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SEED YIELD AS AFFECTED BY THE ECOLOGICAL STABILITY OF THE FIELD PEA (*PISUM SATIVUM*) CULTIVARS

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Abstract. A small–plot field trial was carried out from 2007 to 2009 including seven field pea (*Pisum sativum* L.) cultivars from the Ukraine and Bulgaria. The ecological stability in the tested pea cultivars was determined in relation to seed yield. Stability parameters were determined by the regression analysis according to the methods by Eberhart and Russell and Tai. The analysis of variance proved that the influence of the factors genotype, environment and genotype x environment and seed yield had a very high level of the probability. The cultivars Kerpo from Bulgaria and Usatii 90 from the Ukraine could be considered close to an ideal type (bi=1.04, λi=11.08; bi=1.05, λi= 1.12), suitable for growing in different environments. On the other hand, the Bulgarian Mir (bi=1.56, λi=49.41) and the Ukrainian Harkovskii Etalon (bi=1.28, λi=95.88) were identified as unstable (bi>1), but with good response that provide them with high seed yields in certain environments. The cultivars Vesela (bi=0.77, λi=6.77) from Bulgaria, Pleven 10 (bi=0.71, λi=59.49) from Bulgaria and Rezonator (bi=0.68, λi=35.07) from the Ukraine were assessed as stable (bi<1), but with a low adaptability except for Vesela. In conclusion, the cultivars Kerpo, Usatii 90 and Vesela may be regarded as suitable for including in the future hybridisation programmes and developing novel field pea lines with high and stable seed yields in contrasting environments.

Key words: adaptability, breeding, pea, seed yield, stability

Introduction

In the past, majority of plant breeding programmes were focused mostly to developing the cultivars with high yields.

Recently, stable, quality and reliable yields under various environmental conditions have consistently gained importance over solely increased yield.

Developing cultivars adapted to a wide range of contrasting environments is one of ultimate aims of a plant breeder.

In order to be widely used in breeding programmes, a cultivar has to demonstrate good performance across a range of environments.

However, such cultivars are rather hard to identify, since they widely respond to various environmental factors such as temperature, precipitation, soil type or moisture. This implicates that cultivars targeted for use in breeding programmes should be tested at various locations for several years and analyzed appropriately to determine extent of genotype–environment interaction before being released.

Sustainable agriculture requires that the new cultivars are selected to harmonise high yields, yield stability, high adaptive potential and tolerance to unfavourable environments [ZHUCHENKO, 1980; DRAGAVTSEV, 1994; MUHAMMAD *et al.*, 2003].

Genotypes selected in a breeding program should be tested at various locations for several years, and analyzed appropriately to determine extent of genotype–environment interaction before being released as cultivars [ACIKGOZ *et al.*, 2009]. A modern field crop cultivar is faced with numerous demands, of which most important is high and stable yield in different conditions. In order to answer this strong challenge, there is an increasing need to study ecological stability in a number of cultivars and determine their productiveness [TODOROVA & GORANOVA, 2002; MUHAMMAD *et al.*, 2003; VASSILEVSKA–IVANOVA & NAIDENOVA, 2004; ALEKSIEVA & GEORGIEV, 2005; FIKERE *et al.*, 2009].

The aim of this study was to determine ecological stability of seven Bulgarian and Ukrainian field pea cultivars in relation to seed yield and thus

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determine their suitability as initial material for future breeding programmes.

Material and methods

A small–plot field trial was carried out from 2007 to 2009 at Second Experimental Field of Institute of Forage Crops, Pleven (43.41єN, 24.61єE), situated in the central part of Danube hilly plain. Seven field pea (*Pisum sativum* L.) cultivars were included in trial, namely autumn–sown Mir, Pleven 10 and Vesela from Bulgaria, spring–sown Kerpo from Bulgaria and spring–sown Usatii 90, Rezonator and Harkovskii Etalon from Ukraine. The trial was set up as a randomised block design method with four replications and with a plot size of 5 m^2 (2.0 m x 2.5 m). Each plot had 11 rows with a row spacing 20 cm. The sowing was done by hand, at a depth of 5 cm and with a rate of 120 viable seeds m^{-2}.

All agronomy practices during trial were ordinary and officially approved by Institute of Forage Crops.

Seed yield (kg ha^{-1}) was in each cultivar was measured at a standard seed humidity of 14%. The obtained data were processed by two–factor analysis of variance.

