An-Najah National University
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Phenotypic characterization of faba bean (*Vicia faba* L.) landraces grown in Palestine

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Dedication

To the memory of my late mother and father, brothers, Fakhri and Jamal and to the rest of my brothers and sisters.

My wife, Nisreen, wonderful kids: Mohammad, Lima and Dina.

Acknowledgments

I would like to express my gratitude and appreciation for my supervisor Dr. Munqez Shtaya for his great support and encouragement as well as to the all members of the Department of Plant Production at the Faculty of Agriculture, An-Najah National University.

Last but not least, my thanks and gratitude to my wife for her help and support.

الإقرار

إنا الموقع أدناه مقدم الرسالة التي تحمل عنوان

Phenotypic characterization of faba bean (*Vicia faba* L.) landraces grown in Palestine

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List of Abbreviations

No	Abbreviation	Full Name
1	DS	Disease severity
2	PCR	Polymerase chain reaction
3	RAPD	Random amplified polymorphic DNA
4	Mt	Metric ton
5	RFLP	Restriction fragment length polymorphism
6	SSR	Simple sequence repeat
7	AFLP	Amplified fragment length polymorphism
8	VF	*Vicia faba*
9	AUDPC	Area under disease progress curve
10	SAS	Statistical analysis system
11	NPP	Number of pods per plant
12	NSP	Number of seeds per pod
13	PL	Pod length
14	PW	Pod width
15	SW	100 seed weight
16	TPWP	Total pod weight per plant
17	QTL	Quantitative trait locus
18	REGWQ	Ryan-Einot-Gabriel-Welch based on range

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Phenotypic characterization of faba bean (*Vicia faba* L.) landraces grown in Palestine

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Abstract

This study was conducted to investigate the morphological and agronomical variations and the level of resistance to leaf rust *Uromyces visiae - faba* among nineteen Palestinian faba bean (*Vicia faba* L.) landraces. And analyze their traits including: days to flowering, days to fruit setting, plant height, number of branches on main stem, lowest pod height, pod length, pod width, number of pods per plant, number of seeds per pod, 100-seed weight and total pod weight per plant were studied. Leaf rust severity calculated as the percentage of leaves covered by the pathogens was estimated three times during the growing season. Significant differences were observed among genotypes for all characters. The nineteen faba bean lines were clustered into four groups based on six morphological and agronomic traits (pod length, pod width, number of pods per plant, number of seeds per pod, 100-seed weight and total pod weight per plant). Several genotypes could be considered as promising material for pod production. A significant variation of leaf rust disease severity was observed. Accession VF-13 showed the lowest disease severity (18%), but VF-6 showed the highest disease severity (69%) while the control (susceptible genotype) showed 59.7%. These accessions could be used as a valuable source for leaf rust resistance.

Further studies are needed to compare the productivity of these genotypes with international varieties and identify QTL controlling the productivity of these genotypes and to study the variation between and within these genotypes at the molecular level.

Chapter One

Introduction

Chapter One
Introduction

Faba bean *(Vicia faba* L.*)* is an important winter legume crop originated in between the oriental Mediterranean countries and Afghanistan (Cubero, 1974). The main faba bean producers are China (1.65 Mt), Ethiopia (0.61 Mt), France (0.44 Mt), Egypt (0.29 Mt) and Australia (0.19 Mt) (FAOSTAT, 2009). Faba bean is a valuable protein-rich food that provides a large sector of the human populations in developing countries with a cheap protein source thus partly compensating for the large deficiency in animal protein sources.

In developed countries faba bean provides an alternative to soybean meal for animal feed, this being particularly important in the more industrialized countries. Faba bean plays a significant role in improving the productivity of the soil in the cereal-based rotations where it serves as a break crop; yields of cereal crops following faba bean are improved and needs for nitrogen fertilizer applications are reduced. Studies on the fixation of atmospheric nitrogen through symbiosis in organic farming (Schmidtke and Rauber 2000) have shown that faba bean surpasses peas in the amount of nitrogen fixed.

Faba bean is one of the essential legume crops grown in Palestine mainly under rain fed conditions. The annual production of faba bean in Palestine is very low and varies from year to year and from location to location, with a total production of about 339.5 tons cultivated on 399 ha (PCBS, 2008). Many Palestinian faba bean farmers grow landraces meanwhile others grow imported cultivars because of their high productivity (Ministry of Agriculture, personal communication). These landraces are valuable source of genetic variation and may possess some interesting characteristics such as small size of pods and adaptation to prevailing local environmental conditions.

Many diseases attack faba bean as chocolate spots, leaf and pod spot, powdery mildew and Rust (Sillero et al, 2002). Rust diseases caused by *Uromyces viciae − fabae*, is a serious disease to faba bean with severe attacks in Middle East and in eastern Africa up to 70% (Rashid and Bernier, 1986). Genetic resources are the most partial and efficient method for the control of rust diseases (Torres et al, 2006), several sources of resistance to *U. viciae faba* have been reported in the last decades (Sillero et al, 2000). Most of them displayed a slow-rusting resistance characterized by the presence of susceptible infection type and a slow development of the disease. Macroscopic components of this partial resistance are characterized by reduction in lesian size and infection frequency. In Palestine, faba bean landraces have not been genetically evaluated. Characterization of the genetic variation in the available germplasm is important for further improvement of crop yield and to impart resistance to biotic and abiotic stresses. Using phenotypic data in cultivar identification, study genetic diversity of plants was previously scored for many plants (Abd El-Zaher, 2007).

