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GENOTYPE-ENVIRONMENT INTERACTION AND STABILITY ANALYSIS IN GARDEN PEA (*PISUM SATIVUM* L.) LANDRACES

SUMMARY

Knowledge of presence and magnitude of genotype-environment interactions (GEI) is important to plant breeders in making decisions regarding the development and evaluation of new cultivars. The present investigation was undertaken to identify the stable landraces across different environmental conditions. Ten landraces of garden pea were evaluated for their adaptability in respect of green pod yield and fresh biological yield for three successive seasons 2010/2011–2011/2012 and 2012/2013 at one location. The stability of landraces was assessed using mean yield ($\overline{X}_i$), linear regression of genotypes on environmental index (b_i) and deviation from linear function (S^2d_i). The combined analysis of variance showed highly significant differences among the landraces for both traits studied. Mean squares due to GEI were highly significant indicating that landraces performed differently through the environments of study. Analysis of variance for stability showed higher magnitude of mean squares due to environments (linear) as compared to genotype-environment (linear) exhibiting that linear response of environments accounted for the major part of total variation for pod yield and biological yield. The results revealed that just the landrace *12420* was found to be high performance, stable and widely adaptable for green pod yield, whereas the three landraces *20648*, *12420* and *12831* were found to be good yielding, stable and widely adaptable for fresh biological yield.

Keywords: biological yield, garden pea, GEI, pod yield, stability.

INTRODUCTION

Garden pea (*Pisum sativum* L.) is an important vegetable crop grown almost all year round in various regions the world over. However, its productivity has become static over the last years even if the total planted area has increased tremendously.

This plateau is attributable to the lack of suitable improved cultivars for different agroclimatic conditions (Sood and Kalia, 2006). Yields of grain legumes are smaller and generally more variable than those of many other crop species. In developing countries, grain yields of legumes have not increased as rapidly as those of cereal crops (Jeuffroy and Ney, 1997). Pea yields are very

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sensitive to high temperature and drought, especially during the flowering period (Thorup-Kristensen, 1998).

Overall crop performance is a function of multiple factors; the genotype (G), the environment (E) and the genotype by environment (GE) interaction (Yan and Kang, 2003). Agricultural researchers have long been cognizant of the various implications of GEI in breeding programs. GEI has a negative impact on heritability and genetic gain (Ades and Garnier-Gere, 1996). Understanding the structure and nature of GEI is important in plant breeding programs because a significant GEI can seriously impair efforts in selecting superior genotypes relative to new crop introductions and cultivar development programs (Shafi and Price, 1998). GEI reduces the correlation between phenotypic and genotypic values, increasing the difficulty in identifying truly superior genotypes across environments, especially in the presence of crossover GEI (Karimizadeh *et al*., 2012).

GEI studies are important for scientists and breeders because they pinpoint genotypes and environments of low and high stability. Without GEI analysis, it would be difficult to make positive gains by selection (Kang and Gauch, 1996). In any crop breeding program, crop stability is a high priority. Achieving of ideal trait potential in one specific location because of optimal environmental conditions and management practices is good. However, new genotypes must be able to consistently outperform other competing genotypes and perform well over a range of environments. In other words, stability is the key in the development of successful new genotypes (Lin *et al*., 1986).

Breeders aim to reduce differences in respect to environmental variation either by selecting for genotypic stability or minimizing environmental variability that results in GE interactions (Jinks and Pooni, 1988). Plant breeders generally agree on the importance of high yield stability, but there is less accord on the most appropriate definition of "stability" as well as on methods to measure and to improve yield stability (Becker and Leon, 1988). Sufficient information regarding stability parameters is not available in garden pea which could be used in further breeding programs for crop improvement. Keeping above factors in view, the present research was conducted to evaluate genotype x environment interaction and stability analysis for green pod yield and fresh biological yield in a set of garden pea landraces.

