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EVALUATION OF SOME NEW AND OLD FABA BEAN CULTIVARS (*Vicia faba* L.) FOR EARLINESS, YIELD, YIELD ATTRIBUTES AND QUALITY CHARACTERS

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ABSTRACT: The present study was carried out at Genetic Resources Department, Bahteem, Egypt, during 2014/2015 and 2015 /2016 seasons, to evaluate five new faba bean cultivars (Misr 3, Sakha 4, Wadi1, Nubaria 1and Nubaria 3) as well as five old ones (Giza 2, Giza 3, Giza 40, Giza 429 and Giza 843) for earliness, yield, yield attributes and quality characteristics through mean performance, correlation coefficient, path coefficient and molecular markers of RAPD-PCR analysis. The experimental design was a randomized complete block design in four replications. Results indicated highly significant differences among the ten faba bean cultivars for earliness characters (days to first flower, days to 50% flowering and days to fruiting), yield and its attributes (plant height, number of branches/plant, number of fruiting nodes/plant, pod length, number of pods/node, number of pods/plant, number of seeds/pod, number of seeds/plant, 100- seed weight and seed yield/ plant) as well as quality characters (protein and carbohydrate contents) in the two seasons. The new cultivars were earlier than the old once during the two seasons. The new faba bean cultivar Nubaria 1 gave the highest productivity however Sakha 4 recorded the highest value of protein and carbohydrate contents in the two seasons. Seed yield/plant appeared positive and significant correlation with each of pod length, number of pods/plant, number of seeds/ pod, number of seeds/plant and 100-seed weight during the two seasons. Whereas, negative and significant correlation was detected between seed yield/plant and each of plant height and number of fruiting nodes/plant in both seasons. Path coefficient analysis showed that number of seeds/plant followed by 100-seed weight had the highest direct effect on seed yield/plant during the two seasons. Five primers were used for RAPD analysis to determine genetic variability among the ten cultivars of faba bean, and produced 32 bands, 21 of them were polymorphic with 65.6% polymorphism. Four positive bands markers were recorded in faba bean cultivar Giza 3 in two primes (C06 and C19), and two positive band markers in faba bean cultivar Giza 40 in the two primers (B09 and C19). While, one negative band marker in Giza 429 and one positive marker in Giza 843 were generated by primer (C19).

Key words: Faba bean, mean performance, correlation coefficient, path coefficient, molecular markers RAPD-PCR.

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the main pulse crops grown for seed in Egypt. It is a diploid (2n=12), self pollinated annual plant. It is widely considered as a good source of protein, starch, cellulose and minerals for humans in developing countries and animals in industrialized countries (**Haciseferogullari *et al.,* 2003**). In addition, faba bean is one of the most efficient fixers of the atmospheric nitrogen and hence, can contribute to sustain or enhance

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total soil nitrogen fertility through biological N2- fixation (**Lindemann and Glover, 2003**).

Faba bean (*Vicia faba* L.) is the major legume crop among pulses in Egypt, the cultivated area devoted to faba bean represented 34314 ha, and the corresponding annual national production increased up to 119104 ton with an average seed yield of 9.0 ardab/fad., (**FAO, 2018**).

The possibility of increasing the cultivated area is limited. Hence increasing productivity through developing new high yielding varieties prerequisite. Various attributes such as duration of flowering, number of pods, number of seeds and seed size could be used as selection criteria for the improvement of yield (**El-Hady *et al.*, 1998**).

A successful selection depends upon the information on the genetic variability and correlation of morpho-agronomic characters with seed yield. **Sharifi (2014) and Kumar *et al.* (2017)** recorded significant positive correlation of seed yield with each of pod length, number of seeds/pod and 100- seed weight. Moreover, path analysis is regarded helpful for plant breeders as it partitions genotypic association analysis into direct and indirect components for identifying the most important characters could be used as selection criteria in faba bean breeding programs.

The use of Random Amplified Polymorphic DNA (RAPD) technique offers a simple, fast, efficient and inexpensive method (**Baheer-Salimia *et al.*, 2012**). Furthermore, it does not need knowledge of marker sequence and can produce abundant polymorphic DNA fragments (**Kocsis *et al.*, 2005; Achtak *et al.*, 2009**). Therefore, RAPD is a powerful and accurate tool for analyzing the genetic relatedness and diversity in many species. The DNA markers like RAPD, ISSR. AFLP and SSR were extensively used in assessing genetic diversity in faba bean (**Wang *et al.*, 2012**).The analysis of faba been cultivars leads to collection of information about the genetic diversity at the genome level. The RAPD profile analysis can be useful to the selection of cultivar containing good information and properties in faba bean improvement program (**Tahir, 2015**).

The objectives of the present study were to evaluate five new faba bean cultivars in comparison to five old faba bean cultivars for earliness, yield, its attributes and quality characters through mean performance. Also, identify the most important characters related to seed yield through correlation and path coefficient analysis as well as finding molecular marker be used PCR-based RAPD (Random Amplified Polymorphic DNA) to determine genetic variability among faba bean cultivars.

MATERIALS AND METHODS

The present investigation was conducted during the two winter growing seasons: 2014/2015 and 2015/2016 at Genetic Resources Department, Bahteem, Egypt. Five new faba bean cultivars (Misr 3, Sakha 4, Wadi 1, Nubaria 1 and Nubaria 3) as well as five old ones (Giza 2, Giza 3, Giza 40, Giza 429 and Giza 843) have been employed as the materials in this investigation. The origin and pedigree of the studied faba bean cultivars are presented in Table 1.