The estimation of ecological stability of tested cultivars was done by regression analysis according to Eberhart & Russell (1966) and Tai (1979) [EBERHART & RUSSELL,1966, TAI, 1979]. All experimental data were processed statistically using computer software MS Excel (Microsoft Office 2002) and StatGraphics 2.1 for Windows.

Results

The weather conditions in three trial years differed from each other (Figure 1).

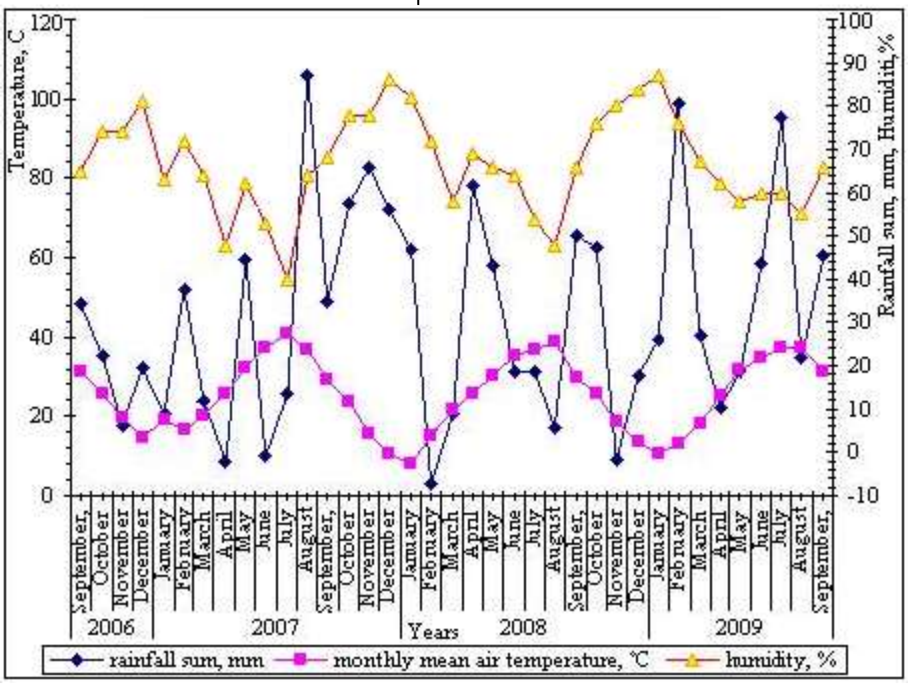

Figure 1. Environmental conditions during the field pea growing season in Pleven from 2007 to 2009

The first trial year (2007) was most ardent for the last 120 years, that is, since the weather data are officially monitored.

The main anomalies in this year were an unusually arid period between 25 March and 17 May, with intensive precipitations at the end of May and the beginning of June and very high temperatures of between 40°C and 43°C at the end of June and the beginning of July.

The optimum combination of temperature and precipitations was in the second trial year (2008).

It reflected positively on the seed yield components, resulting in high seed yields.

The third trial year (2009) was intermediate as compared to 2007 and 2008.

The average monthly precipitation during the growing season of field pea, that is, from October to July, was 28.62 mm in 2007, 51.33 mm in 2008 and 48.79 mm in 2009.

The average monthly temperature was 13.14°C in 2007, 10.45°C in 2008 and 10.99°C in 2009, while average monthly relative humidity was 63.1% in 2007, 70.7% in 2008 and 71.0% in 2009.

It may be said that the total trial period was rather favourable for testing the adaptability and productivity of field pea cultivars since a large variation among the trial years.

Analysis of variance (ANOVA)

Dispersion and regression analyses were used for estimating the ecological stability and plasticity of the tested field pea cultivars.

The ecological stability is determinate in digression to empirical data on the average reaction to genotypes in each condition in environment [PAKUDIN & LOPATINA, 1984].

Single trial years were used as the factor of environmental conditions.

The genotype–environment interaction was assessed by a dispersion analysis.

If the gradations of the factor conditions are not untrustworthy, experiment is considered not incorrect, that is, conditions are equal.

If, on other hand, the genotype–environment interaction is untrustworthy, there is no point for the ecological constancy to be analysed, meaning that a whole mutability of a trait is genetically determinate.

The analysis of the ecological stability is applicable at an actual influence of conditions and at the interaction genotype–environment.

The results of analysis of variance show that the influence of genotype, environment and interaction between them affected seed yield (Table 1).