MATERIAL AND METHODS

Ten landraces of garden pea obtained from the Bank of Genetic Resources, GCSAR, have the following numbers: *20533*, *20648*, *12401*, *12416*, *12420*, *12535*, *12831*, *12840*, *12859* and *12923* were evaluated during three growing seasons 2010/2011 – 2011/2012 and 2012/2013 at Scientific Agricultural Research Center of Dara'a (Semi – arid 32º 45' N, 35º 39' E and ca. 440 meters above sea level) and its soil is clay-loam, slightly alkaline (pH= 7.35), rich in total potassium and phosphors but poor in organic matter (768 ppm, 50.50 ppm and 0.45 %), respectively. The study materials were grown by a randomized complete block design (RCBD) with three replications. The experimental unit at each year consisted of 2 rows 0.70 m apart and 5 m long under rainfed conditions. Some monthly meteorological data of the experimental environments during the period of crop growth are listed in (Table 1). All the agricultural practices used for pea production were carried out in all the experiments in accordance with recommendations of GCSAR for pea crop. Data were recorded for green pod yield and fresh biological yield at the end of growing season on the basis of plot yield and which were converted to ton per hectare.

Data were analyzed across all the environments (seasons) using pooled data according to steel *et al*. (1997) by MSTAT-C statistical computer package software (Michigan State University, 1991), and stability analysis for the traits studied was performed according to the following model of Eberhart and Russell (1966):

$$\boldsymbol{Y_{ij} = u_i + B_i\ I_j + S_{ij}}$$

Where:

Y_{ij} = The mean of i^{th} genotype at the j^{th} environment.

u_i = The mean of i^{th} genotype over all environments.

B_i = Regression coefficient for the response of the i^{th} genotype to varying environments.

I_j = Environmental index obtained as the mean of all the genotypes at a given environment minus the grand mean.

S_{ij} = The deviation from regression of the i^{th} genotype at j^{th} environment.

Table 1. Some monthly meteorological data of the three seasons of study

Seasons	Meteorology	Months							
		Nov.	Dec.	Jan.	Feb.	March	April	May	June
2010/2011	T (º C)	14	10.5	9.25	9.5	14.5	17	21	23.3
	RH (%)	51	74	81	81	70	61	47	50
	W ($m.s^{-1}$)	2.9	3.1	1.7	1.6	2.0	2.2	2.3	3.6
	R (mm)	5	156	44.5	105	41.8	75	25.5	0
2011/2012	T (º C)	12	10.5	7.50	11	9.5	18	24	28
	RH (%)	55	77	74	78	67	56	49	44
	W ($m.s^{-1}$)	2.0	13	1.9	2.2	2.4	3.0	2.8	3.4
	R (mm)	32	28	90	133.5	82	0	5	0
2012/2013	T (º C)	12	10	9.30	9.85	12.25	17.30	21.8	26.5
	RH (%)	64	84	81	78	70	67	47	50
	W ($m.s^{-1}$)	1.7	1.5	2.7	1.8	2.6	2.9	1.7	2.1
	R (mm)	24	61	192.5	35	40.7	14	0	0

T: Temperature, RH: Relative humidity, W: Winds speed, R: Rainfall

RESULTS AND DISCUSSION

The pooled analysis of variance (Table 2) revealed that the differences among the genotypes (landraces) and environments (seasons) were highly significant ($P \leq 0.01$) for both traits studied indicating not only the amount of variability that existed among environments but also the presence of genetic variability among the genotypes. The higher values of mean squares due to environments indicated considerable differences among study environments for these two traits which were greatly affected by environments. The relative importance of years as a factor affecting GE interaction has been repeatedly reported, suggesting the need for testing in more years, rather than more locations (Brandle and McVetty, 1988; Biarnes-Dumoulin *et al*., 1996). Genotype-environment interactions were also highly significant indicating that particular genotypes tended to rank differently for both traits investigated over seasons. The significant component of GEI implies that the garden pea landraces are not fully adapted to the wide range of the study environments, as such, recommendation of specific genotypes for specific environments is necessary (Gebeyehu and Habtu, 2003). These results were in agreement with earlier findings of Abdus (1988); Happy (1994).

