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RELATION OF QUANTITATIVE TRAITS IN WINTER PEAS (*Pisum sativum* L.)

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ABSTRACT

In order to improve the combination of desirable agronomic traits in winter peas, relation between grain yield, seed protein content, thousand grains weight (TGW), earliness, height, winter hardiness and seed dimension has been evaluatedat NARDI Fundulea (South Romania) over three years (2017-2019). Image analysis proved to be an useful tool to assess the seed parameters such as diameter, density and volume.

Very significant correlations between TGW and winter hardiness (r=0.69), grain volume and grain diameter (r=0.70), were found. The highest values of coefficient of correlation were registered for the trait combinations: winter hardiness and either, grain volume and grain diameter (r=0.76).

Were identified winter peas lines 12038MT2, 13008MT28-1, 13002MT, to 12004MT2, 12032MT1 and 13008MT37, mainly derived from winter x spring crosses, that combine desirable agronomic traits, with a good impact on yield and winter hardiness.

Keywords: winter peas, protein content, grain volume, density and grain yield.

INTRODUCTION

Peas are one of the main protein source crops from which high and stable yields of both grain and green mass is obtained. It has many advantages as food and forage crop (Naydenova et al., 2014), improves soil fertility (Pachev et al., 2011) and is a good precursor for other crops (Panov and Davletov, 2007; Zelenov, 2013).

The capability of the variety to adapt to growing conditions plays an important role in increasing the quantity and quality of crops production. An important task of the breeders is to achieve a combination of resistance to abiotic and biotic stress factors (Kosev and Mussa, 2017), but the fundamental goal of pea breeders is to increase seed yield to maximize plant productivity and allow for more widespread use of pea in various agricultural production systems (Uhlarik, 2022).

Many studies have shown a significant influence of environment and genotype-by-environment (GxE) interaction on seed yield and the yield components of their phenotypic performance (Bocianowski, 2019).

Seed size plays a large role in determining productivity of large seeded legumes. In many large seeded legumes such as pea and bean, actual yield, defined here as grain yield at harvest minus the weight of seed planted, is often a better measure of real productivity than grain yield at harvest, because the weight of planted seed varies with seed size. In many grain legumes, the weight of planted seed can be equal to 10% of the total grain yield, and subtracting the weight of planted seed could significantly impact actual yield (Smitchgerand and Weeden, 2018). Yield potential is the genetically determined ability of a crop to generate optimal yield in a given growth environment. Yield potential is thought to be partially determined by seed size, and numerous studies have tried to understand the relationship between seed size and yield in pea and other pulses, with contradictory results (Pate et al., 1977). A lack of correlation between seed size and yield was found in grass pea under drought (Gusmao et al., 2012). In chickpea, a positive correlation was found between seed size and yield, but no effect was seen in lentil. In one study in pea, a strong correlation was found between seed

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size and yield (Biger, 2009) and Krajewski et al. (2012) found that seed size was positively correlated with yield, explaining 20% of the variation of yield in pea. The theoretical effect of seed size on grain yield is positive because larger seeded peas have a higher harvest index than smaller seeded peas (when all other factors are held constant) (Huyghe, 1988). To achieve further progress, it is of great importance to identify factors that have a direct or an indirect effect on yield and just as much it is necessary to know the association of various traits with yield and with each other, as a negative association between the desired attributes under selection may result in genetic slippage. The present work aimed at determining the correlations of some traits in winter peas.

MATERIAL AND METHODS

The study was carried out on 23 pea genotypes over a three year**s** period (2016/2017, 2017/2018, 2018/2019) in the experimental field of the National Agricultural Research and Development Institute Fundulea. Biological material that was the object of this experiment was represented by 11 pea varieties from different countries and 12 advanced winter pea breeding lines created at NARDI Fundulea.

Each year, the experiment with genotypes was conducted in a randomized block design, with three replications, sowing in autumn. Plant density was 130 plants/m². The size of the experimental plot was six m² and the area of harvested plot was four m². The crop was harvested mechanically with Wintersteiger combine.