In 2014/2015 and 2015/2016 seasons, the experimental trials were conducted included ten cultivars using a randomized complete block design with 4 replications. Each plot consisted of 3 rows with 3 m long and distance between rows was 60 cm with single seeded hills, 20 cm a part. Cultural procedures were applied as recommended.

The studied traits were recorded on ten guarded plants for each cultivar and the following characters were studied (days to first flower (day), days to 50% flowering (day), days to fruiting (day), plant height (cm), number of branches/plant, number of fruiting nodes/plant, pod length (cm), number of pods/node, number of pods/plant, number of seeds /pod, number of seeds/plant, 100-seed weight (g), seed yield/ plant (g.), protein content (%) and carbohydrate content %).

Statistical analysis using ANOVA and simple correlation of the collected data were subjected to Duncan's multiple range test **(Duncan, 1955)** at the 5% level and the mean values obtained were compared by the Least Significant Range test (LSR_D).

Table 1. Origin and pedigree of the ten Egyptian faba bean cultivars used in this study

Cultivar	Origin	Pedigree
Misr 3	Egypt	667x (Cairo 241x Giza 461)
Sakha 4	Egypt	Sakha 1 x Giza 3
Wadi 1	Egypt	Rena Blanka x Triple white
Nubaria 1	Egypt	Selection in Rena Blanka
Nubaria 3	Egypt	Selection in Ahnasiaz
Giza 2	Egypt	Individual plant selection from local variety
Giza 3	Egypt	Giza 1 x New Accession 29
Giza 40	Egypt	Individual plant selection from Repaya 40
Giza 429	Egypt	Individual plant selection from Giza 402
Giza 843	Egypt	561/2076/85 Sakha x461/845/83

The contribution of yield components in seed yield in these group of genotypes are estimated using path coefficient analysis according to **Dewy and Lu (1959)**.

For genomic DNA isolation, seeds of each faba bean cultivar were germinated and grown to the four-leaf stage. The seedlings were used for DNA extraction by DNeasy plant minikit (Quigen Inc., Cat.no.69104, and USA). The DNA concentration of the final samples was measured by ultraviolet (UV) spectrophotometer at 260 nm. The integrity of the DNA was checked by electrophoresis in a 1.2% agarose gel in TAE buffer.

Five RAPD primers were used to evaluate the ten faba been cultivars and are shown in Table 2.

DNA amplification was carried out in PCR (Polymerase Chain Reaction) tubes containing 25 µl reaction mixture, having 1 µl template DNA, 1 µl RAPD primer, 15 µl of dd H_2O and 7 µl PCR mix. Amplification was carried out in a PTC-200 thermal cycler (MJ Research, Watertown, USA) programmed as follows: Denaturation, 94°C for 2 minutes, then for 40 cycles. Each cycle consisted of 1 minute at 94°C, 1 minute at 37°C, 2 minutes and 30 second at 72°C, followed by a final extension time of 12 minutes at 72°C and 4°C (infinitive).

Gel electrophoresis was applied according to **Sambrook *et al.* (1989)**. The run was performed for one hour at 80 volt in pharmacia submarine (20 × 20 cm). Bands were detected on UV – trans illuminator and photographed by Gel documentation 2000, Bio- Rad. Fragment sizes of RAPD were estimated from the gel by comparison with the 100 +1.5 kb ladder marker. The bands were recorded as either present or absent into a database of "+"and "-"'.

The data of PCR systems were analyzed to detect the similarity matrices using Gel/works 1D- advanced software UVP-England program. The relationships among different ten cultivars as revealed by dendrograms resolved using SPSS Windows (Version 16) program, were estimated and possible molecular markers for different qualitative and quantitative characteristics were detected for subsequent linkage and genome analysis.

RESULTS AND DISCUSSION

Mean Performance

Earliness characters

Mean performance of earliness characters *i.e.* days to first flower, days to 50% flowering and days to fruiting for the ten faba bean cultivars during the two seasons are presented in Table 3. It is interest to note that, highly significant differences were recorded among the ten faba bean cultivars (old and new cultivars) for earliness characters during the first and second seasons.

Table 2. Names and sequences of the used RAPD primers that were screened

Primer name	Nucleotide sequences
B09	5'-TGGGGGACTC-3'
C06	5'- GAACGGACTC-3'
C08	5'- TGGACCGGTG-3'
C19	5'- GTTGCCAGCC-3'
D13	5'- GGGGTGACGA-3'

Table 3. Mean performance of the ten faba bean cultivars for earliness, yield, its attributes and quality characters during the two seasons of 2014 / 2015 and 2015 / 2016

Genotype	Days to first flower (day)		Days to 50% flowering (day)		Days to fruiting (day)		Plant height (cm)		Number of branches/ plant	
	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016
Misr 3	47d	45e	51cd	50d	63cd	61d	108.8c	108.92c	4.07ab	4.07ab
Sakha 4	44e	46de	50d	50d	60e	60d	111.32c	116.32b	3.25cd	3.50cb
Wadi 1	35g	36g	42f	40f	55f	56e	108.75c	102.50de	3.50bc	3.75b
Nubaria 1	49cd	48cd	53c	53c	64c	64c	88.75e	91.37f	2.75cd	2.85cd
Nubaria 3	40f	40f	45e	45e	62d	61d	112.50c	110.00c	2.75cd	2.85cd
Giza 2	51bc	50bc	56b	56b	69ab	68b	126.27a	127.50a	3.50bc	3.75b
Giza 3	55a	55a	59a	61a	70a	70a	108.75c	106.00cd	3.25cd	3.50bc
Giza 40	51bc	50bc	56b	56b	70a	69ab	95.00d	98.75e	3.25cd	3.50bc
Giza 429	50c	51b	56b	55bc	69ab	70a	118.85b	117.60b	4.65a	4.82a
Giza 843	53ab	55a	61a	62a	68b	70a	95.00d	98.75e	2.50d	2.50d
F. test	**	**	**	**	**	**	**	**	**	**

