

Relationship between Seed Yield and Yield Characteristics in Faba Bean (*Vicia faba* L.) by GGE-Biplot Analysis

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Abstract: *Vicia faba* L. was domesticated around 8000 BC in the Near East; the crop spread to Central Europe and Russia through Anatolia, the Danube Valley and the Caucasus; to Eastern Mediterranean regions through the Mediterranean coast and the Isles; from Egypt and Arabian Coast (the Arabia Felix) to Abyssinia; through Mesopotamia to India and China probably during the first millennium AD (only land races of major type, the latest in being produced, were known in China until recently). Faba bean (*Vicia faba* L.) is grown world-wide as a protein source for food and feed. The importance of nutrients (micro and macro) for human growth is universally recognized. An investigation was carried out to select the most successful faba bean genotypes to estimate for seed yield and some of agro-morphological traits. Effective interpretation of the data on breeding programmes is important at all stages of plant improvement. The GT (genotype by trait) was used for two-way faba bean genotypes with multiple traits. For this purpose, six faba bean genotypes with specific components were tested and the GT biplot for genotype data explained 83% of total variation of the standardized data. The polygon view of GT presented for five traits of faba bean genotypes showed three vertex genotypes as Goryaka, Karacaoglan and Seher. Genotype Goryaka had the highest values for most of the traits. It was demonstrated that the selection of high seed yield will be via hundred seed weight and planth height. These traits should be considered meanwhile as effective selection criteria developing high yielding faba bean genotypes because of their large contribution to grain yield. The genotypes Goryaka and Karacaoglan could be well-considered for improving of desirable candidate in selection of improvement studies.

Key words: Faba bean, GGE-biplot, seed yield, plant height, correlation.

1. Introduction

Faba bean is a diploid ($2n = 12$ chromosomes) important legume crop which is used as a source of protein in human diets as well as a forage crop for animals [1, 2]. It is originated in between the oriental Mediterranean countries and Afghanistan [3]. Faba bean (*Vicia faba* L.) is grown world-wide as a protein source for food and feed and most commonly included in the diets of inhabitants of the Middle East, the Mediterranean region, China and Ethiopia. It can be used in diet as a vegetable, green or dried, fresh or canned [4]. It is a very valuable legume crop that contributes to the sustainability of cropping systems

by its ability of biological N₂ fixation, diversification of cropping systems leading to decreasing disease, pest in soil and increasing biodiversity. The crop is also used as animal feeding and green manure.

Faba bean is popular a cool season legume and it is grown as a winter annual in subtropical areas. It is grown as a winter annual in warm temperate and subtropical areas; hardier cultivars in the Mediterranean region tolerate temperatures of -10 °C without serious damage whereas the most hardy European cultivars can tolerate up to -15 °C [5]. Winter faba bean types were also widely grown already in the beginning of nineteenth century in the continental climate and at high altitude in Burgundy, France [6]. Faba bean is the fourth most widely grown pulse crop in Turkey [7].

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In cold winter climates, faba bean is mostly sown in spring because of the inadequate hard winter conditions of the current fall-sown genotypes.

On the other hand, there is relevance in winter types for the expected advantages in grain yield in winter beans, as compared to spring beans [8]. Winter type faba bean cultivars tenders several benefits in excess of the spring type. Winter hardy faba bean genotypes keep alive winter conditions as young plants. Autumn sowing of faba bean is traditional in the Mediterranean [8]. Therefore, Mediterranean types should not be considered as winter hardy faba beans.

Huge number of faba bean local genotypes have ascended in course of time because of differences in traditional farming applications and taste priorities. These genotypes are a valuable source of genetic variation. In the recent years, a small number of faba bean varieties were developed and released within Turkey; most of the faba bean cultivars were introduced from different countries and started to replace the local genotypes. The Mediterranean region, particularly Turkey, with a concentration of large-seeded forms, is considered to be a secondary center with thousands of local genotypes in their natural growing conditions. Faba bean is also one of the most important edible legumes in Turkey and other Mediterranean countries, very limited genetic and breeding studies have been conducted.

Yield and yield components in faba bean, similar to the other crops, is a complex component and created by many of morphological and physiological components that correlated each other. Plant height, number of stems and pods per plant, biological yield, harvest index, 100-seed weight, days to flowering and maturity are the most important components in faba bean improvement for increasing SY (seed yield) due to direct and indirect correlation with SY [9].