The main objectives of this study were to investigate the morphological, agronomical variations and the level of resistance to leaf rust *Uromyces visiae - faba* among nineteen Palestinian faba bean (*Vicia faba* L.) landraces

Chapter Two

Literature Review

Chapter Two
Literature Review

Landraces are population mixtures containing a great number of different hereditary types due to their genotypic diversity and are adapted to the change in the environmental condition of their habitat (Kuckuck, *et al*., 1991). This available genetic variation has not yet been fully exploited and new variation is still being uncovered, and a considerable range of variation exists both between and within populations (Lawes, *et al*., 1983). In faba bean breeding, landraces are excellent sources of genes for improving grain yield (Suso, *et al*., 1993). For example, genetic diversity were observed among 79 inbred lines of recent elite faba bean cultivars of Asian, European and North African origin by using amplified fragment length polymorphism (AFLP) markers (Zeid, *et al*., 2003). In addition, the AFLP markers were used to investigate the relationship between genetic similarities of 18 European faba bean lines and their hybrid performance and heterosis (Zeid, *et al.,* 2004).

2.1. Days to flowering

Flowering in faba bean depends on the time of sowing, moisture, climatic factors and geographic location, but only 13-64% of flowers produce pods. In fact, the number of flowers produced per node and per plant varies with the genotype and the growing conditions, but always greatly exceeds the number of pods which eventually will be borne (Lawes, *et al*., 1983, Suso, *et al*., 1996). For example, flower abscission monitored in eight faba bean cultivars was found to vary from 36% to 87% (Gates, *et* *al*., 1983). Also, Della (1988) found that faba bean genotypes under irrigation conditions had longer time to flower than that under rain fed conditions.

2.2. Days to fruit setting

Nanda, *et al*. (1988) compared days to pod formation among 25 faba bean genotypes grown under rain fed and irrigated conditions and found highly significant differences under irrigation conditions only. Bashir (1986) reported that sowing date affect significantly the number of days to reach the 50% poding stage. Al-Refaee, et al., (2004) found that plant population and seed size had significant effect on the number of days to start poding; high population plant prolonged days to start poding, whereas the lower population density shortened the time to reach poding.

2.3. Plant height

Plant height depends on plant genotype as well as the environment, but it is usually within the range of 0.5-2.0 m. Some true dwarfs and semi-dwarf varieties are available (Bond, *et al*., 1985). Plant height character was considered as the major source of diversity (Suso, *et al*., 1993). Plant height is affected by seeds size, so usually plants grown from large seeds are taller than plants originate from small seeds (Al-Refaee, *et al*., 2004). According to Della (1988), plant height of Cyprus faba bean genotypes were found to be considerably affected by the environment, with mean values of 83 cm under irrigated and 52 cm under rainfed locations, According to Terzopoulos, *et al*. (2004), European faba bean population is divided into three levels of plant height: high (59-64 cm), medium (54-59 cm) and low (49 -54 cm).

2.4. Primary and secondary branch

Faba bean plants are distinctly annual with strong, hollow, erect stems bearing usually one or more basal branches arising from leaf axils. The growth is indeterminate, though determinate mutants are available. The number of branches per plant in the indeterminate faba bean lines was low during the early vegetative stage and increased, reaching the maximum at flowering stage then declining towards maturity (Silim and Saxena, 1992). Nanda, *et al*. (1988) reported that number of branches per plant varied significantly among 25 genotypes grown under stress conditions only.

2.5. Lowest pod height

Della (1988) found that lowest pod height varied among the different accessions and it was affected by the environment. Suso *et al*. (1993) identified two types of plants: those with a high position of the lowest pod bearing node, and those with a low position, corresponding to the regions. Also, Terzopoulos *et al*. (2004) reported that most of faba bean populations grown at two different locations for two years had pods mainly at the lower part of the plant. Suso *et al*. (1996) reported that among twelve faba bean genotypes, the open pollinated plants bore the first mature pods on lower nodes than self pollinated plants. Musallam, *et al*., (2004) observed that plants with access to bees set more pods on the lower nodes and ripen earlier.

2.6. Pod length and width

Pod length is an important factor in the classification of faba bean genotypes. Pod length in faba bean ranged from 5 – 25 cm, producing two to four flat seeds (Bond, *et al*., 1985). According to Della (1988), pod length for Cyprus faba bean cultivars was short or medium, and pod width was broad in all the accessions. Sadri (1987) found that faba bean genotypes varied considerably in their pod length. The length of the pod is closely related to the number of seeds per pod. Pod length and width are also affected by seed size, so plants originated from medium to large seeds will give more pod length and width than plants originating from small seeds (Al-Refaee, *et al*., 2004). Terzopoulos, *et al*., (2004) studied 55 faba bean populations and they found that 27 populations had short pod length and 23 had medium pod length.

2.7. Number of pods per plant

Pod distribution on the stem may be mainly basal, uniformly along the stem or mainly terminal. The number of pods per node ranges from one to three (Terzopoulos *et al*., 2004). Singh, *et al*., (1987) reported that the main component of faba bean yield was the number of pods per plant, which was lowest under rainfed than irrigated conditions. Pilbeam, *et al.,*

(1992) found that the increase in yield under irrigation was associated with more pods per plant.