Genotype	Number of fruiting nodes/ plant		Pod length (cm)		Number of pods / node		Number of pods / plant		Number of seeds pod	
	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016
Misr 3	10.75de	10.25c	9.60bc	9.25bc	1.50bc	2.00bc	17.50bc	17.25bc	3.50cde	3.50cde
Sakha 4	12.25cd	14.00a	9.60bc	9.25bc	2.00ab	2.65a	14.62cde	14.40cde	4.07bc	4.07bc
Wadi 1	9.25ef	9.25c	9.00cd	9.90b	1.07c	1.15d	10.50f	12.25e	3.75cd	3.75cd
Nubaria 1	9.00f	9.25c	10.17ab	11.15a	1.50bc	1.50cd	17.25bc	17.50bc	5.17a	4.60ab
Nubaria 3	16.00a	14.75a	9.32bc	8.25de	2.00ab	1.50cd	13.75def	13.75de	3.00e	3.00e
Giza 2	17.50a	14.50a	8.75cd	8.82cd	2.60a	2.32ab	21.65a	20.62a	3.50cde	3.25de
Giza 3	12.50bc	14.25a	9.60bc	9.50bc	1.82b	2.00bc	12.32ef	12.25e	3.25de	3.25de
Giza 40	14.00b	14.00a	10.75a	8.82cd	1.50bc	1.50cd	18.85ab	18.00ab	4.50b	4.87a
Giza 429	17.50a	14.50a	8.25d	8.25de	1.50bc	1.50cd	16.50bcd	15.75bcd	3.00e	3.00e
Giza 843	9.25ef	12.00b	9.32bc	7.75e	1.50bc	2.00bc	16.00bcd	15.50bcd	3.25de	3.50cde
F. test	**	**	**	**	**	**	**	**	**	**

Genotype	Number of seeds / plant		100- seed weight (g.)		Seed yield / plant (g.)		Protein content (%)		Carbohydrate content (%)	
	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016	2014 / 2015	2015 / 2016
Misr 3	44.75c	41.25f	96.70a	97.45a	43.20b	41.87c	24.82b	24.19d	63.45b	63.22b
Sakha 4	42.95c	41.50f	92.65a	94.02ab	38.02cd	39.02d	27.55a	28.26a	65.51a	65.15a
Wadi 1	34.75d	43.12f	86.22b	88.77c	29.95e	38.20d	23.88e	23.57e	54.45g	53.03f
Nubaria 1	71.95a	61.75c	94.72a	91.70bc	70.42a	57.10a	24.35cd	24.65c	58.32e	57.15e
Nubaria 3	42.50c	46.50e	58.60f	62.55f	27.30e	28.05e	24.51bcd	24.24d	56.98f	56.92e
Giza 2	59.82b	70.25b	60.00f	60.22f	35.85d	42.30c	22.81f	22.62f	52.77h	52.77f
Giza 3	37.30d	41.00f	75.65d	74.37de	28.02e	30.57e	24.71bc	25.175b	60.88c	60.55c
Giza 40	57.25b	74.87a	70.42e	70.00e	40.30bc	52.32b	24.22de	25.08b	59.75d	59.34d
Giza 429	45.00c	52.00d	85.30b	70.40e	38.65cd	36.42d	22.13g	22.25g	51.15j	51.20g
Giza 843	45.00c	47.25e	80.75c	79.10d	36.57d	37.52d	22.34g	22.447fg	52.10i	51.33g
F. test	**	**	**	**	**	**	**	**	**	**

**: Significant at 0.01 level of probability.

Generally, mean performance of the ten faba bean cultivars for earliness characters indicated that the new faba bean cultivars were earlier than the old faba bean ones during the two seasons. The two new cultivars, Wadi 1 and Nubaria 3 were the earliest ones, while, the two old cultivars, Giza 843 and Giza 3 were the latest ones in both seasons. **Verma *et al.* (2015), Jalal *et al.* (2016) and Hamza and Khalifa (2017)** recorded highly significant differences among faba bean cultivars for days to 50% flowering.

Yield and its attributes

Mean performance of yield and its attributes for the ten faba bean cultivars during the two seasons are given in Table 3. Highly significant ($P < 0.01$) differences were recorded among the ten faba bean cultivars for yield and its attributes during both seasons, indicating the presence of adequate genetic variability in the used genetic material. In this respect, highly significant differences among faba bean cultivars were recorded for plant height, number of branches / plant, pod length, number of pods/plant, number of seeds/pod, number of seeds/plant, 100-seed weight and seed yield/plant by **Ahmed *et al.* (2013), Sharifi (2014), Mitiku and Wolde (2015), Sharifi (2015), Tamene *et al*. (2015), Verma *et al.* (2015), Degife and Kiya (2016), Hamza (2017), Hamza and Khalifa (2017) and Hussein *et al.* (2017)**.

For plant height it is clear from Table 3, that the faba bean cultivars Nubari 1 (88.75, 91.37 cm), Giza 40 (95.00, 98.75 cm) and Giza 843 (95.00, 98.75 cm) were the shortest ones among the evaluated faba bean cultivars during the two seasons, respectively. Therefore, these cultivars are considered as dwarf cultivars. On the other hand, the faba bean cultivars Giza 2 (126.27, 127.50 cm) and Giza 429 (118.85, 117.60 cm) were the tallest ones during the first and the second seasons, respectively. These results are in agreement with those reported by **Bakry *et al*. (2011)**, who found that faba bean cultivars Nubari 1 and Giza 843 were had the shortest plants.

