked to the following yield components: number of productive tillers per plant and total tillers number per plant. Negative value is obtained for trait yield. This shows that total tillers number per plant is very important for establishing the yield but for higher yields it should be taken into consideration the number of productive tillers per plant, but not the total number tillers number per plant. This illustrates that during selection of genotype with high yield it should be taken into consideration for the number of spikes per m^2, and not for the total and productive number of tillers per plant.

Table 4.

Main components values for every genotypes in both locations are presented in Table 5.

For OP location indicates that positive and high values on the four main components have the genotypes *Emon*, *Lardeya* and *Odisej* (Table 5). This indicates that they are adequate to the conditions of the environment for this location and are performing good yields. Probably, due to the fact that genotypes *Lardeya* and *Odisej* are drought resistant thus are suitable for the location conditions in OP (Valcheva and Valchev, 2009; 2013).

As for S location it should be stated that only the values of genotype *NS 565* are positive on the all main four components (Table 5).

Table. 5.

For better link visualization between tested genotypes to the yield and yield components, two separate projections (Scatter-plots) for both locations were made (Figure 5 and 6).

The Figure 5, for OP location illustrates that the vectors for yield components who have longest length are number of productive tillers per plant (NPTP) and grain weight per plant (GWP). As a matter of fact these are the traits that have strongest influence over yield. Figure 6, for S location illustrates that highest influence to the yield have the traits: grain weight per plant (GWP) and plant height (PH). The vector for trait grain weight per plant (GWP) makes sharp angle with the vector yield in both locations, which indicates that this trait is heavily linked to the yield. The other yield components which contribute for obtaining high yields for OP location are: number of spikes per m^2 (NS m^2), plant height (PH) and total tillers number per plant (TTNP), as for S location are the following: number of spikes per m^2 (NS m^2), total tillers number per plant (TTNP) and 1000 grain weight (1000 GW).

Fig. 5.

Fig. 6.

The yield components vectors that have shortest length influence less over the yield. For OP location (Figure 5) it is the trait 1000 grain weight (1000 GW), as for S location it is number of grains per spike NGS (Fugure 6).

Figure 5, for OP location illustrates that the yield components vectors: spike length (SL), number of grains per spike (NGS) and number of sterile spikelets per spike (NSSS) make shallow angles with the yield vector and by that prove that by these traits cannot be made selection of high yield genotypes, as they cannot be considered as firm criteria. As for S location, the only uncertain criterion is the trait number of grains per spike (NGS) (Figure 6).

The vectors of higher number of yield components for S location are located on the right quadrant of the coordinative system, and this shows that the traits complement each other to achieve a higher yield. It is high probability in S location to select a genotype with high productivity, as there are better links between the yield and yield components.

The overall research showed that genotypes *Emon, Lardeya, Kuber, Odisej* and *Asparuh* stand out as the most suitable genotypes for growing in conditions in OP location (Figure 5), while for S location the genotypes: *NS 525, NS 565, Asparuh, Sajra, Rex* and *Zlatko* are most appropriate (Figure 6). Mentioned genotypes can be introduced in the production of barley or to be chosen as the most suitable varieties for new parents in any future breeding process, in order to get the new high yielding varieties suitable for cultivation in the regions examined.

Conclusion

From the performed research it can be concluded that tested genotypes are with high productivity. Genotype *NS 525* indicated highest yield, followed by genotypes *Kuber* and *NS 565*.

The research had proved that the influence of year i.e. weather conditions in the period of the study are the strongest over yield.

By yield and yield components, most distant, are genotypes *Hit* and *Izvor* compare to genotypes *Ladreya* and *Odisej*.

For Ovche Pole location, the highest influence to the yield had the traits: number of productive tillers per plant and grain weight per plant, while for Strumica location, the highest influence to the yield had the traits grain weight per plant and plant height.

Genotypes *Emon, Lardeya, Kuber, Odisej* and *Asparuh* stand out as the most suitable genotypes for growing in conditions in Ovche Pole location, while for Strumica location the genotypes *NS 525, NS 565, Asparuh, Sajra, Rex* and *Zlatko* are most appropriate. Mentioned genotypes can be introduced in the production of barley or to be chosen as new parents in any future breeding process, in order to get the new high yielding varieties suitable for cultivation in the regions examined.