2.8. Yield components

Due to environment and genotype, much variation in the number of fruit-bearing nodes as well as number of fruits per node are exist (Bond, *et al*., 1985). Neal and Mcvetty (1983) concluded that 68.5 - 76.4% of the yield variability was accounted mainly by three yield components: pods per plant, seeds per pod, and 1000-seed weight. While, Hassan and Ishaq (1972) reported that the number of seeds per pod ranged from 2 to 5 for all varieties tested in their study. According to Mohamed and Bashir (1986), the factors essential for high yield are: number of pods per plant, seed weight, stem length and number of branches per plant. Pilbeam, *et al.* (1992) studied two faba bean cultivars (Minicia and Ticol), and found that the greater yield of Minicia cultivar was attributed to the greater number of seeds per pod and a greater seed weight compare to Ticol cultivar, which had more flowers, more immature pods and total pods than Minicia cultivar.

Singh, *et al*. (1987) found that the irrigated faba bean crop produced significantly higher grain and biological yield than the unirrigated faba bean crop during two growing seasons and the increase in yield due to irrigation ranged from 8-52% for the various treatments (branch initiation, flowering and mid-pod filling). Suso, *et al*. (1996) suggested that yield regulation operated by different mechanisms for various genotypes, particularly abortion of young pods, ovules and seeds and seed size adjustments. In many genotypes, many young pods were produced but few matured; in others, few ovules developed into seeds. Della (1988) found that faba bean pod weight per plot varied among the accessions with minimum pod weight of 800 g per plot at irrigated location and 270 g per plot at rain fed location and maximum values of 1915 g and 1038 g, respectively.

2.9. Rust resistance

Sillero et al. (2000), examined a collection of 648 accessions of faba bean for resistance to rust (*Uromyses viciae- fabae*) and identifies two types of resistance which reduce disease severity and area under disease progress curve, but are different in the expession of hypersensitivity. The resistance increased latent period, decreased colony size and reduced infection frequency. The presence of necrosis was an additional component in the hypersensitive resistance response.

Sillero and Rubiales (2002) noticed by studying the components of resistance to the faba bean rust in seedlings and adult plants, that the resistance of resistant lines was characterized macroscopically by an increased latent period, decreased colony size, relatively decreased infection frequency and some necrosis. Histological investigation revealed few differences in spare germination and appressorium formation, resistance was mainly due to a restriction of haustorium formation with varying levels of early abortion of the colony development, especially in adult plants.

Sache and Zadoks (1994), reported that the average grain weight and number of pods per stem are decreased with increased severity level of *Uromyses viciae fabae.*

Williams (1978), reported that *Uromyces visiae fabae* infection decrease leaf area ratio without increase net assimilation rate during the stage of pod filling, decrease the weight of beans per pod and yield of bean per plant.

Chapter Three

Materials and Methods

Chapter Three
Materials and Methods

3.1. Source of seeds

Seeds of nineteen faba bean landraces collected from farmers in different regions in Palestine (Table 1) were used in this study.

Table (1): Faba bean *(Vicia faba* L.*)* landraces collected from different regions in Palestine.

Accession	Collection site	موقع الجمع	Province	المحافظة	Seed size
VF-1	Al-Ras	الراس	Qalqilya	قلقيلية	Small
VF-2	Al-Zababdeh	الزبابدة	Jenin	جنين	Small
VF-3	Emateen	إماتين	Qalqilya	قلقيلية	Small
VF-4	Bet-Iba	بيت إيبا	Nablus	نابلس	Small
VF-5	Beta	بيتا	Nablus	نابلس	Small
VF-6	Tayaseer	تياسير	Tubas	طوباس	Small
VF-7	Jayous	جيوس	Qalqilya	قلقيلية	Small
VF-8	Senjel	سنجل	Ramallah	رام الله	Small
VF-9	Qabatya	قباطية	Jenin	جنين	Small
VF-10	Selet-Aldaher	سيلة الظهر	Jenin	جنين	Small
VF-11	Shwakeh	شويكة	Tulkarm	طولكرم	Small
VF-12	Tubas	طوباس	Tubas	طوباس	Small
VF-13	Tubas	طوباس	Tubas	طوباس	Small
VF-14	Tulkarm	طولكرم	Tulkarm	طولكرم	Small
VF-15	Azoun	عزون	Qalqilua	قلقيلية	Small
VF-16	Anabta	عنبتا	Tulkarm	طولكرم	Small
VF-17	Aean-Albeda	عين البيضا	Tubas	طوباس	Small
VF-18	Nablus	نابلس	Nablus	نابلس	Small
VF-19	Ne'eleen	نعلين	Ramallah	رام الله	Small
Brocal	Cordoba	قرطبة	Spain	اسبانيا	Large

3.2. Experimental Site

Field experiment was conducted at the experimental farm of the Faculty of Agriculture, An-Najah National University, Tulkarm (Khadouri), Palestine_(32.31519º N and 35.02033º W and altitude of 75 m) during the 2009/2010 growing season in a heavy clay soil. All accessions were sown at the 1st of December 2009 in three complete randomized blocks. Each accession was represented by 10–15 seeds in a single row, 1 m long per replicate. The susceptible faba bean variety 'Brocal' was sown every five accessions of the collection as a spreader and control for leaf rust. Ten seedlings remained after removing the excess seedlings in every row. The average rainfall in the experiment site is about 600 mm and the average temperature during the growing season was 14.6 and 23.5 (for minimum and maximum temperature respectively) (PMD, 2010)

3.3. Cultural practices

The experimental open field was plowed two times before planting. All accessions were sown in a clay loamy soil. Protection against aphids was made by spraying "Berimor, a.i. " at a rate of 40 g per 20 L. Plants were not protected against foliar fungal diseases. Hand weeding between and within rows were done and continued throughout the growing season, no fertilizers or supplementary irrigation where used during the growing season.