Measurements and determinations for this study included: grain yield, seed protein content, thousand grains weight (TGW), earliness, height, winter hardiness, grain volume, diameter and density. Grain yield obtained from the plots was calculated per 1 ha, adjusted to 14% humidity. TGW was determined by weighing with high precision balances. Seed protein concentration was determined by near-infrared (NIR) method using a Grain Analyzer (Infratech 1241, Foss Tecator). The earliness was expressed as number of days from January 1st till the end of flowering time. The level of winter hardiness was estimated in the field, early in the spring, using a scale 1 to 9, where score 1 is very resistant and 9 very susceptible. Plant height was measured in cm, total length of plant from the ground till the topat the end of flowering time.

Axial dimensions of seed were determined by image analysis of 100 grains samples, that were photographed, by using the software *ImageJ* (http://imagej.nih.gov/ij/). The parameters evaluated were:

Diameter (D), mm: $D = (x+y)/2$

Grain volume (V), cm³: $V = 4/3*\pi*r^3$

Density (p), gm/cm³: $p = m/v$

where:
x = length of grains (mm);
y = width of grains (mm);
m = mass of sample.

The obtained results were statistically evaluated by ANOVA and regression analysis.

This paper is a continuation of the researches, the material being analyzed in another work (Bărbieru, 2021).

Regarding meteorological conditions, NARDI Fundulea area is characterized by a continental temperate climate, with uneven distribution of rainfall by months. The data regarding temperature and rainfall registered during the years of testing, delivered by the Weather station of NARDI Fundulea, are presented in Figure 1. Weather conditions (of the three years) during winter peas vegetation period and especially during the grain filling period, were very different.

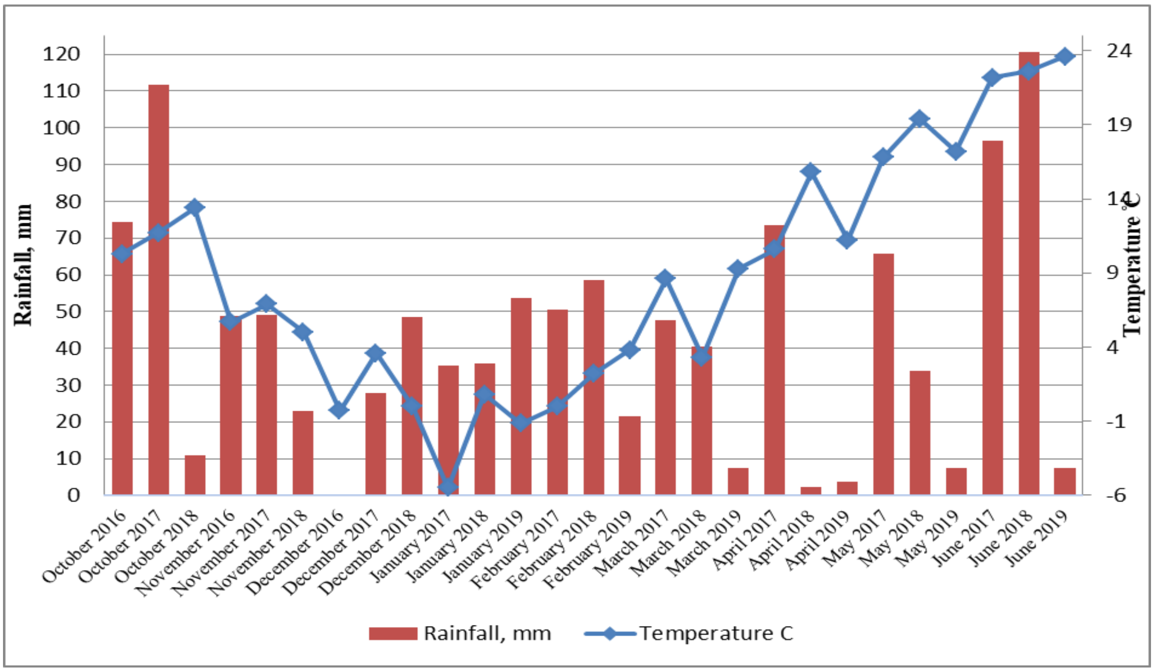

Figure 1. Climatic characterization of the experimental period at NARDI Fundulea (2017-2019)

As shown in the Figure 1, year 2017 had higher rainfall, more uniformly distributed during the vegetation, 2018 had less rainfall and not uniformly distributed, while 2019 had less rainfall but uniformly distributed in time. Overall monthly temperatures were positive on average, not allowing a good selection of genotypes according to their frost tolerance, the lowest negative temperature registered being -5.5 in 2017.