The biplot according to GGE (genotype and genotype-by-environment) model is a biplot that represents the GGE of multi-environment trials dataset. It is established by plotting the first two principal

components (PC1 and PC2) originated from singular value decomposition of the environment-centered data [10]. However, it can also be equally used for all types of two-way data that assume a two way structure. The genotypes can be generalized as rows and the multiple traits as columns. Ref. [11] used a genotype by trait (GT) biplot, which is an application of the GGE biplot technique to study the genotype by trait data.

The objective of the study was to reveal clear relationships between seed yield and yield characteristics determine true selection criteria for seed yield in faba bean genotypes. For this reason it was to determine the seed production capacities of faba bean, to assess the effects of different traits on the yield, yield components of the genotypes. In addition, determining the most convenient genotype and trait interaction of faba bean uses GT biplot technique, under the North side Coast of Marmara Sea conditions of Turkey.

2. Material and Methods

Field experiments were conducted over a period of two years at Tekirdag, Southern Trakya Region of Turkey (40°59'26.0" N, 27°57'92.0" E). The upper 0-20 and 20-40 cm of the soil was classified as a clay loam structure that contained low organic matter contents with an average of 1.28%, lime of 0.91% with pH 6.89, 117.89 ppm and 9.66 ppm available K and P, 4,851.00 ppm Ca, 318.75 ppm Mg, 0.24 ppm Zn and 14.5 ppm Fe.

Total precipitation of the growing season (from sowing to physiological maturity) was around 704.3 mm and 452.1 mm during first and second growing season. Fertilizers were not applied.

2.1 Plant Material and Crop Sowing

Six faba bean genotypes including four ecotypes (Karamaslı, Karacaoğlan, Naip and Goryaka) which are grown widely were collected asseed from different locations of Trakya region and two commercial

cultivars (Seher and Sakız) were used as experimental material.

All faba bean ecotypes and the two cultivars plantings were done on 25 October 2012 first year and second year on 7 December 2013 by hand. Field experiments were conducted in randomized block designed with 3 replications at the research and implementation area of the Tekirdağ Namık Kemal University, Agricultural Faculty, Field Crops Department, Tekirdağ, Turkey. Plot size was 10 m² (5 m long, 4 rows, 0.50 m between adjacent rows, plants were spaced 10 cm apart within rows). The area harvested was 4 m² and unit of harvested yield was kg da⁻¹. Harvest was done on 4 July 2012 and 14 July 2013 by hand in first and second year respectively.

Ten plants of each plot were harvested by hand and weight of seed and pod per plant were measured before and at physiological maturity stage for all of the genotypes. The plant height (PH) was calculated before harvesting. The remainder of plants in each plot were harvested by hand at harvest maturity stage and branch number/plant (BNP), pod number/plant (PNP) and hundred seed weight (HSW) measured on ten plants selected randomly from all plots.

2.2 Statistical Analysis for GGE-Biplot

The GT biplot method [11] was used to show the faba bean by trait two-way data in a biplot. These statistical methods have been described in detail by Refs. [10, 11]. All biplots presented in this study were generated using the software GGE biplot package [12].

3. Results and Discussion

3.1 Biplot Analysis

Ref. [13] demonstrated the numerous utilities of GGE biplot in visual analysis of genotype-by trait data. All GGE biplots presented in this study were generated using software GGE biplot package program.

In this study, first two principle components (PC1 and PC2) explained 50.4% and 32.6% respectively. In the GT biplot with a polygon view it presents the data six faba bean varieties with traits (Fig.1). Vector is drawn from the biplot origin to each marker of traits to facilitate visualization of relationship between genotype and traits the following. The vertex genotypes are Goryaka, Karacaoglan, and Seher.