3.4. Data collection

3.4.1. Agronomic data

During the growth season and before maturity, the following data were recorded:

1. Days to flowering: number of days from planting the seeds until 90% of the plants per accession were flowering.

2. Days to fruit setting: number of days from planting the seeds until 90% of the plants per accession were setting fruits.

At maturity stage (green pods), the following measurements were taken from each line by harvesting five plants from the centre of the row:

1. Plant height: from ground level to the plant shoot tip.

2. Number of branches on the main stem: from basal and mediated nodes.

3. Lowest pod height: from ground level to the first pod on the plant.

4. Pod length: for five random pods, measured as the distance between the edges of pod.

5. Pod width: was measured for five random pods at the center of pod using a caliper.

6. Number of pods per plant: was measured as the average of five plants.

7. Number of seeds per pod: was counted for ten random pods.

8. 100-seed fresh weight: determined by mixing the whole samples, then 100 seeds were randomly counted and weighted.

9. Total pod weight per plant: was measured as the average of five plants.

For the statistical analysis, the average of the five harvested plants was used for each treat.

3.4.2. Rust severity

When rust development started, disease severity was assessed at two week intervals by a visual estimation of the leaf area covered with rust pustules. The data were used to calculate the area under the disease progress curve (AUDPC) using the formula

$$\text{AUDPC} = \sum_{i=1}^{k} \frac{1}{2} \left[(s_i + s_{i+1})(t_{i+1} - t_i)\right]$$

Where s_i is the rust severity at assessment data i, t_i is the number of days after the first observation on assessment data, i and k is the number of successive observations (Sillero et al 2000).

3.5. Statistical analysis

Analysis of variance (ANOVA) was conducted using PROC GLM of SAS/STAT software (version 9.0 for Windows) (SAS institute, 2002). Multiple comparisons among pairs of lines were made by the REGWQ-test. Cluster analysis was performed using the complete-linkage method.

Chapter Four

Results and discussion

Chapter Four
Results and discussion

4.1. Days to flowering

Significant variation in days to flowering between landraces was observed (Table 3). The majority of the collection (84%) presented early flowering genotypes (from 60–63 days after planting). Three accessions (VF-14, VF-10 and VF-12) showed significantly longer days to flowering (76.7, 70.0 and 66.7 respectively), and differed from all the other genotypes, ($P < 0.05$). These results were in agreement with Suso *et al.* (1993), who found significant difference in days to flowering among Spanish faba bean cultivars. Other studies showed that faba bean genotypes had longer time to flowering when grown under irrigation condition than those grown under rainfed conditions (Della, 1988).

4.2. Days to fruit setting

Significant variation in days to fruit setting was observed (Table 3). Accession VF-14 scored the longest days to fruit setting when compared to the other genotype. The average period needed to fruit setting was 72 days. These results were in agreement with Al- Refaee *et al*. (2004), who found that the date of fruit setting among faba bean genotypes varied significantly. Fruit setting is affected by genetic make up and environmental factors. The effect of genetic make up is shown in the differences between genotypes used in the current study.

Nanda et al, (1988) reported that significant differences were observed for days to pod formation between 25 faba bean genotypes grown under irrigation conditions. The environmental factors affecting fruit setting are mainly related to change in temperature and rainfall.

4.3. Plant height

Significant variation on plant height was observed (Table 3). Accessions VF-8, VF-12 and VF-13 were significantly the tallest (96.67 cm) (Table 3) while, VF-6 and VF-7 were the shortest plants (61.67 cm). These results were in agreement with Della (1988) who found that plant height of faba bean genotypes varied significantly under rainfed conditions. Suso et al, (1993) reported that plant height was an important trait discriminating among different geographic regions

Table (2): Days to flowering, days to fruit setting and plant height of nineteen faba bean landraces grown during 2009/2010 growing season.

Accession	Days to flowering	Days to fruit setting	Plant height (cm)
VF-1	62.0[cd*]	70.0[cd*]	70.0[efg*]
VF-2	63.3[cd]	70.0[cd]	78.3[cd]
VF-3	60.0[d]	70.0[cd]	75.0[def]
VF-4	60.0[d]	66.7[d]	68.3[fgh]
VF-5	60.0[d]	66.7[d]	78.3[cd]
VF-6	60.0[d]	70.0[cd]	61.7[h]
VF-7	60.0[d]	66.7[d]	61.7[h]
VF-8	60.0[d]	70.0[cd]	96.7[a]
VF-9	60.0[d]	73.3[bcd]	65.0[gh]
VF-10	70.0[b]	80.0[b]	78.3[cd]
VF-11	60.0[d]	76.7[bc]	76.7[de]
VF-12	66.7[bc]	80.0[b]	96.7[a]
VF-13	63.3[cd]	76.7[bc]	96.7[a]
VF-14	76.7[a]	93.3[a]	85.0[bc]
VF-15	60.0[d]	70.0[cd]	70.0[efg]
VF-16	60.0[d]	70.0[cd]	70.0[efg]
VF-17	60.0[d]	66.7[d]	80.0[cd]
VF-18	60.0[d]	66.7[d]	63.3[gh]
VF-19	60.0[d]	70.0[cd]	88.3[b]

 Means in the same column with similar letters are not significantly different (REGWQ, $P \geq 0.05$).

4.4. Lowest pod height

Significant variation in the lowest pod height was observed among accessions (Table 4). Accession VF-11 showed the lowest average pod height and VF-19 with the highest value (6.67 and 58.33 cm respectively). These results are in agreement with the results of Della (1988), who reported that faba bean genotypes varied significantly in different environmental conditions for the lowest pod height. Terzopoulos et *al*. (2003) found that the lowest pod height ranged from 2 to 24 cm among 55 faba bean genotypes. Suso et *al*. (1993) reported that late flowering faba bean genotypes gave a high position of the lowest pod-bearing nodes, while plants early in flowering gave low position of the lowest pod bearing node corresponding to the region grown in.