RESULTS AND DISCUSSION

Analyses of variance were performed considering years as a random factor and genotypes a fixed factor. Considerable genetic variability among the studied 23 winter peas genotypes was observed for characters under study. Results demonstrate the significant effect of genotypes and years on earliness, protein content, plant height, grain weight and yields (Table 1).

In Table 3 the correlation indexes between these characters overall cultivars are presented. The highest values of correlation indexes were found between grain volume and their diameter (r=0.98***), while between winter susceptibility, grain volume and diameter this was r=0.76***. TGW was strongly and positively correlated only with winter susceptibility (r=0.69***), grain volume (r=0.70***) and diameter (r=0.70***). The value of r=0.42*indicates the significant and positively relation with density (r=0.42*) and on the other hand, between grain yield and the number of days to the end of flowering.

The results obtained in our study support the conclusions partially made by Li et al. (2015) in rapeseed. The authors established significant positive correlations between TGW and seed diameter and grain volume, but is showed no significant correlation with density. This results are basically in agreement with studies in other crops. In rice, grain volume was found to be the major contributor (77%) to final grain weight variation (Xu et al., 2001). Grain weight is also determined by factors that affect grain volume in wheat (Miilet and Pinthus, 1984).

Grain yield, seed protein concentration and earliness are among the major selection criteria for field pea improvement. The current study revealed significant correlation between grain yield and earliness (r=0.42*) and negative no significantly correlation between grain yield and protein content. Kielpinski and Blixt (1982), Karjalainen and Kortet (1987) and Tar'an et al. (2004) also reported negative correlation between grain yield and seed protein concentration in pea.

Table 1. ANOVA for grain yield, earliness, protein, TGW, height, winter hardiness, grain volume, diameter and density for winter peas cultivars, NARDI Fundulea (mean values, 2017-2019)

Source of variation		Grain yield		Earliness		Protein concentration		TGW		Plant heigth		Winter hardiness		Grain volume		Diameter		Density	
	df	F	P-value	F	P-value	F	P-value	F	P-value	F	P-value	F	P-value	F	P-value	F	P-value	F	P-value
Genotypes	22	1.94*	0.030	2.52**	0.004	2.10**	0.017	4.24**	0.000	1.78**	0.050	1.19	0.30	1.28	0.23	1.27	0.24	0.57	0.922
Years	2	74.01**	0.000	83.93**	0.000	139.09**	0.000	24.79**	0.000	176.16**	0.000	2.52	0.09	104.26**	0.000	30.9**	0.000	41.67**	0.000
Interaction	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-				

Table 2. Coefficients of correlations between quantitative traits in 23 winter pea genotypes at NARDI Fundulea (2017-2019)

	Grain yield	TGW	Winter hardiness	Earliness	Protein content	Plant height	Grain volume	Diameter	Density
Grain yield	X								
TGW	0.31	X							
Winter hardiness	0.11	**0.69*** **	X						
Earliness	**0.42***	0.01	0.12	X					
Protein content	-0.04	-0.27	-0.38	0.01	X				
Plant height	0.23	0.17	0.04	0.31	-0.23	X			
Grain volume	0.07	**0.70*** **	**0.76*** **	-0.01	-0.27	-0.19	X		
Diameter	0.09	**0.70*** **	**0.76*** **	0.0006	-0.31	-0.09	**0.98*** **	X	
Density	0.23	**0.42***	0.02	-0.008	0.06	0.13	-0.21	-0.30	X
	ns - not significant; * and *** significant at p<0.5 and p<0.01.								