Table 1.
Analysis of variance of seed yield in the tested field pea cultivars during the trial in Pleven from 2007 to 2009

Source of variation	Sum of squares	% from total	Df	Mean Square	F	F crit
Cultivars	29356.12	4.64	6	4892.69	2.66	2.32
Years	410854	64.89	5	82170.88	44.64	2.44
Interactions	115618	18.26	30	3853.95	2.09	1.73
Within	77317	12.21	42	1840.88		
Total	633146	100.00	83			

The tested cultivars distinguished trustworthy in their genetic nature, despite the smallest part of influence (4.64%) in the general variation.

Environment makes the largest part of influence (64.89%), since cultivars show considerable variability in seed yield over years, that is, seed yield depends to a greater extent on environment.

The participation on genotype x environment interaction in seed yield was smaller (18.26%), but proved very well.

A considerably smaller quantity of this factor affects a greater stability of the tested cultivars and justifies the necessity of estimating the ecological stability of the seed yield in the tested field pea cultivars.

Seed yield in the tested cultivars (Table 2), compared to the average seed yield adaptation (Si^2), showed that most perspective cultivars could be Vesela (114.14%, Si^2=627.20) and Kerpo (102.15%, Si^2=475.05).

The Ukrainian field pea cultivars showed values below the average (95.90%–97.71%).

An estimate for cultivar stability was done by means of regression coefficient and the average degree of trait. Moll & Stuber (1974) note that cultivars with high stability show mainly moderately high or low yields, as well as that they react feebly at bettering conditions of breeding [MOLL & STUBER, 1974].

Table 2.

Ecological stability parameters of the seed yield in the tested field pea cultivars during the trial in Pleven from 2007 to 2009

Cultivar	Grain yield (kg ha^{-1}) Mean value x	In relation to average %	Stability parameters: Eberhart and Russel (1966) bi	Si^2	F	Tai (1971) ai	λ i
Kerpo	2165.8	102.15	1.04	475.05**	2.86	0.04	11.08
Usatii 90	2033.3	95.90	1.05	2204.73***	13.29	0.09	51.12
Rezonator	1901.7	89.69	0.68	1524.34***	9.19	–0.30	35.07
Harkovskii Etalon	2071.7	97.71	1.28	5346.34***	32.23	–0.13	95.88
Vesela	2420.0	114.14	0.77	627.20***	3.78	–0.02	6.77
Mir	2342.5	110.48	1.56	3076.80***	18.55	0.21	49.41
Pleven 10	1906.7	89.93	0.71	3713.46***	22.39	0.11	59.42
Average	2120.2	100					

This opinion was confirmed with the results of the field pea cultivars tested in our trial.

According to the demonstrated level and stability of seed yield, tested cultivars with a coefficient of regression bi>1.0 could be considered high–yielding.

Such cultivars have very predictable reaction to the conditions of environment. They can decrease their seed yield at worsening environmental conditions.

The cultivars Mir (x=110.48%; bi=1.56) and Harkovskii Etalon (x=97.71%; bi=1.28) may be assigned to this group.

The cultivars with a coefficient of regression bi≈1.0 are close to be regarded as ideal genotype. They react well to improvements on the environment and can be accepted as control cultivars for high adaptability, meaning they will have high and predictable yield in most of environmental conditions.

This group comprises Kerpo (x=102.15%; bi=1.04) and Usatii 90 (x=95.90%; bi=1.05). The coefficient of regression bi<1.0 was in Vesela (x=114.14%; bi=0.77), Pleven 10 (x=89.67%; bi=0.71) and Rezonator (x=98.69%; bi=0.68).

These are stable genotypes, but also, with an exception of Vesela, with a low adaptive ability. By this reason, they do not necessarily produce higher yields in a more favourable environment and are eligible only for extensive agriculture and less favourable environmental conditions.

The parameters by Tai make estimate for stability more precise.

This model determines the stability of the genotypes with ai and λi, analogous to bi and Si^2, but obtained by variation and covariance analysis. The parameter for stability λi validates the estimate by Eberhart & Russell. Finlay and Wilkinson (1963) stated that genotypes with high mean yield [FINLAY and WILKINSON, 1963], regression coefficient equal to unity (bi=1) and deviation from regression as small as possible are considered a stable.

However Eberhart and Russell (1966) model is one of most widely used stability models that considers linear and non–linear components of genotype–environment interaction in judging the stability of genotypes [EBERHART and RUSSELL 1966]. In this model a variety with high mean, regression coefficient bi=1 and deviation not significantly different from zero is said to be stable.

Accordingly a relatively great ecological stability had Kerpo (ai=0.04; λi=11.08) and Usatii 90 (ai=0.09; λi=51.12), while the highest instability was in Rezonator (ai=–0.30; λi=35.07) and Mir (ai=0.21; λi=49.41).