4.5. Number of branches on main stem

Significant variation was observed in number of branches on main stem (Table 4). Accessions VF-14, VF-13 and VF-15 gave the highest number of primary branches per plant (5.3, 6.3 and 6.3 branches per plant respectively), while accession VF-7 gave the lowest number of primary branches per plant (zero branch per plant). These results are in agreement with Silim and Saxena (1992), who found that genotypes were different on the number of branches. The differences in the present study may be due to the high temperatures prevailed at Tulkarm during the early growing stage.

Table (3): Lowest pod height (cm) and Number of branches on main stem of nineteen faba bean landraces grown during 2009/2010 growing season.

Accession	Lowest pod height (cm)	No. of branches on main stem
VF-1	25.00^{cde*}	0.67^{fgh*}
VF-2	16.67^{fgh}	3.67^{bc}
VF-3	13.33^{hi}	5.00^{bc}
VF-4	11.67^{hij}	0.33^{gh}
VF-5	28.33^{c}	3.00^{cde}
VF-6	10.00^{ij}	2.00^{def}
VF-7	11.67^{hij}	0.00^{h}
VF-8	15.00^{hig}	2.33^{cde}
VF-9	26.67^{cd}	0.67^{fgh}
VF-10	41.67^{b}	2.67^{cde}
VF-11	6.67^{j}	2.33^{cde}
VF-12	28.33^{c}	0.33^{gh}
VF-13	13.33^{hi}	6.33^{a}
VF-14	41.67^{b}	5.33^{a}
VF-15	13.33^{hi}	6.33^{a}
VF-16	20.00^{efg}	3.33^{cd}
VF-17	21.67^{def}	1.67^{efg}
VF-18	15.00^{hig}	2.00^{def}
VF-19	58.33^{a}	0.67^{fgh}

* **Means in the same column with similar letters are not significantly different (REGWQ, $P \geq 0.05$).**

4.6. Pod length

Significant variation in pod length was observed (Table 5). Accessions VF-4 and VF-10 showed the highest pod length (11.17 and 11.47, cm respectively), while VF-2 genotype gave the lowest pod length (4.47 cm). These results are in agreement with those reported by Suso *et al.* (1993) who found that genotypes varied significantly in pod length. Li-juan et al. (1993) reported, by analyzing agronomic and yield traits for 1500 germplasm from different provinces in China, that pod lengths were less than 10 cm and 24% of the germplasm exceeded 7.6 cm

4.7. Pod width

Significant variation in pod width was observed (Table 4). Accessions VF-10 and VF-4 showed the highest pod width (2.03 and 2.07 cm respectively), while VF-3 gave the lowest pod width (1 cm). Pod width is highly affected by seed size (Al-Rifaee *et al.* 2004). All the genotypes used in the present study originated from small seeds, so the variation on pod width may be due to pod flesh.

Table (4): Pod length (cm) and pod width (cm) of nineteen faba bean landraces grown during 2009/2010 growing season.

Accession	Pod length (cm)	Pod width (cm)
VF-1	4.97[hi*]	1.20[efgh*]
VF-2	4.47[i]	1.03[jk]
VF-3	5.17[hi]	1.00[kl]
VF-4	11.17[a]	2.07[a]
VF-5	9.43[b]	1.67[b]
VF-6	7.10[d]	1.27[def]
VF-7	5.10[hi]	1.07[ijk]
VF-8	5.07[hi]	1.17[fghi]
VF-9	8.63[c]	1.33[d]
VF-10	11.47[a]	2.03[a]
VF-11	6.27[ef]	1.23[defg]
VF-12	5.97[efg]	1.10[hijk]
VF-13	6.67[de]	1.10[hijk]
VF-14	5.40[gh]	1.20[efgh]
VF-15	5.17[hi]	1.03[jk]
VF-16	6.17[efg]	1.30[de]
VF-17	6.07[efg]	0.90[l]
VF-18	5.50[fgh]	1.13[ghij]
VF-19	5.50[fgh]	1.53[c]

Means in the same column with similar letters are not significantly different (REGWQ, P ≥ 0.05).

4.8. Number of pods per plant

Significant variation in pods number per plant was observed (Table 6). Accession VF-13 gave significantly the highest average pod number per plant (25.53 pods). Accessions VF-19, VF-7 and VF-17 gave the lowest average number of pods per plant (2.33, 2.67 and 3 pods respectively). These results agree with the results reported by Hassan and Ishaq (1972), who found that genotypes varied in their pod number per plant. Pilbeam *et al*. (1992) reported that pod number per plant in Ticol faba bean variety was greater than Minica variety during two growing seasons.

4.9. Total pod weight per plant

Significant variation in total pod weight per plant was observed (Table 6). Accession VF-4 significantly gave the highest pod weight per plant (91.67 gm). Accessions VF-19, VF-7, VF-2 and VF-17 significantly gave the lowest pod weight per plant (17.40, 20, 20.13 and 20.53 gm respectively).The variation on total pod weight per plant was due to the total number of pods per plant and not due to seed size since all the genotypes originated from small seeds. These results are in agreement with Della (1988), who found significant differences in pod weight

Table (5): Number of pods per plant and total pod weight per plant (gm) of nineteen faba bean landraces grown during 2009/2010 growing season.