Table 3. Stability of grain yield registered in winter peas trials at NARDI Fundulea (2017-2019)

No.	Genotype	Yield (kg/ha)			Mean	Minim (y_2)	Maxim (y_1)	Stress tolerance (y_2-y_1)	Std.	C.V.%
		2017	2018	2019						
1.	Checo	5333	2342	4006	3894	2342	5333	-2991	1498,8	38,5
2.	Dove	4167	2375	3256	3266	2375	4167	-1792	895,9	27,4
3.	Isard	3992	2283	2767	3014	2283	3992	-1709	880,7	29,2
4.	Dexter	6417	2583	6264	5088	2583	6417	-3834	2170,7	42,7
5.	James	5708	2192	5605	4502	2192	5708	-3516	2000,9	44,4
6.	Balkan	4352	2320	3438	3370	2320	4352	-2032	1017,7	30
7.	Enduro	4078	2450	2666	3065	2450	4078	-1628	884,2	28,9
8.	Aviron	4578	2145	5348	4024	2145	4578	-2433	1671,8	41,6
9.	Curlling	4210	2867	6244	4440	2867	6244	-3377	1700,1	38,3
10.	Ball trap	5097	2879	6426	4801	2879	6426	-3547	1792,1	37,3
11.	Nicoleta	4375	2342	3270	3329	2342	4375	-2033	1017,8	30,6
12.	13008MT37	4957	2517	4155	3876	2517	4957	-2440	1243,7	32,1
13.	12032MT1-4	5413	2492	2803	3569	2492	5413	-2921	1604,4	45
14.	13008MT28-1	5979	2408	4827	4405	2408	5979	-3571	1822,4	41,4
15.	12004MT2	5691	3342	3550	4194	3342	5691	-2349	1300,6	31
16.	Lavinia F	6331	2600	3913	4281	2600	6331	-3731	1892,5	44,2
17.	12013MT7	5667	2842	3757	4089	2842	5667	-2825	1441,2	35,2
18.	12018MT1	4875	2875	4051	3934	2875	4875	-2000	1005,1	25,6*
19.	12023MT1-1	5083	2850	3928	3954	2850	5083	-2233	1116,9	28,2*
20.	12032MT1	5708	3067	3474	4083	3067	5708	-2641	1422,2	34,9
21.	13002MT	5458	2950	4656	4355	2950	5458	-2508	1281,06	29,4
22.	13020MT	6000	3458	5529	4996	3458	6000	-2542	1352,3	27,1*
23.	12038MT	5333	2842	4686	4287	2842	5333	-2491	1292,7	30,2

*significant at P<0.5

Grain yield varied in winter peas trials performed at NARDI Fundulea, on average, between 3014 (Isard) and 4996 (13020MT) kg/ha. Significant yield differences between genotypes have not been registered, but data suggest a better stability of this parameter associated with a good yield capacity in the breeding lines 12018MT1 (CV%=25.6), 13020MT (CV%=27.1) and 12023MT1-1 (CV%=28.2) (Table 3).

The valuable property of a variety is its ability to confront various biotic and abiotic stresses. The variance is value of tolerance to stress conditions of growth has negative sign and is calculated by difference Y_2-Y_1. The smaller this gap, the higher the stress tolerance of the variety and the wider the range of its adaptive possibilities (Sapega, 2015). According to our research, there are a series of pea varieties characterized with good stress tolerance, such as Enduro (1628), 12018MT1 (2000) (Table 3). This criterion does not limit the growth area with the winter peas genotypes, but it is very important and indicates the necessity to evaluate and select genotypes in the process of selective work not only by the productivity level but also by their ecological sustainability.