References

Abad, A., Khajehpour, M. R., M. Mahloji and A. Soleymani, 2013. Evaluation of phonological, morphological and physiological traits in different lines of barley in Esfahan region. *International Journal of Farming and Applied Science*, **2** (18): 670-674.

Ataei, M., 2006. Path analysis of barley *(Hordeum vulgare* L.) yield. Ankara University, Faculty of Agriculture. *Journal of Agriculture Science*, **12** (3): 227-232.

Dimova, D., Valcheva, D., S. Zapranov and G. Mihova, 2006. Ecological plasticity and stability in the yield of winter barley varieties, Jubilee conference 65 years agrarian science in Dobrudzha. *Field Crop Studies*, **III** (2): 197-203.

Dofing, SM. and CW. Knight, 1994. Yield component compensation in uniculm barley lines. *Agronomy journal*, **86**: 273-276.

Evans, L.T. and I.F. Wardlaw, 1976. Aspects of the comparative physiology of grain yield in cereals. Academic Press, New York. *Advance in Agronomy*, **28**: 301-359.

Fathie, G. and K. Rezaie, 2000. Path analysis of barley yield and yield components in Ahvaz region. *Agriculture science and industrialization*, **14**: 39-48.

Grafius, JE., 1964. A geometry for plant breeding. *Crop science*, **4**: 241-246.

JMP, 2002. Version 5.0 1a, A BUSINESS UNIT OF SAS 1989 - 2002 SAS Institute Inc.

Johnson, L. P. V. and R. Aksel, 1959. Inheritance of yielding capacity in a fifteen-parent diallel crosses of barley. *Canadian journal of genetics and cytology*, **1**: 208-265.

Mersinkov, N., 2000. Contribution to the selection of winter malting barley. PhD thesis, Karnobat, Bulgaria, 153.

Penchev, P. and V. Koteva, 2002. Impact of agro-meteorological conditions on productivity of winter forage barley. *Selection and agro technology arable crops*, **II**: 517-522.

Rasmussen, D. C. and R. Q. Chanel, 1970. Selection for grain yield and components of yield in barley. *Crop Science*, **10**: 51-54.

Reid, D.A. and G.A. Wiebe, 1979. Taxonomy, botany, classification, and world collection. Washington D.C. *Barley Agriculture Handbook*, **338**: 78-103.

Sinebo, W., 2002. Determination of grain protein concentration in barley: Yield relationship of barleys grown in a tropical highland environment. *Crop science journal*, **24**: 428-437.

SPSS Statistics 19, 2010. SPSS Inc., an IBM Company.

Tsenov, N., T. Gubatov and V. Peeva, 2006. Study of the interaction genotype X environment in winter varieties soft cereal grains. II Grain yield. *Field Crop Studies*, **III** (2): 167-175.

Valcheva, D. and Dr. Valchev, 2009. Lardeja new Bulgarian winter malting barley variety. *Plant Science*, **5**: 475-480.

Valcheva, D. and Dr. Valchev, 2013. Cultivation and winter two-row barley variety Odisej. *Scientific work*, **2** (1): 171-176.

Valcheva, D., Dr. Valchev and St. Navushanov, 1996. Adaptive capabilities of American barley varieties to conditions of Southeast Bulgaria, *Scientific Works*, **VII**: 42-47.

Valcheva, D., Mihova, G., Dr. Valchev and Iv. Venkova, 2010. Influence of environmental conditions on the yield of regional varieties of barley. *Field Crop Studies,* **VI** (1): 7-16.

Yau, S. K. and J. Hamblin, 1994. Relative yield as a measure of entry performance in variable environments. *Crop Science*, **34** (3): 813-817.