Accession	No. of pods per plant	Total pods weight per plant(gm)
VF-1	6.66^{g*}	45.53^{e*}
VF-2	4.47^{h}	20.13^{k}
VF-3	10.53^{e}	30.53^{ij}
VF-4	16.27^{c}	91.67^{a}
VF-5	16.33^{c}	41.60^{fg}
VF-6	16.33^{c}	32.87^{hi}
VF-7	2.67^{i}	20.00^{k}
VF-8	11.00^{de}	38.87^{g}
VF-9	10.53^{e}	49.40^{d}
VF-10	16.60^{c}	63.80^{c}
VF-11	12.13^{d}	48.87^{d}
VF-12	10.53^{e}	31.67^{hi}
VF-13	25.53^{a}	43.87^{ef}
VF-14	10.93^{de}	33.73^{h}
VF-15	15.80^{c}	67.40^{b}
VF-16	19.93^{b}	46.93^{de}
VF-17	3.00^{i}	20.53^{k}
VF-18	9.07^{f}	27.80^{j}
VF-19	2.33^{i}	17.40

. Means in the same column with similar letters are not significantly different (REGWQ, P ≥ 0.05).

4.10. Number of seeds per pod

Significant variation in number of seeds per pod was observed (Table 7). Accession VF-10 significantly had the highest average seed number per pod (8.93 seeds) while VF-7 and VF-19 significantly showed the lowest average seed number per pod (4 and 4.27 seeds respectively). Suso *et al*. (1996) reported significant differences in seed number per pod among twelve faba bean genotypes. Li-juan et al. (1993) reported that number of seeds per pod ranged from 1.7 to 2.9 in a collection of 1500 accessions from different provinces in China. Abdelmola and Abuanja (2007) reported that number of seeds per pod was more influenced by genetic than environmental factors.

4.11. One hundred-seed weight

Significant variation in 100-seed weight was observed (Table 7). Accession VF-4 gave significantly the highest 100-seed weight (239 gm) while VF-17 and VF-2 gave the lowest 100-seed weight (35.67 and 41.67 gm respectively). These results were in agreement with Della (1988) who found that seeds weight varied considerably among the genotypes.

Table (6): Number of seeds per pod and 100 seed weight (gm) of nineteen faba bean landraces grown during 2009/2010 growing season.

Accession	Number of seeds per pod	100 seed weight (gm)
VF-1	2.23^{hi*}	92.00^{efg*}
VF-2	5.33^{fg}	41.67^{k}
VF-3	6.07^{de}	82.67^{fgh}
VF-4	7.27^{c}	239.00^{a}
VF-5	7.20^{c}	165.33^{b}
VF-6	6.93^{c}	105.67^{e}
VF-7	4.00^{ij}	60.00^{j}
VF-8	6.27^{d}	95.67^{ef}
VF-9	8.00^{b}	143.00^{c}
VF-10	8.93^{a}	175.67^{b}
VF-11	5.40^{fg}	121.00^{d}
VF-12	6.20^{d}	79.33^{ghi}
VF-13	3.60^{j}	123.33^{d}
VF-14	5.67^{def}	77.67^{ghi}
VF-15	5.53^{efg}	64.67^{ij}
VF-16	5.33^{fg}	127.00^{d}
VF-17	5.07^{fg}	35.67^{k}
VF-18	4.93^{gh}	104.00^{e}
VF-19	4.27^{i}	72.001^{hij}

. Means in the same column with similar letters are not significantly different (REGWQ, P ≥ 0.05).

4.12. Correlation between the studied agronomic traits

Pearson correlation coefficients between the studied characters were computed and presented in Table (8). The highest positive significant correlations were found between 100-seed weight and pod length (0.879), followed by 100-seed weight and pod weight (0.851), and between pod width and pod length (0.874). Pod length with number of seeds per pod and total pod weight per plant with 100-seed weight were also highly correlated (0.756 and 0.779, respectively). These results reflected the importance of pod width, pod length, 100-seed weight and total number of pods per plant in the determination of pod weight in faba bean. Sprent *et al.* (1977) reported that the major factor affecting yield is the number of pods per plant which reach maturity.

Table (7): Correlation coefficients for six agronomic characters of nineteen faba bean landraces grown during 2009/2010.

	NPP[1]	**NSP[1]**	**PL[1]**	**PW[1]**	**SW[1]**
NSP	0.283^{ns}				
PL	0.465^{*}	0.756^{***}			
PW	0.321^{ns}	0.622^{**}	0.874^{***}		
SW	0.608^{**}	0.604^{**}	0.879^{***}	0.851^{***}	
TPWP	0.609^{**}	0.500^{**}	0.666^{***}	0.628^{**}	0.779^{***}

[1] NPP: Number of pods per plant; NSP: Number of seeds per pod; PL: Pod length; PW: Pod width; SW: 100 seed weight; TPWP: Total pod weight per plant.

*** significant at P < 0.05**

**** significant at P < 0,01**

***** significant at P < 0.001**

^{ns} not significant.

4.13. Genetic similarities among genotypes

Cluster analysis was used to further investigate the inter-relationships of the accessions using six agronomic traits (pod length, pod width, number of pods per plant, number of seeds per pod, 100-seed weight and total pod weight per plant). The accessions were grouped into two main clusters (A and B). Each of the main clusters was divided into two sub clusters (Figure 1). More than half of the accessions (53.6%) were grouped in the same cluster (cluster A), and the rest of the accessions were grouped in the other cluster (B). It is clear that accessions VF-4 and VF-10, VF-5 and VF-9 are related to each other and are far from the rest of the collection.