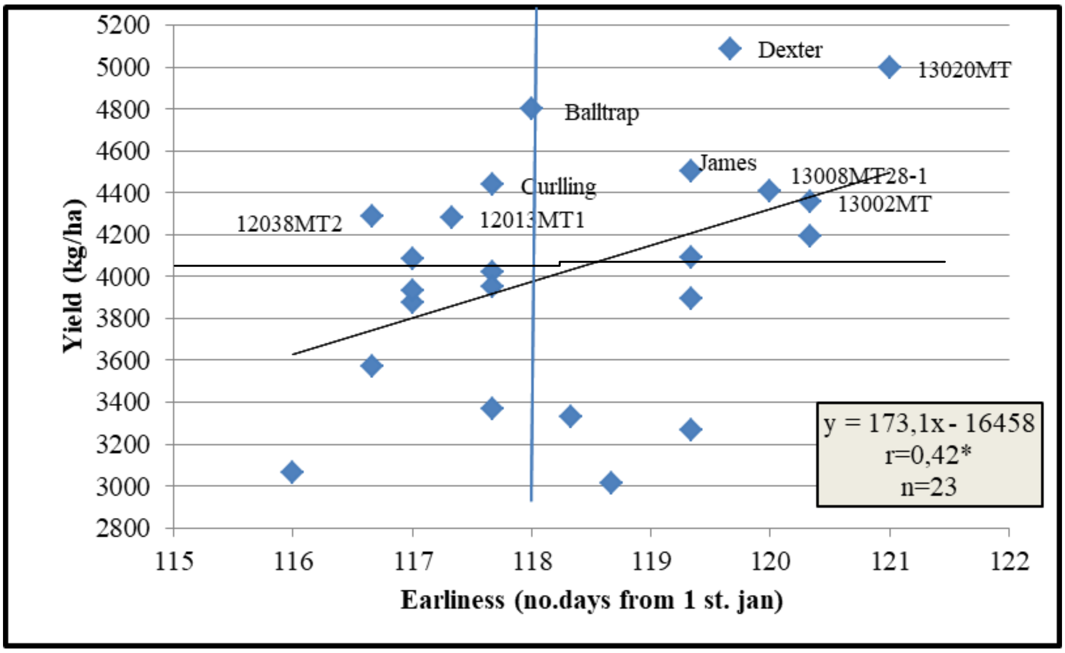

Figure 2. Relationship between earliness and yield in winter peas
(Fundulea, 23 genotypes, 2017-2019)

The relationship between yield and the number of days till the end of flowering was significant positive (0.42*) but winter peas genotypes with high yield and with earliness could be identified, such as two winter pea cultivars Balltrap and Curlling and two lines created at NARDI Fundulea, 12038MT2 and 12013MT1 (Figure 2).