FIGURE CAPTIONS:

Fig. 1. Average monthly temperatures (°C) for period of study and long-term average values in Ovche Pole and Strumica locations

Fig. 2. Monthly sum of precipitations (mm) for period of study and long-term period in Ovche Pole and Strumica locations

Fig. 3. Average values and range of variation for yield at barley varieties during the period of study average for both locations

Fig.4. Cluster analysis for yield and yield components at tested barley genotypes

Fig.5. Projection (Scatter-plot) of genotypes according to yield and yield components in the factorial space in the Ovche Pole location

Fig.6. Projection (Scatter-plot) of genotypes according to yield and yield components in the factorial space in the Strumica location

FIGURE EXPLANATIONS:

Fig. 3. 1-*Hit*; 2-*Izvor*; 3-*Egej*; 4-*Line 1*; 5-*Line 2*; 6-*Zlatko*; 7-*Rex*; 8-*NS 525*; 9-*NS 565*; 10-*Obzor*; 11-*Perun*; 12-*Emon*; 13-*Lardeya*; 14-*Orfej*; 15-*Imeon*; 16-*Zagorec*; 17-*Asparuh*; 18-*Kuber*; 19-*Sajra*; 20-*Devinija*; 21-*Odisej*

Fig. 4. 1-*Hit*; 2-*Izvor*; 3-*Egej*; 4-*Line 1*; 5-*Line 2*; 6-*Zlatko*; 7-*Rex*; 8-*NS 525*; 9-*NS 565*; 10-*Obzor*; 11-*Perun*; 12-*Emon*; 13-*Lardeya*; 14-*Orfej*; 15-*Imeon*; 16-*Zagorec*; 17-*Asparuh*; 18-*Kuber*; 19-*Sajra*; 20-*Devinija*; 21-*Odisej*

Fig.5. 1-*Hit*; 2-*Izvor*; 3-*Egej*; 4-*Line 1*; 5-*Line 2*; 6-*Zlatko*; 7-*Rex*; 8-*NS 525*; 9-*NS 565*; 10-*Obzor*; 11-*Perun*; 12-*Emon*; 13-*Lardeya*; 14-*Orfej*; 15-*Imeon*; 16-*Zagorec*; 17-*Asparuh*; 18-*Kuber*; 19-*Sajra*; 20-*Devinija*; 21-*Odisej*
NSm2-number of spikes per m^2; PH-plant height; TTNP-total tillers number per plant; NPTP-number of productive tillers per plant;SL-spike length; NGS-number of grains per spike; NSSS-number of sterile spikelets per spike; GWS-grain weight per spike; GWP-grain weight per plant; 1000GW-1000 grain weight; Y-yield

Fig.6. 1-*Hit*; 2-*Izvor*; 3-*Egej*; 4-*Line 1*; 5-*Line 2*; 6-*Zlatko*; 7-*Rex*; 8-*NS 525*; 9-*NS 565*; 10-*Obzor*; 11-*Perun*; 12-*Emon*; 13-*Lardeya*; 14-*Orfej*; 15-*Imeon*; 16-*Zagorec*; 17-*Asparuh*; 18-*Kuber*; 19-*Sajra*; 20-*Devinija*; 21-*Odisej*
NSm2-number of spikes per m^2; PH-plant height; TTNP-total tillers number per plant; NPTP-number of productive tillers per plant;SL-spike length; NGS-number of grains per spike; NSSS-number of sterile spikelets per spike; GWS-grain weight per spike; GWP-grain weight per plant; 1000GW-1000 grain weight; Y-yield