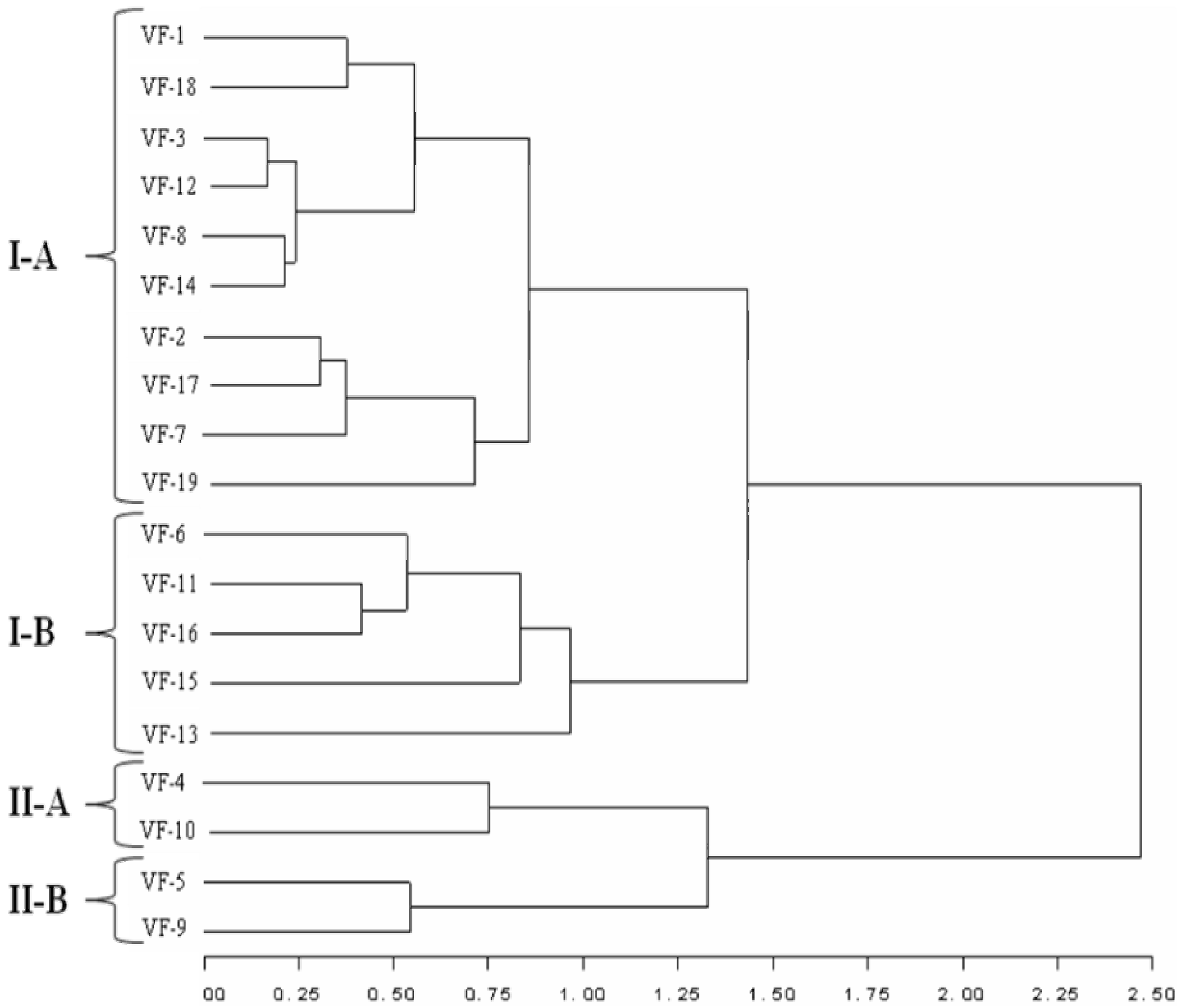

Figure (1): Cluster analysis showing the relationships among faba bean accessions determined on the basis of six yield traits.

4.14. Rust severity

Significant variation in disease susceptibility was observed in the collection (Table 9). High susceptibility to rust was very common, but good levels of resistance were also found. Accession VF-13 showed the lowest DS (18%) while VF-6 showed the heights DS (69%). The susceptible control (Brocal) showed DS of 59.7%. Accession VF-9 showed significantly higher DS than the susceptible control (69%). Eight lines showed moderate infection levels, with DS values between 20 and 40%. However, most of the accessions (53%) displayed DS values higher than 40%. Rashid and Bernier (1986) evaluated 252 faba bean accessions from diverse origins for their ability to retard the development of the leaf rust, they found significant differences among accessions for the final rust severity (DS).

Table (8): Disease severity (DS%) of nineteen faba bean landraces grown during 2009/2010 growing season against leaf rust.

Accession	Disease severity (DS %)
VF-1	41.67^{f*}
VF-2	29.00^{gh}
VF-3	60.67^{bc}
VF-4	32.33^{g}
VF-5	57.33^{cd}
VF-6	69.00^{a}
VF-7	23.33^{hi}
VF-8	43.33^{ef}
VF-9	56.33^{cd}
VF-10	27.67^{gh}
VF-11	31.67^{g}
VF-12	50.67^{de}
VF-13	18.00^{i}
VF-14	45.33^{ef}
VF-15	39.67^{f}
VF-16	67.00^{ab}
VF-17	41.00^{f}
VF-18	22.67^{hi}
VF-19	22.33^{hi}
Brocal	59.67^{bc}

. Means in the same column with similar letters are not significantly different (REGWQ, P ≥ 0.05).