Mean performance of number of branches/ plant (Table 3) indicated that faba bean cultivars Giza 429 (4.65 and 4.82) and Misr 3 (4.07 and 4.07) exhibited the highest number of branches/ plant among the studied cultivars during the two seasons, respectively. Whereas, the cultivar Giza 843 (2.50) was the fewest and produced 2.50 branches during the first and the second seasons.

Concerning number of fruiting nodes/plant during the two seasons (Table 3). The results indicated that faba bean cultivars Giza 2 and Giza 429 (17.50, 14.50) and Nubaria 3 (16.00, 14.75) produced the greatest number of fruiting nodes/plant during the two seasons, respectively, revealing that these cultivars are promising for this trait. While, the two faba bean cultivars Nubria 1 (9.00, 9.25) and Wadi 1 (9.25, 9.25) produced the lowest number of fruiting nodes/plant during both seasons, respectively.

Results given in Table 3 indicate that the two cultivars Giza 40 (10.75 cm) and Nubaria 1 (10.17 cm) produced the longest pods in first season, and Nubaria 1 (11.5 cm) in the second one. Hereby, both cultivars are the promising ones and could be involved in faba bean breeding programs for improving pod length. Otherwise, the old faba bean cultivars Giza 429 (8.25, 8.25 cm) and Giza 2 (8.75, 8.82 cm) produced the shortest pods during the two seasons, respectively.

The maximum number of pods /node were recorded by Giza 2 (2.60, 2.32) followed by Sakha 4 (2.00, 2.65) in first and second seasons, respectively. On the other hand, the fewest number of pods/ node was recorded by Wadi 1 (1.07, 1.15) during the two seasons, respectively (Table 3).

In continuous as shown in Table 3, number of pods/plant showed that, faba bean cultivars Giza 2 (21.65, 20.62), Giza 40 (18.85, 18.00), Misr 3 (17.50, 17.25) as well as Nubaria 1 (17.25, 17.50) produced the greatest number of pods/plant during the two seasons, respectively. Whereas, cultivars Wadi 1 (10.50, 12.25) and Giza 3 (12.32, 12.25) produced the lowest number of pods/plant during the first and the second seasons, respectively.

As given in Table 3, the faba bean cultivars Nubaria 1 (5.17, 4.60), Giza 40 (4.50, 4.82) as well as Sakha 4 (4.07, 4.07) produced the greatest number of seeds/pod during both seasons, respectively. Whereas, faba bean cultivars Nubaria 3 (3.0, 3.0) and Giza 429 (3.0,

3.0) produced the lowest number of seeds/ pod during the two seasons, respectively. **Bakry *et al.* (2011)** found that Nubaria 1 variety had the highest number of seeds/pod.

The maximum number of seeds/plant was recorded from Nubaria 1 (71.95) in the first season, Giza 40 (74.87) and Giza 2 (70.25) in the second one. While, the lowest number was registered from Wadi 1 (34.75) in first season as well as Giza 3 (41.00) in second season (Table 3). This result revealed that faba bean cultivars Nubaria 1, Giza 40 and Giza 2 cultivars has large seed size. Seed size is one of the important parameters for the choice of the cultivars by the growers.

Mean performance of 100-seed weight (Table 3) indicated that the new faba bean cultivars Misr 3 (96.70, 97.45 g), Sakha 4 (92.65, 94.02 g) as well as Nubaria 1 (94.72, 91.70 g) exhibited the heaviest 100-seed weight during both seasons, respectively. On the other hand, the cultivars Nubaria 3 (58.60, 62.55 g) and Giza 2 (60.00, 60.22 g) exhibited the lightest 100- seed weight during the two seasons, respectively.

Mean performance of seed yield/plant indicated that faba bean cultivars Nubaria 1 (70.42, 57.10 g), Misr 3 (43.20, 41.87g) as well as Giza 40 (40.30, 52.32g) gave the highest productivity during the first and the second seasons, respectively. Whereas, the cultivar Nubaria 3 (27.30, 28.05 g) as well as Giza 3 (28.02, 30.57g) gave the lowest productivity during the two seasons, respectively. These results are in agreement with the finding of **Bakry *et al.* (2011)** who reported that Nubaria 1 variety was the highest in seed yield / plant compared to the other varieties.

Quality characteristics

Results given in Table 3 clearly indicate highly significant differences among faba bean cultivars for both protein and carbohydrate contents, suggesting that, faba bean cultivars were genetically different in genes controlling quality characters. Similar trend of results were obtained by **Awadalla *et al.* (2013) and Verma *et al.* (2015)**. Results revealed that the highest value of protein and carbohydrate contents were registered by Sakha 4 (27.55% and 28.26% protein) and (65.5% and 65.15% carbohydrate) during first and second seasons, respectively, followed by Misr 3 (24.82% protein) in the first season, Giza 40 (25.08% protein) in the second season, respectively, Misr 3 (63.45% and 63.22% Carbohydrate) during the two seasons, respectively. While, the lowest values of protein and carbohydrate contents were registered by Giza 429 (22.13% and 22.25% protein) as well as (51.15% and 51.20% carbohydrate) during the two seasons, respectively. **Awadalla *et al.* (2013)** found that Sakha 4 variety had the highest carbohydrate content rather than the other varieties.