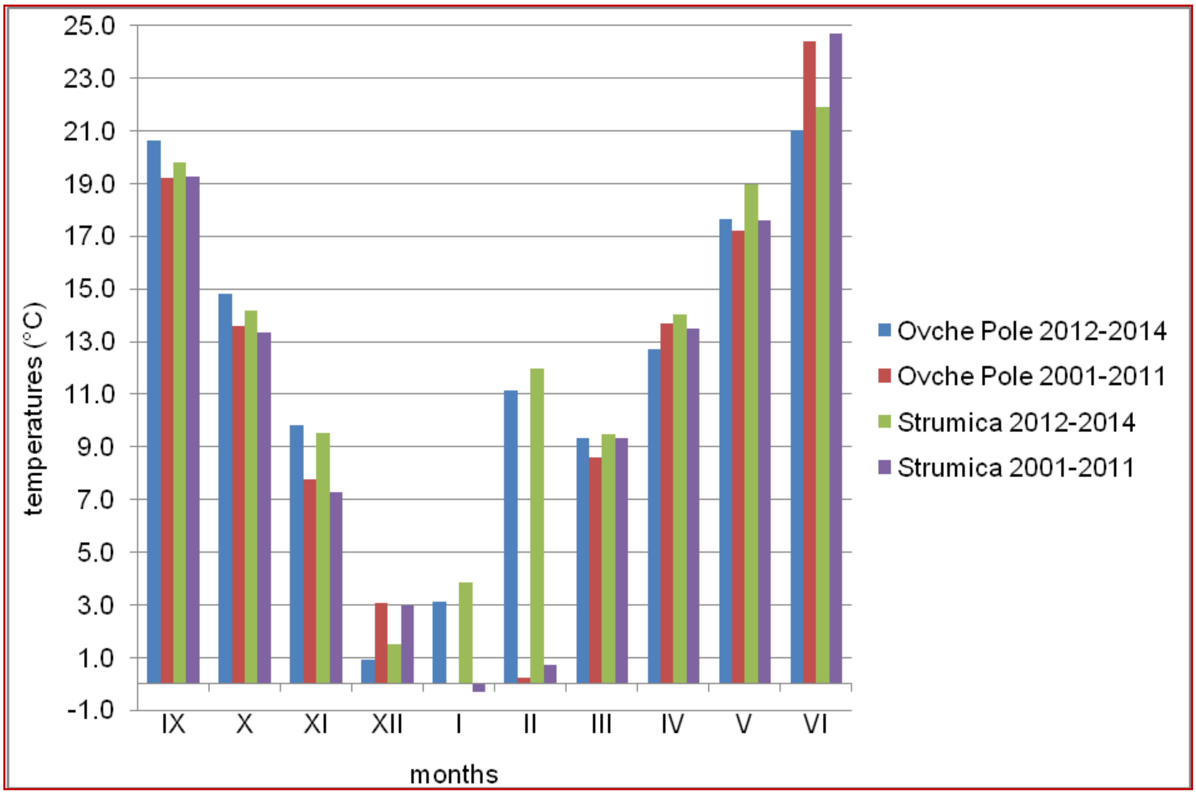
25.0
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0
-1.0
temperatures (°C)
IX X XI XII I II III IV V VI
months
Ovche Pole 2012-2014
Ovche Pole 2001-2011
Strumica 2012-2014
Strumica 2001-2011

Fig.1.