General discussion

This study was conducted to investigate the morphological, agronomical variation and the level of resistance to leaf rust *Uromyces visiae - faba* among nineteen Palestinian faba bean (*Vicia faba* L.) landraces and analyze their traits including: days to flowering, days to fruit setting, plant height, number of branches on main stem, lowest pod height, pod length, pod width, number of pods per plant, number of seeds per pod, 100-seed weight and total pod weight per plant.

All the studied characters were highly correlated. The highest positive significant correlations were found between 100-seed weight and pod length (0.879), followed by 100-seed weight and pod weight (0.851), and between pod width and pod length (0.874). Pod length with number of seeds per pod and total pod weight per plant with 100-seed weight were also highly correlated (0.756 and 0.779, respectively). These results reflected the importance of pod width, pod length, 100-seed weight and total number of pods per plant in the determination of pod weight in faba bean. Sprent *et al*. (1977) reported that the major factor affecting yield is the number of pods per plant which reach maturity.

The majority of the genotypes (84%) were considered to be early flowering and early fruit setting genotypes (around 60 and 70 days after planting for flowering time and fruit setting respectively). These results were in agreement with other studies (Suso *et al.* 1993; Della, 1988; Nanda et al, 1988). Flowering and fruit setting is affected by genetic makeup and environmental factors. The environmental factors affecting fruit setting are mainly related to change in temperature and rainfall (Nanda et al, 1988).

Significant variation in plant height and lowest pod height was observed. Late flowering faba bean genotypes gave a high position of the lowest pod-bearing nodes, while plants early in flowering gave low position of the lowest pod bearing node. The variation on total pod weight per plant was due to the total number of pods per plant and not due to seed size since all the genotypes originated from small seeds.

Relatedness among accessions was conducted based on six morphological and agronomic traits (pod length, pod width, number of pods per plant, number of seeds per pod, 100-seed weight and total pod weight per plant). The accessions were grouped into two main clusters (A and B). Each of the main clusters was divided into two sub clusters (Figure 1). More than half of the accessions (53.6%) were grouped in the same cluster (cluster A), and the rest of the accessions were grouped in the other cluster (B). It is clear that accessions VF-4 and VF-10, VF-5 and VF-9 are related to each other and are far from the rest of the collection.

A significant variation in leaf rust disease severity was observed. Several accessions showed low disease severity (significantly lower than the susceptible genotype). These accessions could be used as a valuable source for leaf rust resistance.

Conclusions

From the results of the present study, the following conclusions can be drawn:

1. Clear phonotypic variation was observed between genotypes and it was enough to distinguish between them.
2. Many of these genotypes are promising for pod yield.
3. Variation among genotypes in pod length presented positive correlation with pod width, 100- seed weight, number of seeds per pod, and total pod weight per plant
4. The collection could be considered as a valuable source for partial resistance to leaf rust that can be utilized in selection programs.
5. Further studies are needed to investigate the variation between and within these genotypes at molecular level.

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جامعة النجاح الوطنية
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قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في الإنتاج النباتي بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2012م

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الملخص

أجريت هذه التجربة لدراسة الاختلافات الشكلية الخارجية والانتاجية وكـذلك اختبـار مستوى مقاومة صدأ الاوراق لتسعة عشر صنفاً من اصناف الفول الفلسطيني(*Vicia faba* L.) وذلك خلال الموسم الزراعي 2009–2010 حيث زرعت الأصناف في ثلاثة مكـررات. تـم دراسة أحدى عشرة صفة وهي (عدد الايام من الزراعة حتى الازهار، عدد الايام من الزراعة حتى بداية عقد الازهار، أرتفاع النبات، عدد التفرعات على الساق الرئيسية، أرتفاع أول قـرن عن الارض، طول القرن، عرض القرن، عدد القرون على النبات، عدد البـذور فـي القـرن الواحد، وزن المئة بذرة ووزن جميع القرون على النبات). خلال موسم النمو تم كـذلك تقيـيم نسبة اصابة النباتات بمرضي البياض الدقيقي وصدأ الأوراق ثلاث مـرات بواقـع مـرة كـل اسبوعين.

وجد اختلاف معنوى بين الاصناف ولجميع الصفات التي درست في التجربة. أظهرت النتائج أن الاصناف التسعة عشر يمكن تقسيمها الى أربعة مجموعات اعتمادا على سـتة مـن الصفات ذات العلاقة بالانتاج (طول القرن، عرض القرن، عدد القرون على النبات، عدد البذور في القرن الواحد، وزن المئة بذرة ووزن جميع القرون على النبات). يمكن اعتبار عدد من هذه الاصناف كمصدر واعد لأي برنامج تحسين وراثي لزيادة الانتاجية من الفول الاخضر. كذلك وجد اختلاف معنوي في شدة الاصابة بمرض صدأ الاوراق بين اصناف المجموعة حيث كـان الصنف VF-13 الادنى من حيث شدة الاصابة (18 %) بينما كان الصنف VF-18 الاكثـر شدة اصابة بالمرض في حين بلغت شدة الاصابة على الصنف الشـاهد (الحسـاس للمـرض) 59.7% . يمكن اعتبار هذه الاصناف مصدراً مهماً لمقاومة مرض صدأ الاوراق.

هناك حاجة لمقارنة الانتاجية والصفات المورفولوجية لهـذه الاصـناف المحليـة مـع الاصناف العالمية ودراسة الجينات الموجودة فيها لمقاومة مرض صدأ الاوراق كـذلك هنـاك حاجة لدراسة التنوع والاختلافات بين اصناف المجموعة على مستوى الوراثة الجزيئية.