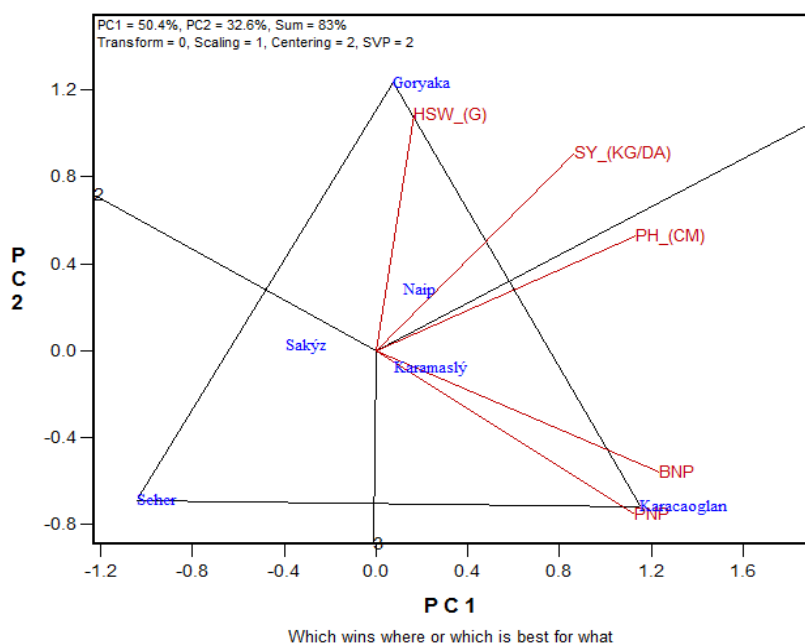


Fig. 1 Biplot analysis indicating polygon view for some of traits in faba bean genotypes.

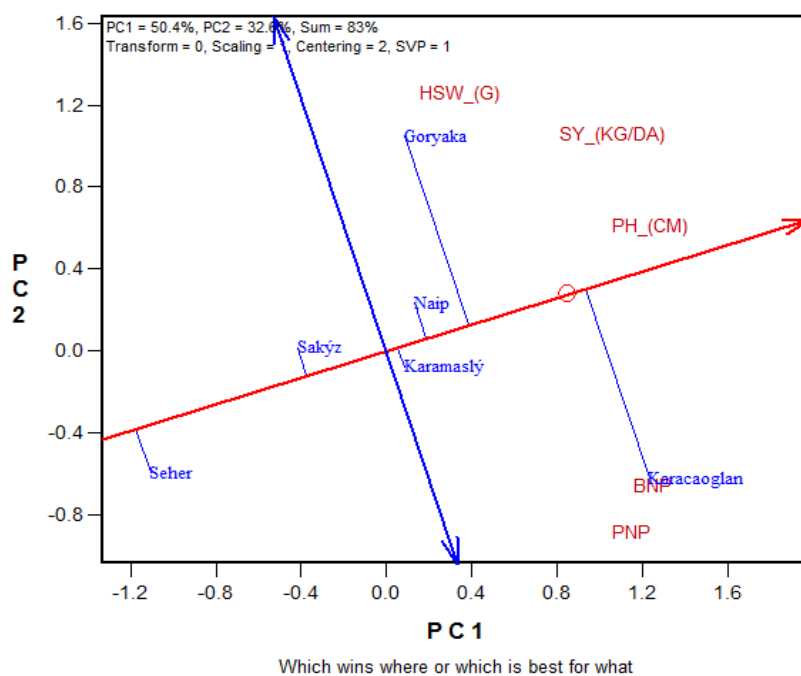


Fig. 2 The average tester coordination view for some of traits in faba bean genotypes.

Therefore, it seems that genotype Goryaka had the highest values of seed yield and hundered seed weight; another vertex genotype Karacaoglan had the highest plant height, branch number/plant and traits.

The rest of genotype Seher and closer to biplot origin genotype Sakız which fall in its sector any trait and not favourable for any traits (Fig. 1).

According to the average tester coordination, arrows points to higher mean performance for the genotypes and consequently help to rank the genotypes according to their mean performance (Fig. 2). Thus the current faba bean genotypes were ranked according to their mean performance as follows: The average tester comparison view of genotypes by trait biplot,

Karacaoglan \geq Goryaka \geq Naip \geq Karamaslı \geq meanperformance \geq Sakız \geq Seher. This genotypic performance ranking on based on the average tester coordination is nearly coincided with the performance of genotype.

3.2 Correlation Analysis

The tester vectors are the lines that originate from the biplot origin and reach markers of the traits (Fig.

3). Since the cosine of the angle between the vectors of any two traits approximates the correlation coefficient between them, this view of the biplot is best for visualizing the interrelationship among traits. Fig. 3 suggests close positively associations among plant height, seed yield and hundered seed weight.