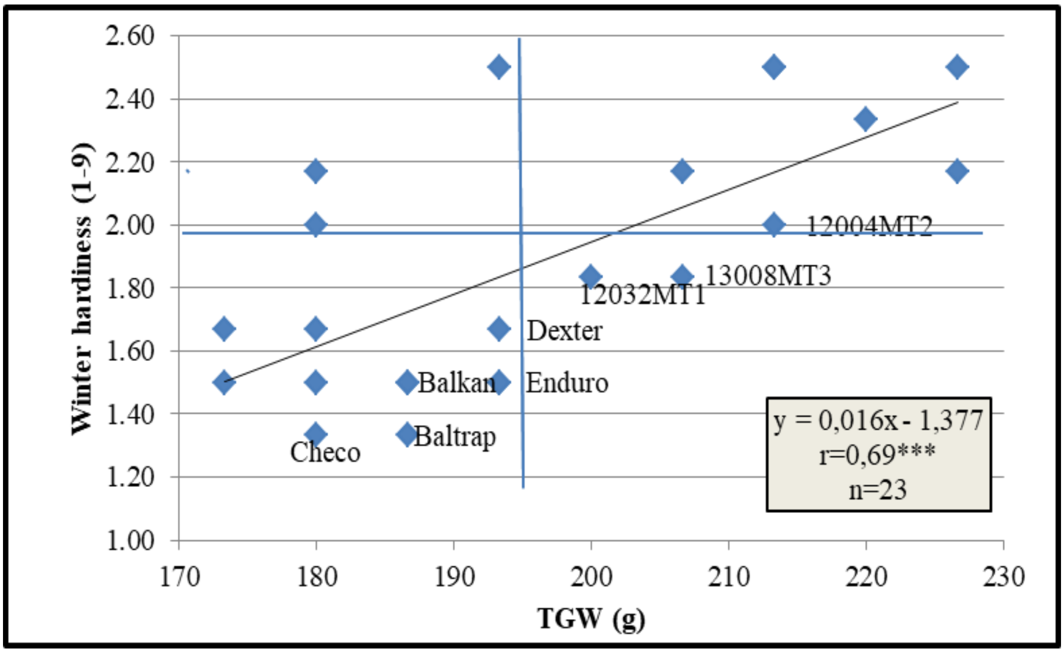

Figure 3. Relationship between thousand grains weight and winter hardiness in winter peas
(Fundulea, 23 genotypes, 2017-2019)

The relationship between TGW and winter hardiness for 23 genotypes of winter pea was negative and distinctly significant and winter pea genotypes with a good level of winter hardiness and different values of TGW were highlighted (Figure 3).

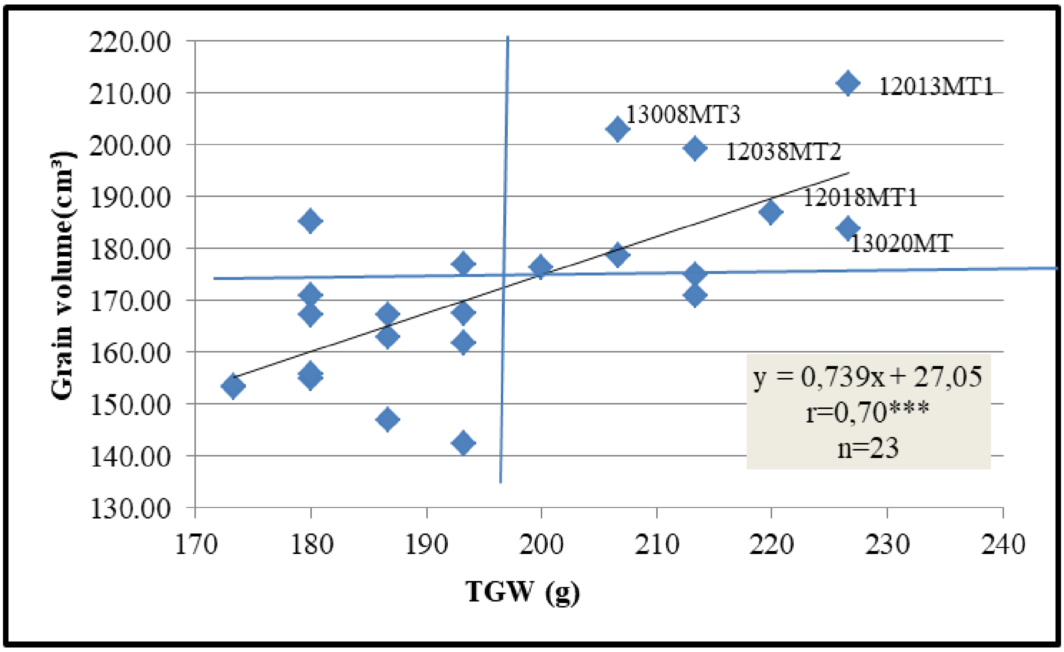

Figure 4. Relationship between thousand grains weight and grain volume in winter peas (Fundulea, 23 genotypes, 2017-2019)

The distinctly significant positive relationships between TGW and grain volume (r=0.70***) (Figure 4) and on the other hand, those significant with the grain volume (r=0.42*) (Figure 5) demonstrate their close correlation, the both characters, grain volume and density, determining a higher TGW.