Correlation Coefficient Analysis

Correlation coefficient was used to determine the most effective characters which played an important role in seed yield/plant. As given in Table 4, seed yield/plant was positively and significantly correlated with each of pod length, number of pods/plant, number of seeds/pod, number of seeds/plant as well as 100-seed weight during the two seasons. In this respect, positive and significant association was recorded between seed yield with each of number of pods/plant, number of seeds/pod and 100- seed weight by many others (**Ulukran *et al.*, 2003; Ahmed *et al.*, 2013; Sharifi, 2014; Verma *et al.*, 2015; Jalal *et al.*, 2016; Hamza, 2017; Hamza and Khalifa, 2017; Kumar *et al.*, 2017; Tekalign *et al.*, 2017**). Also, **Mitiku and Wolde (2015)** showed that, number of seeds/pod with seed yield/plant was positively and significantly correlated. Otherwise, correlation between seed yield/plant and each of plant height as well as number of fruiting nodes/plant were negative and significant during the two seasons, suggest that selection in negative direction for these characters will also increase faba bean yield. Insignificant correlation was recorded between seed yield/plant with days to first flower, days to 50% flowering as well as days to fruiting during the two seasons. These results are supported by the finding of **Tadesse *et al.* (2011), Ahmed *et al.* (2013) and Tekalign *et al.* (2017)** who observed insignificant association between days to flowering and seed yield. **Also Jalal *et al.* (2016)** showed that, days to 50% flowering with seed yield was insignificantly correlated during the two seasons.

Table 4. Correlation coefficient analysis among earliness, yield, its attributes and quality characters during the two seasons of 2014 / 2015 and 2015 / 2016

Character	Dff	D 50%F	Df	Ph	Nb	Nfnp	Pol	Npon	Npop	Nsepo	Nsep	100- Swt	PC (%)	CC (%)	*Sy*
2014 / 2015															
Dff		0.921**	0.883**	-0.153	0.051	0.154	0.128	0.207	0.329*	0.006	0.332*	-0.094	-0.284	-0.060	0.191
D 50%F			0.861**	-0.171	-0.017	0.098	0.035	0.114	0.420**	-0.050	0.278	-0.0719	-0.354*	-0.171	0.122
Df				-0.007	0.098	0.431**	0.074	0.278	0.450**	-0.135	0.332*	-0.366*	-0.438**	-0.234	0.029
Ph					0.441**	0.649**	-0.577**	0.416**	0.087	-0.586**	-0.346*	-0.333*	-0.081	-0.189	-0.525**
Nb						0.301*	-0.315*	0.015	0.101	-0.214	-0.19	0.182	-0.124	-0.058	-0.084
Nfnp							-0.323*	0.442**	0.255	-0.351*	0.024	-0.611**	-0.232	-0.268	-0.365*
Pol								-0.074	0.083	0.572**	0.337*	0.086	0.358*	0.482**	0.335*
Npon									0.225	-0.114	0.168	-0.392*	0.109	0.022	-0.106
Npop										0.174	0.643**	-0.130	-0.2241	-0.103	0.372*
Nspo											0.620**	0.314*	0.287	0.324*	0.666**
Nsp												-0.018	-0.134	-0.064	0.798**
100- Swt													0.304*	0.364*	0.514**
PC (%)														0.903**	0.041
CC (%)															0.131
2015 / 2016															
Dff		0.947**	0.890**	-0.021	-0.033	0.353*	-0.227	0.326*	0.225	-0.019	0.245	-0.235	-0.133	-0.081	0.097
D 50%F			0.888**	-0.023	-0.089	0.348*	-0.269	0.311*	0.273	-0.010	0.271	-0.273	-0.160	-0.098	0.091
Df				0.062	0.049	0.471**	-0.353*	0.117	0.257	-0.095	0.429**	-0.520**	-0.359*	-0.310*	0.058
Ph					0.399*	0.540**	-0.356*	0.393*	0.141	-0.476**	-0.025	-0.340*	-0.079	-0.043	-0.398*
Nb						0.155	-0.021	0.082	-0.050	-0.186	-0.024	-0.045	-0.154	-0.025	-0.104
Nfnp							-0.522**	0.287	0.046	-0.291	0.169	-0.683**	0.095	0.025	-0.429**
Pol								-0.095	0.040	0.478**	0.057	0.451**	0.297	0.280	0.459**
Npon									0.137	-0.091	-0.129	0.051	0.314*	0.333*	-0.100
Npop										0.213	0.662**	-0.176	-0.196	-0.093	0.545**
Nspo											0.404**	0.335*	0.386*	0.294	0.716**
Nsp												-0.461**	-0.210	-0.263	0.663**
100- Swt													0.427**	0.475**	0.306*
PC (%)														0.865**	0.103
CC (%)															0.086

*, **=significant at 0.05 and 0.01 levels of probability, respectively.

Dff = Days to first flower (day), D 50% F = Days to 50% flowering (day), Df = Days to fruiting (day), Ph= Plant height (cm), Nb = Number of branches/plant, Nfnp = Number of fruiting nodes/plant, Pol = Pod length (cm), Npon = Number of pods /node, Npop = Number of pods/plant, Nspo = Number of seeds/pod, Nsp = Number of seeds/plant, 100- Swt = 100 - seed weight (g.), PC (%) = Protein content (%), CC (%) = Carbohydrate content (%) and Sy = Seed yield / plant (g.).

Furthermore, correlation of seed yield/plant with protein and carbohydrate contents was insignificant during the two seasons. Similar results were obtained by **Verma *et al.* (2015)** for protein content.

Path Coefficient Analysis

Path coefficient analysis helps to estimate the influence of each variable upon the resultant variable by partitioning the correlation coefficients. Seed yield/plant was selected as resultant variable and plant height, number of fruiting nodes/plant, pod length, number of pods/plant, number of seeds/pod, number of seeds/plant and 100-seed weight as causal variable. The results of path coefficient analysis are illustrated in Table 5.