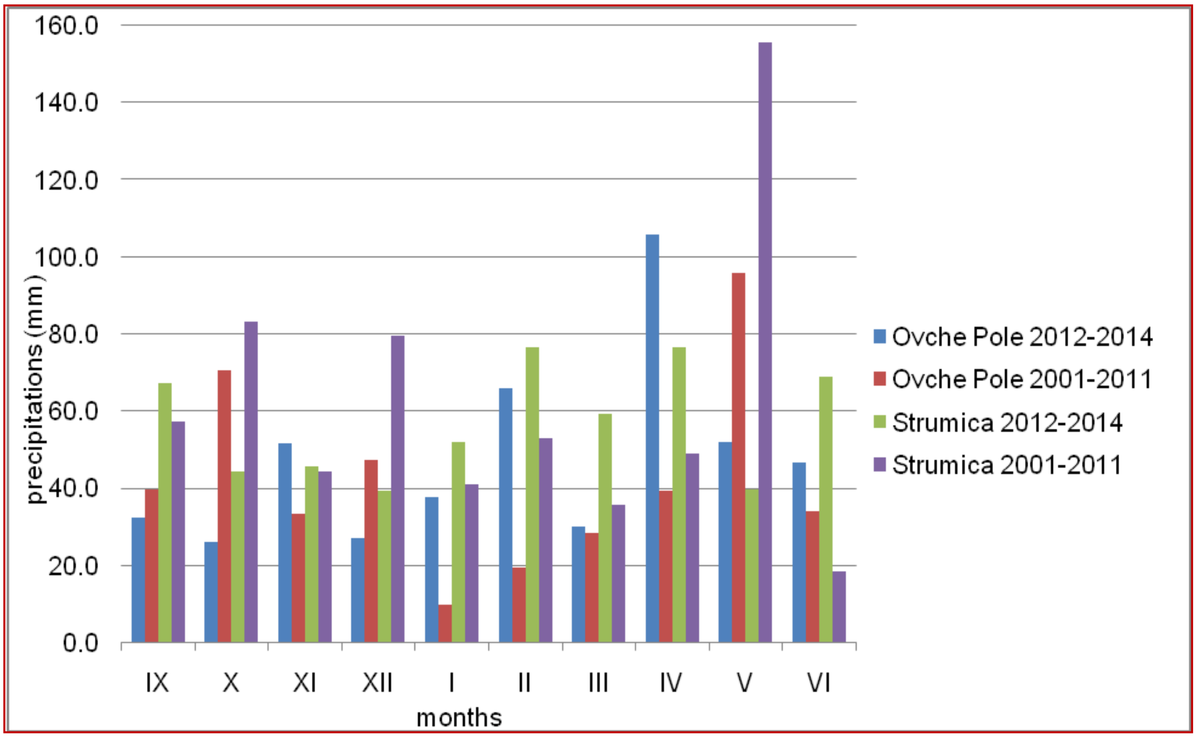
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
precipitations (mm)
IX X XI XII I II III IV V VI
months
Ovche Pole 2012-2014
Ovche Pole 2001-2011
Strumica 2012-2014
Strumica 2001-2011

Fig.2.

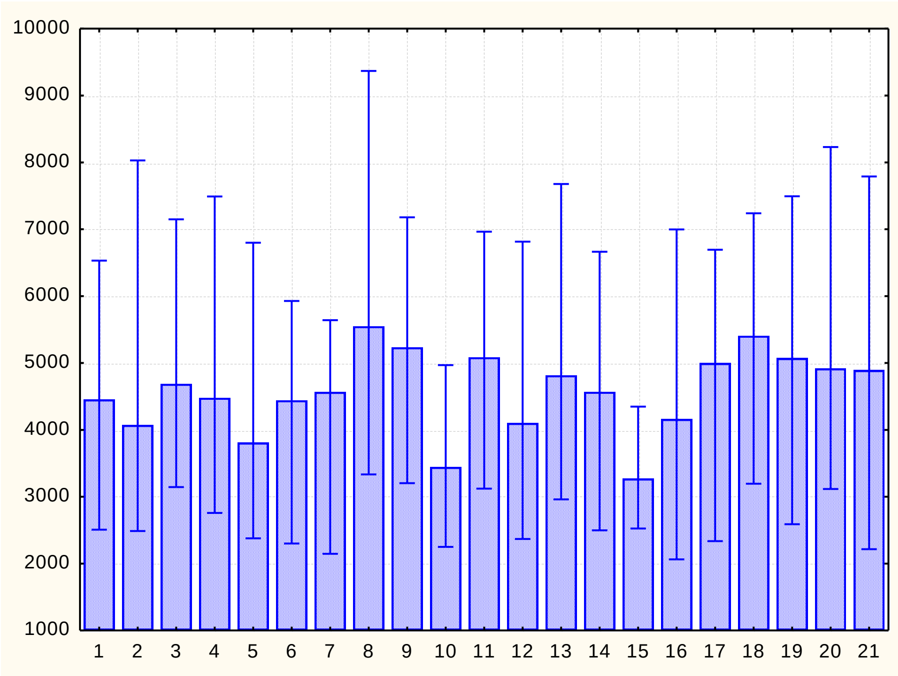
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

Fig. 3.