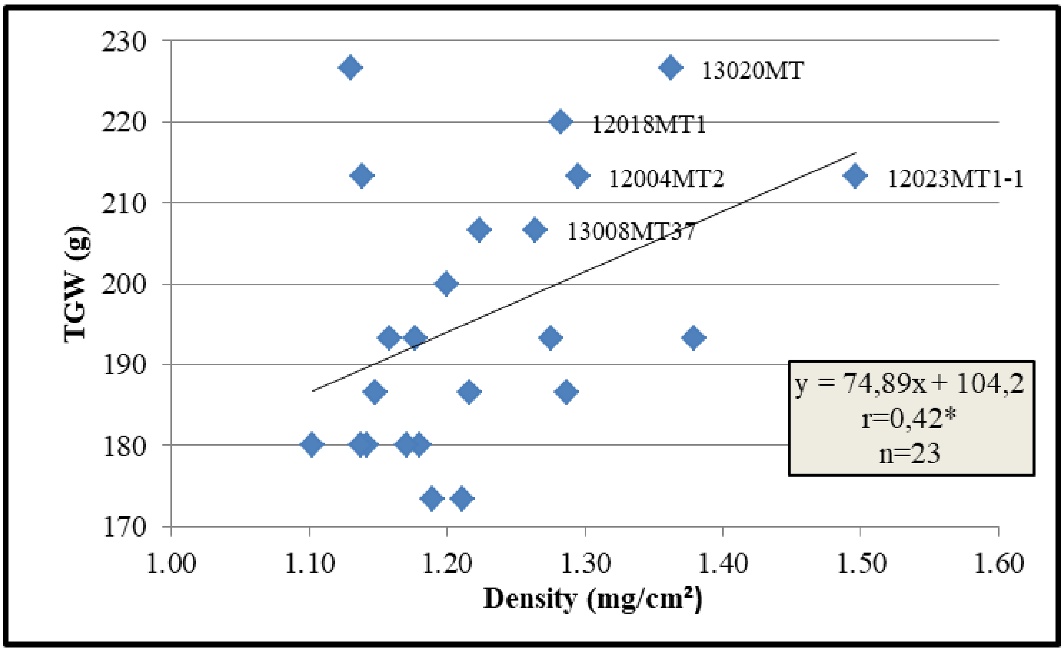

Figure 5. Relationship between thousand grains weight and grain density in winter peas (Fundulea, 23 genotypes, 2017-2019)

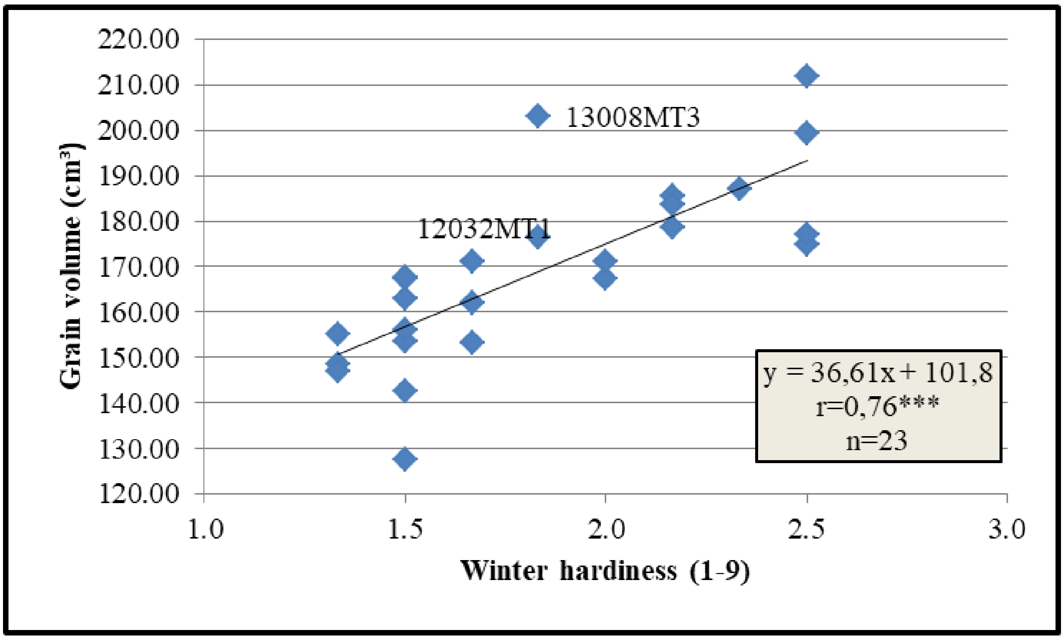

Figure 6. Relationship between winter hardiness and grain volume in winter peas (Fundulea, 23 genotypes, 2017-2019)