The highest positive direct effects on faba bean seed yield were exhibited by number of seeds/plant (0.931, 0.873) followed by 100-seed weight (0.492, 0.594) during the two seasons, respectively. Hereby, number of seeds/plant followed by 100-seed weight may be used as direct selection criteria in faba bean breeding program designed to increase seed yield. Similarly, number of seeds/plant showed positive indirect effects *via* number of fruiting nodes/plant, pod length, number of pods/plant and number of seeds/pod during the two seasons. Also, the indirect effects of 100-seed weight *via* pod length and number of seeds/pod were found to be positive during the two seasons, suggested that indirect selection for number of seeds/plant and 100-seed may increase seed yield. In this respect, positive direct effect was recorded for 100-seed weight on seed yield /plant by **Tadesse *et al.* (2011), Sharifi (2015), Verma *et al.* (2015), Hamza and Khalifa (2017), Kumar *et al.* (2017) and Tekalign *et al.* (2017)**.

Table 5. Path coefficient analysis showing direct and indirect effects of different attributes on seed yield/plant during the two seasons of 2014/2015 and 2015/2016

Character	Plant height (cm)	Number of fruiting nodes/plant	Pod length (cm)	Number of pods/ plant	Number of seeds/ pod	Number of seeds/ plant	100-seed weight (g.)	Correlation with yield
Direct (Diagonal) and indirect effect of yield attributes on yield (2014/2015)								
Plant height (cm)	**-0.044**	-0.037	0.003	-0.011	0.051	-0.322	-0.164	-0.525
Number of fruiting nodes/ plant	-0.029	**-0.057**	0.002	-0.033	0.030	0.022	-0.301	-0.365
Pod length (cm)	0.026	0.018	**-0.005**	-0.011	-0.049	0.314	0.042	0.335
Number of pods/plant	-0.004	-0.015	-0.001	**-0.129**	-0.015	0.599	-0.064	0.372
Number of seeds/pod	0.026	0.020	-0.003	-0.022	**-0.086**	0.577	0.154	0.666
Number of seeds/plant	0.015	-0.001	-0.002	-0.083	-0.054	**0.931**	-0.009	0.798
100 - seed weight (g.)	0.015	0.035	-0.001	0.017	-0.027	-0.017	**0.492**	0.514
Direct (Diagonal) and indirect effect of yield attributes on yield (2015/2016)								
Plant height (cm)	**-0.097**	-0.048	-0.010	0.011	-0.030	-0.022	-0.202	-0.398
Number of fruiting nodes/ plant	-0.052	**-0.089**	-0.014	0.003	-0.018	0.148	-0.406	-0.429
Pod length (cm)	0.034	0.047	**0.027**	0.003	0.030	0.050	0.268	0.459
Number of pods/plant	-0.014	-0.004	0.001	**0.075**	0.014	0.578	-0.105	0.545
Number of seeds/pod	0.046	0.026	0.013	0.016	**0.063**	0.353	0.199	0.716
Number of seeds/plant	0.002	-0.015	0.002	0.050	0.026	**0.873**	-0.274	0.663
100 - seed weight (g.)	0.033	0.061	0.012	-0.013	0.021	-0.402	**0.594**	0.306

The direct effect of pod length, number of pods/plant and number of seeds/pod on seed yield was positive in the second season. So, these characters could be considered as a selection criteria for improving faba bean seed yield. These results also agree with those of **Tadesse *et al.* (2011), Sharifi (2014), Sharifi (2015), Verma *et al.* (2015) and Kumar *et al.* (2017)** they found that pod length, number of pods/plant and number of seeds/pod had positive direct effect on seed yield. Meantime, pod length had positive indirect effect *via* plant height and number of fruiting nodes/plan in the first season as well as number of pods/plant, number of seeds/pod, number of seeds/plant and 100-seed weight in the second one. Also, indirect effects of number of pods/plant *via* 100-seed weigh in the first season as well as plant height, number of fruiting nodes/plan, pod length, number of seeds/pod and number of seeds/plant in the second season were positive. Number of seeds/pod exhibited positive indirect effects *via* plant height, number of fruiting nodes/plan in the first season as well as pod length, number of pods/plant, number of seeds/plant and 100-seed weight in the second one. While, direct effect of plant height, number of fruiting nodes/plant during the two seasons as well as pod length, number of pods/plant and number of seeds/pod in the first season on seed yield was negative. Meantime, plant height had negative indirect effect *via* number of fruiting nodes/plant and number of pods/plant during the two seasons.

Molecular Markers RAPD-PCR

In the present study, five primer of RAPD were selected to identify genetic diversity among the ten faba bean cultivars. These primers produce multiple bands, which ranged between 4 bands for primer D13 to 9 bands for primer C06. The total number of bands were 32,

which 21 of them were polymorphic with 65.6% polymorphism. The highest level of polymorphism could be observed in primer C19 which showed 75%, while the lowest polymorphism valued 50% in primer D13 (Table 6 and Fig. 1).

RAPD analysis can produce four positive markers was observed in Giza 3 faba bean cultivar, which present in the two primers (C06 and C19) at different molecular weight (MW) produce 2 bands, 1850 bp and 1200 bp in primer C06 and the other two at mw 2850 bp and1850 bp in primer C19 . Giza 40 which present two positive markers one of them in primer B09 in MW 580 bp, while the other in MW 1210 bp at primer C19. Whereas, Giza 429 recorded one band negative at 450 bp in primer C19. Giza 843 has one band positive marker at 1020 bp in primer C19. **Yahia *et al.* (2014)** used SSR and RAPD markers to evaluate the genetic diversity of 13 Tunisian faba bean genotypes and showed that the polymorphic fragments percentages were 100 and 60.63% for SSR and RAPD markers, respectively.