The partitioning of mean squares of interaction into linear (predictable) and non-linear (unpredictable) components showed that environments (linear) significantly differed and were quite diverse with respect to their effects on the performance of genotypes for green pod yield as well as fresh biological yield and indicated that response to environments (seasons) was genetically controlled. Furthermore, the higher magnitude of mean squares due to environments (linear) as compared to GE (linear) exhibited that linear response of environments accounted for the major part of total variation observed for pod yield and biological yield. these results corroborate the views of Badhan *et al*. (2000); Pan *et al*. (2001).

The significance of mean squares due to GE (linear) component against pooled deviation for the two traits investigated suggested that the landraces were diverse for their regression response to change with the environmental fluctuations. Although smaller in magnitude compared to the linear components, the significant deviation from the regression for fresh biological yield, demonstrated the presence of a degree of non-linearity in the GE interactions; the latter may be resulted from either interactions specific to certain genotype-environmental combinations or change in the expression of interaction from environment to another (Tai *et al.,* 1982). The higher magnitude of pooled deviation than the pooled error for fresh biological yield revealed that there was a relationship between non-linear regression components and elite landraces and this relationship strengthens the conclusion that landraces responded differently across environments (seasons) for this trait. Sharma *et al*. (2006) found that the linear component mainly regulated the GEI for pod yield. In the contrast, Swathi (2009) indicated that pooled error was higher in magnitude than pooled deviation for green pod yield in vegetable soybean.

Because of genotype-environment interactions were highly significant, stability analysis was performed and values using two different stability parameters were estimated. Estimates of stability parameters (b_i and S^2d_i) as well as mean values of green pod yield and fresh biological yield of garden pea landraces are presented in Table 3.

Table 2. Analysis of variance for stability over three environments (seasons) for green pod yield and fresh biological yield in ten garden pea landraces

		Mean sum of squares for the traits studied	
Sources	d.f.	Green pod yield	Fresh biological yield
Genotypes (G)	9	22.75**	122.72**
Environments (E)	2	53.83**	416.38**
G x E	18	23.11**	68.52**
E + (G x E)	20	12.32**	72.28**
E (linear)	1	107.52**	832.75**
G x E (linear)	9	15.24**	58.21**
Pooled deviation	10	0.18	8.93*
Pooled error	60	0.75	4.37

*, ** : significant at 0.05 and 0.01 probability level, respectively

Eberhart and Russell (1966) emphasized that both linear (b_i) and non-linear (S^2d_i) components of GE interaction should be considered in judging the phenotypic stability of a particular genotype and their responses are independent from each other. Therefore, a genotype considered as desirable, stable and widely adapted should meet criteria of high mean performance, with (b_i) equal to unity; non-significantly different from one and (S^2d_i) approaching zero; non-significantly deviated from regression line (Crossa, 1990).

Green pod yield:

Regression coefficients ranged from (-1.27) for *12535* to (2.80) for *12840*. All the landraces studied non-significantly deviated from zero; hence, they were performance stable. Among these landraces only the three landraces *viz.*, *12401*, *12420* and *12923* were average responsive and suitable to all the environments. However, unfortunately, just the landrace *12420* recorded higher mean yield (14.45 ton/ha) than the grand mean (13.07 ton/ha) and so it could be recommended for a wide array of environments.

Among the others, the landraces *20533*, *12416*, *12831*, *12840* and *12859* were highly responsive; because they had ($b > 1^*$) and all these five landraces except *20533* recorded high performance of pod yields in comparison with the general mean and, therefore, they could be recommended for cultivation under productive environments. The landrace *20648* was insensitive to environmental changes ($b < 1^*$) and had high mean performance (13.89 ton/ha),so, such a landrace could be recommended for cultivation in poor or low yielding environments (Table 3). Pan and Krishna (2000) found that out of 13 genotypes, only the two genotypes; *HUVP-1 and Pant Uphar* were high-yielding, stable and suitable for favorable environments. In another study, Pan et al. (2001) mentioned that out of 9 varieties and lines, just the two lines *viz.*, *KS 226* and *VL6*, were stable, better performing and suitable for favorable environments regarding green pod yield.