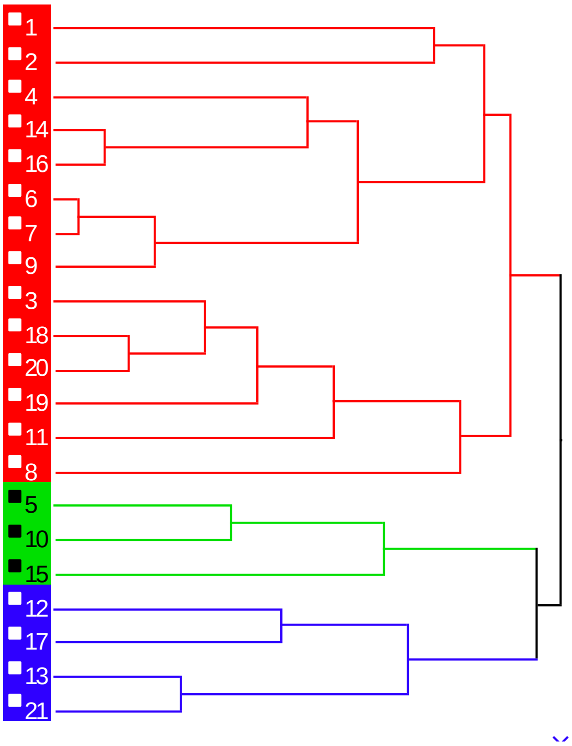
1
2
4
14
16
6
7
9
3
18
20
19
11
8
5
10
15
12
17
13
21

Fig. 4.

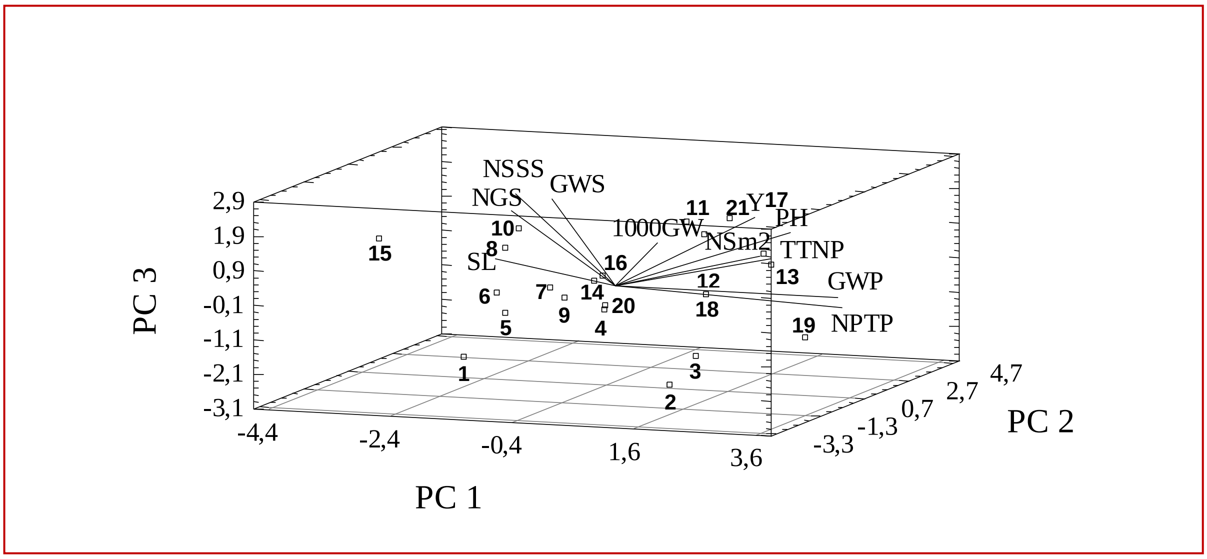
PC 1
PC 2
PC 3
NSSS
GWS
NGS
SL
1000GW
Y
PH
NSm2
TTNP
GWP
NPTP

Fig. 5.