Combined Analysis for Seven Faba bean Cultivars

Similarity index and dendrogram across the ten faba been cultivars under investigation based on RAPD analysis are shown in Table 7 and Fig. 2, respectively. The comparison revealed that the highest genetic similarity was recorded between Sakha 4 and Wadi 1 (0 .970), followed by Misr 3 and Nubaria 3 (0.919). The lowest relationship was recorded for cultivars Giza 3 and Giza 429 (0.619). The dendrogram (Fig. 2) resulted in two main clusters. One of them involved the cultivars Giza 3 and Giza 40, while the second cluster involved the rest cultivars. The second cluster was divided into two subclusters, one included Misr 3 and Nubaria 3, while the second cluster involved Sakha 4, Wadi 1, Nubaria 1, Giza 429, Giza 2 and Giza 843.

Table 6. Levels of polymorphism by the five RAPD primers a cross ten faba bean cultivars

Primer name	MW(bp)	Number of Monomorphic bands (nmb)	Number of Polymorphic bands (npb)	NB	P (%)	Genotypes	MM	
							PM	NM
B09	2600:580	2	3	5	60	Giza 40	580	
C06	1850:310	3	6	9	66.7	Giza 3	1850	
							1200	
C08	2800:675	2	4	6	66.7			
C19	2850:450	2	6	8	75	Giza 3	2850	
							1850	
						Giza 40	1210	
						Giza 843	1020	
						Giza 429		450
D13	1220:450	2	2	4	50			
Total		11	21	32	65.6			

Where:

NB, Number of bands **MM,** Molecular marker **P (%),** Polymorphism (%)

PM, Positive marker **NM,** Negative marker

MW, Molecule weight

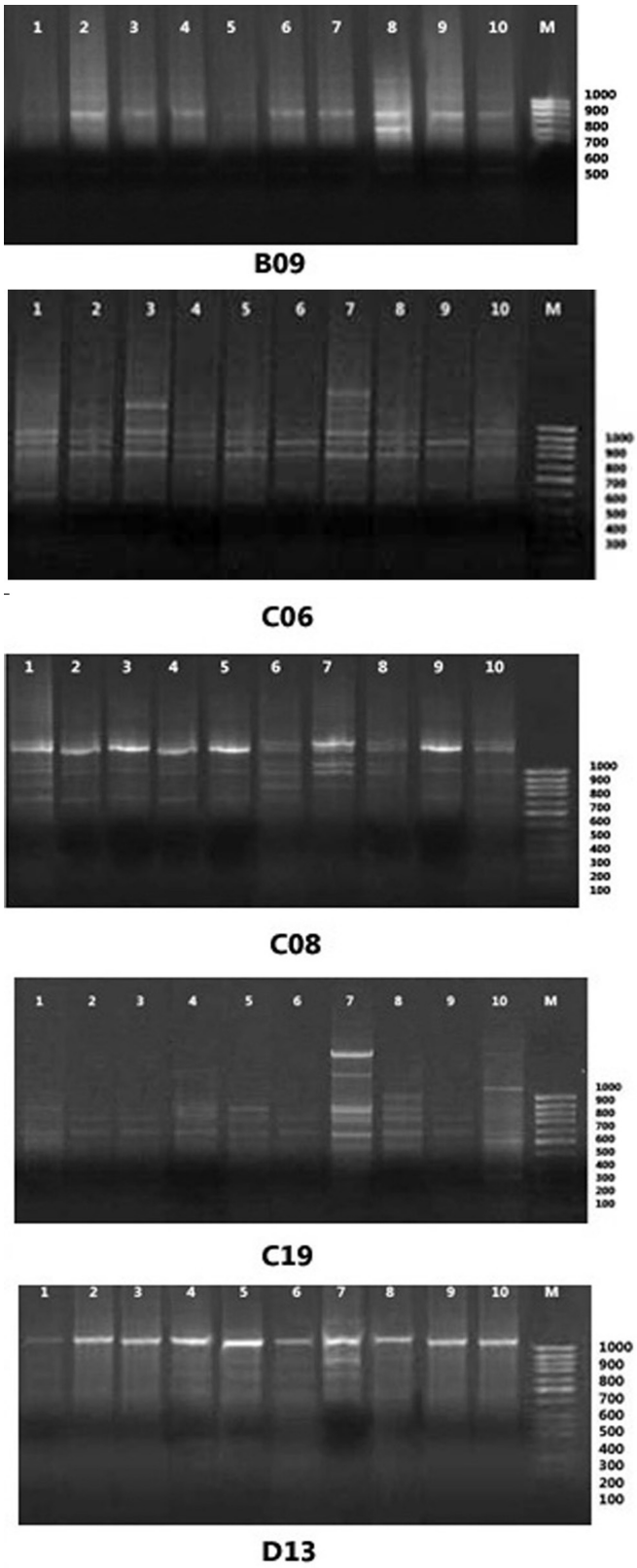

Fig. 1. RAPD banding patterns amplified with 5 primers a cross ten faba bean cultivars

Table 7. Similarity matrix among the ten faba bean cultivars using RAPD analysis

Cultivar	Misr 3	Sakha 4	Wadi 1	Nubaria 1	Nubaria 3	Giza 2	Giza 3	Giza 40	Giza 429
Sakha 4	0.778								
Wadi 1	0.757	0.970							
Nubaria 1	0.811	0.909	0.882						
Nubaria 3	0.919	0.848	0.842	0.882					
Giza 2	0.872	0.800	0.778	0.833	0.778				
Giza 3	0.809	0.651	0.682	0.682	0.727	0.783			
Giza 40	0.744	0.769	0.811	0.750	0.700	0.762	0.800		
Giza 429	0.686	0.902	0.875	0.875	0.750	0.824	0.619	0.737	
Giza 843	0.789	0.882	0.857	0.800	0.800	0.865	0.711	0.780	0.848