Fresh biological yield:

All the landraces under study except *12535* and *12840* were found stable; because they non-significantly deviated from zero. Among them, only the landraces *20533*, *20648*, *12420*, *12831*, *12859* and *12923* had average responsiveness and were suitable for a wide array of environments. However, out of these six landraces, just *20648*, *12420* and *12831* had higher biological yields than the grand mean (32.30 ton/ha) and, hence, they could be considered stable, widely adapted and desirable; due to they have the ability to express their yield potential through a wide range of environmental conditions.

The landrace *12416* which had ($b > 1^*$); was sensitive to environmental changes and, hence, it could be recommended for cultivation in favorable or high-yielding environments; due to it had higher mean performance (42.98 ton/ha) than the general mean (Table 3). Similarly, Nizam *et al*. (2011) found that the genotype *42.1* was stable, low yielding and adapted to special environments for herbage yield.

Table 3. Stability parameters, based on the regression model for ten garden pea landraces grown in three environments (seasons)

Genotypes	Green pod yield			Fresh biological yield		
	$\bar{x}_i$	b_i	S^2d_i	$\bar{x}_i$	b_i	S^2d_i
20533	11.57	1.90*	-0.60	30.56	2.80	-2.11
20648	13.89	0.77*	-0.76	34.89	0.88	1.74
12401	8.53	0.08	-0.60	24.36	1.19*	-3.82
12416	17.53	2.16*	-0.79	42.98	1.74*	-4.85
12420	14.45	0.19	-0.69	35.53	0.58	-4.07
12535	9.97	-1.27	0.02	21.91	-0.47	44.26*
12831	16.38	1.65*	-0.62	39.74	1.29	2.13
12840	13.34	2.80*	-0.48	29.72	2.08	19.93*
12859	13.42	1.09*	-0.70	31.52	0.22	-3.35
Grand mean ±S.E.	13.07±0.95	1.00±0.13	-	32.30±2.11	1.00±0.33	-

CONCLUSION

-The response levels of landraces studied largely differed in accordance with the traits under study.

-Green pod yield was more stable than fresh biological yield within this experimentation.

-The landrace *12420* was found desirable, stable and widely adapted for both green pod yield and fresh biological yield.

-The landrace *12416* had the ability to express its yield potential just in the favorable conditions for both traits.

- Generally, the highest yielding landraces were sensitive to environmental changes in comparison with low and intermediate ones and seemed to have a specific adaptation for high yielding environments.

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ANALIZA INTERAKCIJE GENOTIP-OKOLINA I STABILNOSTI U POPULACIJAMA GRAŠKA (PISUM SATIVUM L.)

SAŽETAK

Poznavanje prisustva i intenziteta interakcija genotip-okolina (GEI) važno je za oplemenjivače pri donošenju odluka vezanih za razvoj i evaluaciju novih kultivara. Ovo istraživanje je preduzeto u cilju identifikovanja populacija koje su stabilne pod različitim uslovima okoline. Ocjenjivana je prilagodljivost deset populacija graška u pogledu prinosa mahuna i bioloskog prinosa u tri uzastopne sezone 2010/2011–2011/2012. i 2012/2013. na jednoj lokaciji. Stabilnost populacija je ocijenjivana pomoću srednje vrijednosti prinosa, linearne regresije genotipova na indeks okoline (bi) i odstupanja od lienarne funkcije (S2di). Kombinovana analiza varijanse pokazala je visoko značajne razlike među populacijama za obje proučavane odlike. Sredina kvadrata je bila visoko značajna zbog GEI što ukazuje da su tokom proučavanja populacije imale različite rezultate zavisno od okoline. Analiza varijanse stabilnosti pokazala je veći iznos sredine kvadrata zbog okoline (linearna) u odnosu na genotip-okolinu (linearna) što pokazuje da je linearni odgovor okoline najvećim dijelom uticao na ukupnu varijaciju prinosa mahuna i biološkog prinosa. Rezultati su pokazali da je samo populacija 12420 visokih performansi, stabilna i veoma prilagodljiva u pogledu prinosa mahuna, dok su tri populacije – 20648, 12420 i 12831 imale dobar prinos, bile stabilne i veoma prilagodljive u pogledu biološkog prinosa.

Ključne riječi: biološki prinos, grašak, GEI, prinos mahuna, stabilnost.