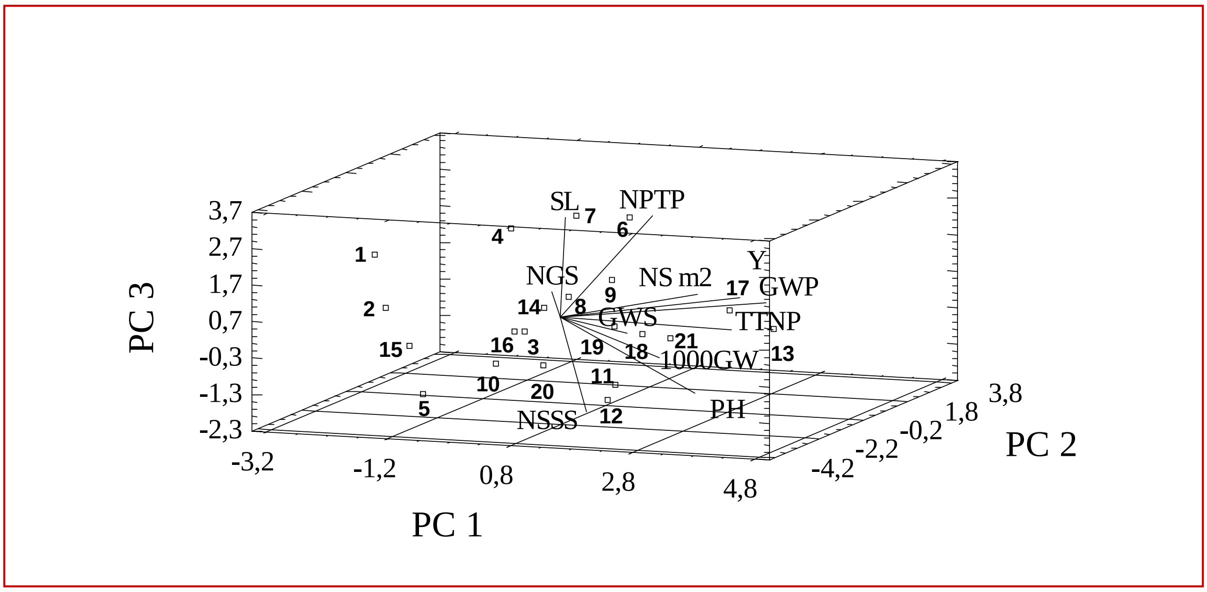
PC 1
PC 2
PC 3
SL
NPTP
NGS
NS m2
Y
GWP
GWS
TTNP
1000GW
PH
NSSS

Fig. 6.

TABLES:

Table 1. ANOVA for grain yield over genotypes, years and locations studied

Factor	***SS***	***df***	***MS***	***F***	**η**	**Sig.**
Total	383.404	252				
Factor (A) - genotype	86.756	20	4.338	39.389	23.78	0.000
Factor (B) - year	188.421	1	188.421	1710.929	51.64	0.000
Factor (C) - location	21.698	1	21.698	197.029	5.94	0.000
A x B	34.921	20	1.746	15.855	9.57	0.000
A x C	8.692	20	0.435	3.946	2.38	0.000
B x C	5.000	1	5.000	45.406	1.37	0.000
A x B x C	19.414	20	0.971	8.814	5.32	0.000
Erorr	18.502	168	0.110			

SS –sum of squares; **df**- degrees of freedom; **MS**-mean squares; **F**-F test; η – effect of factor

Table 2. Average, minimum, maximum values and coefficient of variation for examined traits for barley varieties in both locations

Location		Number of spikes per m^2	Plant height (cm)	Total tillers number per plant	Number of productive tillers per plant	Spike length (cm)	Number of grains per spike	Number of sterile spikelets per spike	Grain weight per spike (g)	Grain weight per plant (g)	1000 grain weight (g)
Ovche Pole	Average	673	104	18	8	8.5	27	2	1.28	9.53	47.30
	Min.	567	99	14	7	7.2	26	1	1.23	7.54	45.93
	Max.	776	110	20	9	9.5	29	3	1.38	10.65	49.63
	CV (%)	8.56	3.19	7.12	8.78	7.77	2.57	23.32	3.15	8.64	1.82
Strumica	Average	711	102	18	9	8.6	27	1	1.27	9.93	46.37
	Min.	590	98	16	8	7.3	26	1	1.20	8.43	42.86
	Max.	811	109	20	10	10.0	29	3	1.39	11.26	48.57
	CV (%)	9.57	3.18	7.11	7.29	8.60	2.55	49.46	4.36	6.93	3.18