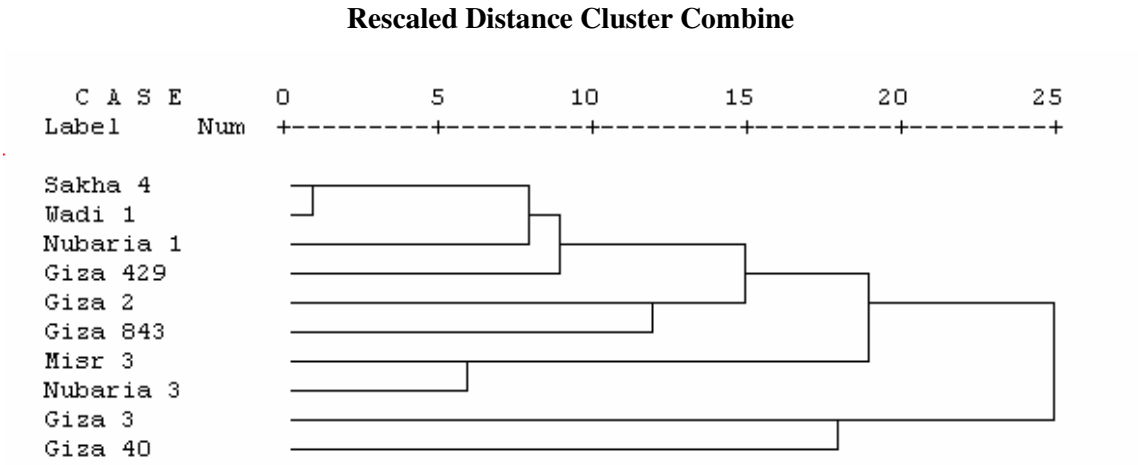

Fig. 2. Dendrogram of the genetic distances among the ten faba bean cultivars based on RAPD analysis

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تقييم بعض الأصناف الحديثة والقديمة من الفول البلدى لصفات التبكير، المحصول ومساهماته والجودة

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أجريت هذه الدراسة بمحطة البحوث الزراعية ببهتيم بقسم بحوث الأصول الوراثية- مركز البحوث الزراعية، خلال موسمى ٢٠١٤/٢٠١٥ و ٢٠١٥/٢٠١٦، بهدف تقييم عشرة أصناف من الفول البلدى وهى خمسة أصناف حديثة (مصر٣، سخا ٤، وادى١، نوبارية ١ و نوبارية ٣) وخمسة أصناف قديمة (جيزة ٢، جيزة ٣، جيزة ٤٠، جيزة ٤٢٩ وجيزة ٨٤٣) فى تصميم القطاعات كاملة العشوائية فى ٤ مكررات لصفات التبكير (عدد الأيام حتى بداية التزهير، عدد الأيام حتى ٥٠% من التزهير وعدد الأيام حتى الإثمار)، المحصول ومساهماته (ارتفاع النبات، عدد الفروع/النبات، عدد العقد الثمرية/ النبات، طول القرن، عدد القرون/العقدة، عدد القرون/النبات، عدد البذور/القرن، عدد البذور/النبات، وزن الـ ١٠٠ بذرة ومحصول البذور/النبات) وصفات الجودة (محتوى البروتين ومحتوى الكربوهيدرات) من خلال تقدير متوسط السلوك، معامل الارتباط، معامل المرور والمعلمات الجزيئية RAPD-PCR ، وقد أظهرت النتائج وجود اختلافات عالية المعنوية بين أصناف الفول البلدى تحت الدراسة لصفات التبكير، المحصول ومساهماته وصفات الجودة خلال موسمى الزراعة، وبصفة عامة كانت أصناف الفول البلدى الحديثة أكثر تبكيراً من أصناف الفول البلدى القديمة، كما أظهرت النتائج أن الصنف الحديث نوبارية ١ أعطى أعلى إنتاجية خلال موسمى الزراعة، وسجل الصنف سخا ٤ أعلى القيم لمحتوى البروتين والكربوهيدات فى الموسمين، وأوضحت نتائج تحليل الارتباط وجود إرتباط موجب ومعنوى بين محصول البذور/ النبات وكلا من طول القرن، عدد القرون/النبات، عدد البذور/القرن، عدد البذور/النبات ووزن الـ١٠٠ بذرة فى موسمى الزراعة، بينما سجل ارتباط سالب ومعنوى بين محصول البذور/النبات وكلا من ارتفاع النبات وعدد العقد الثمرية/النبات خلال موسمى الزراعة، ولقد أظهرت نتائج تحليل معامل المرور أن صفة عدد البذور/النبات يليها وزن الـ١٠٠ بذرة كانت لها أعلى تأثير مباشر على محصول البذور/النبات خلال موسمى الزراعة، وبتوظيف تكنيك RAPD - PCR باستخدام خمس بوادئ للتفرقة بين العشرة تراكيب وراثية من الفول البلدى أظهرت النتائج وجود ٣٢ واسم جزيئي منهم ٢١ واسم جزيئي مختلف بنسبة ٦٥,٦%، تميز التركيب الوراثى جيزه ٣ له بأربع واسمات جزيئيه موجبه مميزه له تحت بادئ C06 وبادئ C19، بينما تميز جيزه ٤٠ بوجود واسمتين جزيئين موجبتين مميزه له واحده عند البادئ B09 والأخرى عند البادئ C19، وأظهر التركيب الوراثى جيزة ٤٢٩ واسمه جزيئيه سالبة عند البادئ C19، بينما اظهر التركيب الوراثى جيزه 843 واسمه جزيئيه موجبة عند البادئ C19.

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