According to the calculated coefficients of regression (bi), the tested field pea cultivars can be classified into four groups (Figure 2.): high and stable seed yields, with Kerpo;high but not so stable seed yields, with Vesela; high and unstable seed yields, with Mir and

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Harkovskii Etalon; and low and stable seed yields, with Pleven 10.

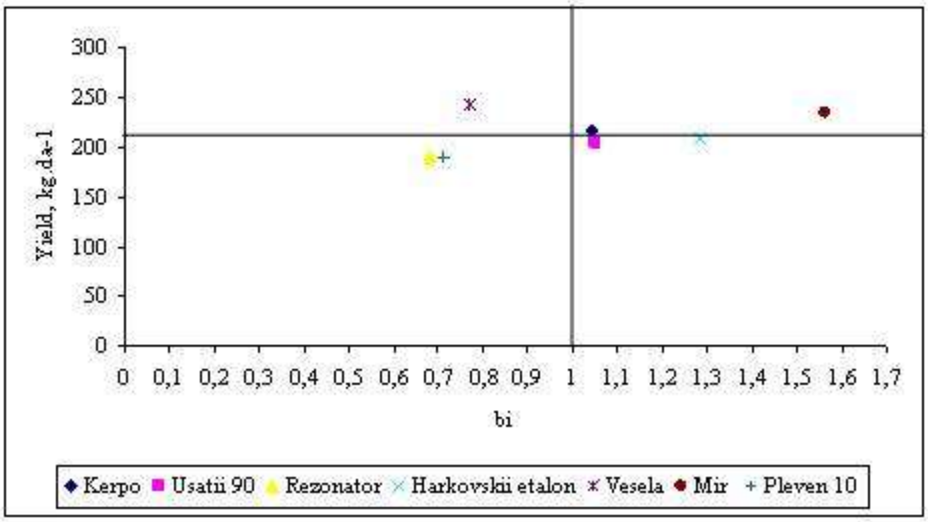

Figure 2. *Assessing the breeding potential of the field pea cultivars in Pleven from 2007 to 2009 by regression coefficient (bi) and seed yield (kg ha^{-1})*

From a plant breeder's viewpoint, the field pea cultivars of the first three groups are suitable for including in the future breeding programmes, since one may expect that their progeny combine high and stable seed yields.

Discussion and conclusions

Jain & Pandya and Goa & Hussen [JAIN & PANDYA 1988, GOA1 & HUSSEN 2013] suggested that desired genotype in any practical situation is one with high mean performance, desired linear response (bi) and low non–linear sensitivity coefficients (Si^2). Zubair & Ghafoor [ZUBAIR & GHAFOOR 2001] evaluated 12 genotypes of mung bean (*Vigna radiata* L.) for stability of grain yield at seven different environments in Pakistan. They reported highly significant genotype–environment interaction with regard to yield. Wamatu [WAMATU & THOMAS 2002] tested early maturing genotypes of pigeon pea (*Cajanus cajan* L.) and they found a substantial environment interaction for grain yield. Acikgoz [ACIKGOZ *et al.*, 2009] reported that best genotype of field pea (*Pisum sativum* L.) at one environment is not the best at other environments [JAIN & PANDYA, 1988, GOA1 & HUSSEN, 2013, ZUBAIR & GHAFOOR, 2001; WAMATU & THOMAS, 2002; ACIKGOZ *et al.*, 2009].

The experiments were carried out to estimates ecological stability for grain yield among field pea genotypes. The result of study shows that there was significant difference among genotype and genotype–environment interaction indicating the need to assess stability of genotypes.

The field pea cultivars Kerpo and Usatii 90 could be considered close to an ideal type (bi=1.04, λi=11.08; bi=1.05, λi=51.12), suitable for growing over a wide range of environments.

At same time, Mir (bi=1.56, λi=49.41) and Harkovskii Etalon (bi=1.28, λi=95.88) were identified as unstable (bi>1), but with good response providing them with high yields at moderately favourable environments. In the end, Vesela (bi=0.77, λi=6.77), Pleven 10 (bi=0.71, λi = 59.49) and Rezonator (bi=0.68, λi=35.07) were determined as a stable (bi<1), but with a low adaptability and an exception of Vesela, suitable for growing under unfavourable conditions.

The cultivars Kerpo, Usatii 90 and Vesela are suitable for including in future breeding programmes and developing novel field pea lines with high and stable seed yields.

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