Seed yield indicated a weak but positive correlation with BNP and PNP as well as BNP and PNP as indicated by the small obtuse angles between their vectors There was a near zero correlation between HSW and SY with PNP and BNP (Fig. 3). Some of mentione results can be verified using correlation coefficients of Table 1. Some discripancies between the biplot predictions and original data were expected because the biplot accunted for < 100% of total variation (about 83%). Ideal genotypes are those that sould have large PC1 scores (high traits means) and small (absolute) PC2 scores (low variability). Genotypes with above-avarage means (i.e., Goryaka, Naip and Karacaoglan) were selected, whereas the rest (i.e., Sakız, Karamaslı and Seher) were allocated. Genotypes Goryaka, Naip and Karacaoglan were the most favorable genotypes respecting all of the measured traits. Among this genotypes, Naip was the

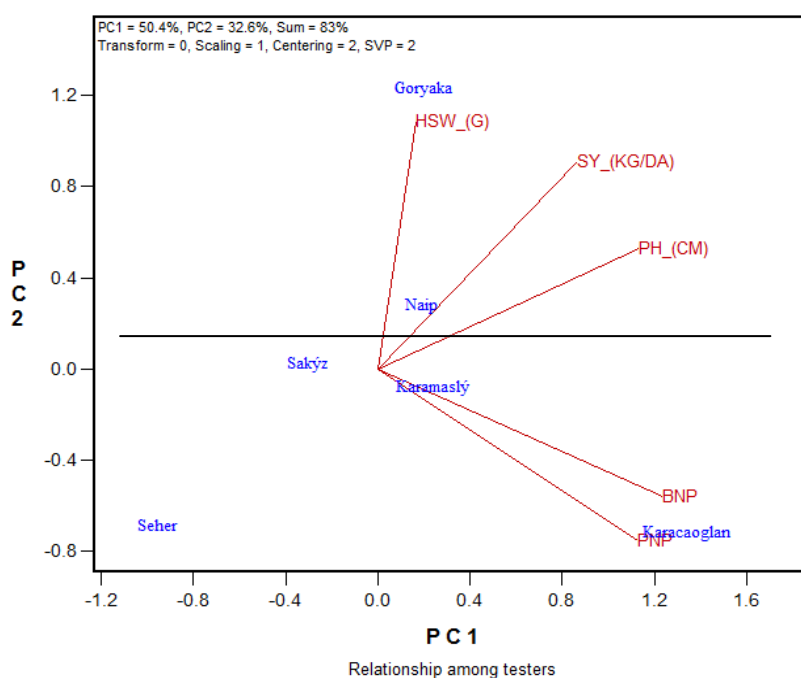


Fig. 3 Biplot analysis indicating relationships between some of traits in faba bean genotypes.

Table 1 Simple correlation coefficients among five faba bean traits.

Traits	PH	PNP	BNP	HSW
PNP	0.126ns			
BNP	0.066ns	0.710**		
HSW	-0.397*	-0.059ns	0.092ns	
SY	0.813**	0.073ns	0.050ns	-0.445**

Traits are SY (seed yield), PH (plant height), PNP (Pod number/plant), BNP (branch number/plant) and HSW (hundred seed weight), ns: non-significant.

least variable genotype due to its low distance from horizontal axis while Goryaka was the most variable genotype due to its relatively high distance from horizontal axis. On the other hand Sakız was the least favorable genotype among all studied genotypes for its low mean yield for measured traits and high variability. The requirement for the use of site regression based GT biplots in the identification of most superior genotypes is to make possible the identification of most superior genotypes [14]. The study has clearly shown that the SREC model can analyze patterns and relationships of genotypes and traits successfully as well as provide a valuable prediction [15]. Ref. [16], for some reason, mentioned that multivariate methods and their graphical tools are too complicated to provide a simple measure of

genotypes favorability. In faba bean growing, improvement for achieving high seed yield as an important desirable character is the purpose of many adaptation and breeding programs.

GGE biplots were also used for identifying traits that are closely associated with and therefore can be used in indirect selection for, a target trait [13]. Ref. [17] used biplot method to determine the interrelationships among physiological traits of thirty cowpea cultivars and identify suitable traits for indirect selection for improved crop yield.

4. Conclusion

This study demonstrates that the GT biplot is an excellent tool for visualizing genotype by trait data. The GT biplot effectively revealed that SY is derived

from a composite of traits, which is interrelated, the most important being HSW and PH. In addition agro-morphological traits were significantly differed in the investigated faba bean genotypes. Among the 6 faba bean genotypes used in this study, Goryaka and Karacaoglan showed significantly higher magnitude values than other genotypes. These genotypes could be used as commercial cultivars or after further improvement and selection as pure or as potential lines for development faba bean cultivars for southern part of Thrace region.

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