Table 3. PCA analysis for main components in both locations

Component number	Ovche Pole			Strumica		
	Eigen value	Percent of variability (%)	Cumulative percentage (%)	Eigen value	Percent of variability (%)	Cumulative percentage (%)
PC1	3.16	28.77	28.77	2.70	24.57	24.57
PC2	2.60	23.60	52.37	2.56	23.30	47.87
PC3	1.67	15.19	67.55	1.20	18.10	65.97
PC4	1.27	11.59	79.14	1.27	11.52	77.52

Table 4. Yield component weights to main components in both locations

Yield components	Ovche Pole	Strumica

	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4
Number of spikes per m^2	0.40	-0.32	0.32	0.01	0.18	0.52	-0.01	-0.41
Plant height	0.35	0.08	0.33	0.13	0.28	0.19	-0.42	0.20
Total tillers number per plant	0.23	0.34	0.08	-0.34	0.42	0.09	-0.04	0.37
Number of productive tillers per plant	0.39	0.35	-0.18	0.18	0.18	0.16	0.52	0.38
Spike length	-0.16	-0.31	0.23	-0.26	-0.01	0.06	0.51	-0.19
Number of grains per spike	-0.32	0.32	0.29	0.36	0.12	-0.40	0.27	-0.19
Number of sterile spikelets per spike	-0.23	0.06	0.48	0.32	0.14	-0.21	-0.42	-0.12
Grain weight per spike	-0.26	0.45	0.32	-0.10	0.34	-0.48	0.10	-0.22
Grain weight per plant	0.38	0.34	-0.12	0.23	0.51	0.07	0.11	0.28
1000 grain weight	-0.01	0.31	0.15	-0.69	0.38	-0.33	-0.07	-0.16
Yield	0.35	-0.18	0.49	-0.03	0.35	0.34	0.04	-0.53

Table 5. Main components values for every genotype in both locations

Genotype	**Ovche Pole**				**Strumica**			
	PC1	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**
Hit	-1.40	-2.99	-1.43	-2.06	-3.13	0.25	1.36	-0.27

Izvor	0.60	0.82	-3.03	0.10	-2.87	0.03	-0.01	1.42
Egej	0.95	1.01	-2.22	0.75	-1.02	1.19	-0.78	-0.88
Line 1	-0.24	0.17	-0.75	0.06	-1.29	1.19	2.03	0.97
Line 2	-1.90	0.26	-1.03	-0.50	-1.58	-1.85	-1.77	-0.27
NS 525	-1.73	-0.60	-0.20	1.58	1.28	-0.42	2.96	0.05
NS 565	-0.71	-0.98	0.13	-0.45	0.25	0.05	2.81	0.45
Zlatko	-0.64	-3.21	1.86	0.12	-0.26	1.10	0.25	-2.31
Rex	0.04	-2.40	0.27	0.88	0.81	0.07	1.08	-1.85
Obzor	-2.34	2.06	0.91	0.61	-0.14	-2.55	-0.62	1.17
Perun	1.25	-0.20	2.04	-0.76	0.38	1.45	-2.18	-0.34
Emon	0.41	2.87	0.79	0.43	1.69	-2.54	-1.45	0.85
Lardeya	2.23	0.92	0.58	0.72	3.14	1.02	-0.29	1.61
Orfej	-0.43	0.20	0.05	-0.58	-0.74	1.30	-0.15	0.97
Imeon	-4.39	1.41	0.59	-0.02	-0.95	-4.18	0.19	-1.32
Zagorec	-0.55	0.96	-0.01	-1.13	-0.71	0.12	-0.43	1.38
Asparuh	1.66	2.12	0.54	-2.98	3.00	-0.62	0.62	-0.97
Kuber	1.95	-1.27	0.25	-0.14	0.75	1.64	-0.82	-0.70
Sajra	3.23	-0.48	-1.08	-0.24	0.20	1.90	-0.71	0.74
Devinija	0.21	-1.03	-0.30	1.15	-0.73	1.26	-1.72	-1.03
Odisej	1.74	0.35	2.03	1.56	1.87	-0.18	-0.36	0.32