Relationship between winter hardiness and grain volume was distinctly significant (r=0.76***) and winter peas genotypes with a medium level of winter hardiness and a grain volume ranging from 170-200 cm^3 were also identified (Figure 6).

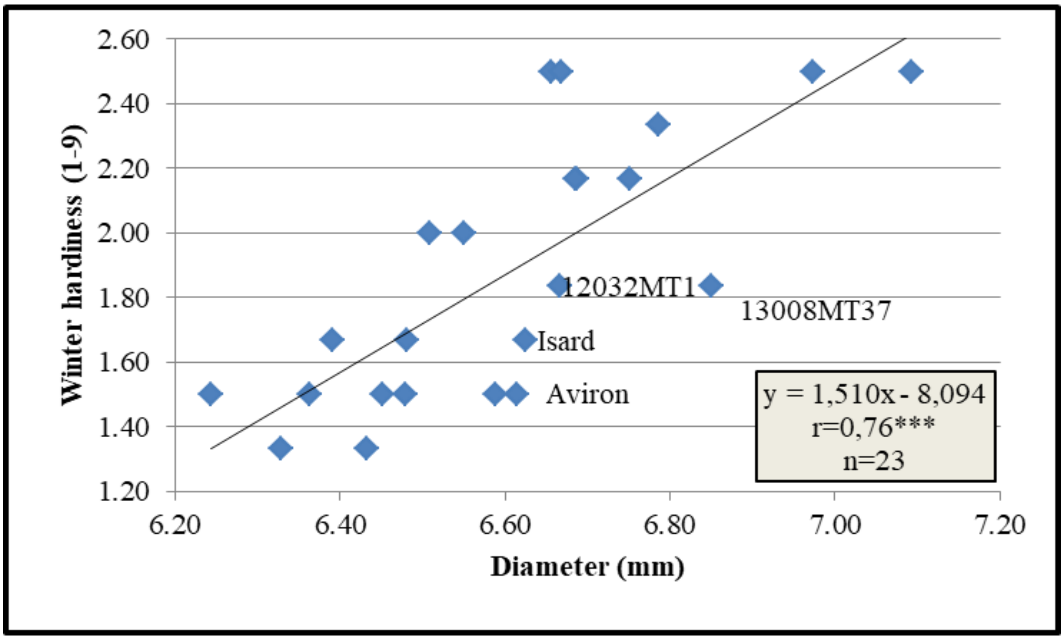

Figure 7. Relationship between winter hardiness and diameter in winter peas (Fundulea, 23 genotypes, 2017-2019)

Very significant correlation coefficient between winter hardiness and diameter were found (r=0.76***), and the presence of winter pea genotypes that combine a good level of winter hardiness with different diameters ranged from 6.40-6.90 mm has been also noticed (Figure 7).

CONCLUSIONS

Examination of phenotypic diversity of different pea genotypes indicated considerable variation for a range of traits.

Environmental conditions influence seed development and compositions. Genotype x year interaction was defined as the unequal response of the average value of the genotype trait for weather conditions and the pressure of diseases and pest in different years. In our study the impact of environment is the most important driving factor in winter peas grain yield, protein content, TGW, earliness, plant height, winter hardiness, grain volume, diameter and density.

The result of this study should contribute to a better knowledge of variability and seed yield stability of pea genotypes used in Romania for future production and breeding. Obtained phenotypic results could improve pea breeding by developing new cultivars carrying favourable traits to attain more sustainable production and higher yields. In conclusion, this work should promote the broader use of pea as a grain legume within diverse agricultural systems to provide multiple beneficial advantages, in line with the principles of sustainability.

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