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Evaluation and path analysis for yield and its components in some genotypes of lentil (*Lens culinaris* Medikus) under Upper Egypt conditions

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Abstract

Evaluation of lentil genotypes is important to choose selection criteria for improvement of seed yield. This investigation was conducted at El-Mataana, Agricultural Research Station, Luxor governorate, ARC, Egypt to assess the genotypic variability, correlation and path analysis of some lentil genotypes. Twenty-two genotypes of lentil including one as the check variety (Giza 9) were tested in a Randomized Complete Block Design (RCBD) with three replicates for three years; 2017/2018, 2018/2019 and 2019/2020. For each season and over seasons, significant ($p<0.01$) differences were observed among genotypes for all the studied traits; days to flowering, plant height, no of pods plant^{-1}, 100-seed weight, seed yield plant^{-1} and harvest index. Also, the differences among years and years $\times$ genotypes interactions were significant ($p<0.01$) for all the studied traits. The combined mean demonstrated that the genotypes X2012-S-291 and Flip 2003-37L produced the highest seed yield plant^{-1}, no of pods plant^{-1}, 100-seed weight and earliest compared to the check variety (Giza 9). These genotypes were promising and could be used as new lentil cultivars *i.e.* parents in breeding programmes to produce high-yielding varieties for Upper Egypt. Estimates of broad sense heritability were high for all traits under investigation except seed yield plant^{-1} was moderate. Seed yield plant^{-1} was correlated positively with all the studied traits except days to 50% flowering. Path analysis illustrated that 100-seed weight and number of pods plant^{-1} were the two important traits for seed yield improvement.

Keywords: Lentil; Evaluation; Correlation; Path analysis.

Introduction

Lentil (*Lens culinaris* Medikus) belonging to the family Fabaceae is considered as one of the ancient, domesticated, economically important winter legume crop which has the ability in nitrogen fixation, and agriculturally cultivated worldwide as human food. The seeds of this plant are commonly used as edible for human because of their high protein content and a good source of vitamins and other important nutrients such as iron, and zinc. However, lentils cook quickly, global consumption is rising faster than human population growth, and production is increasing in many regions of the world.

Lentil plays an important role in human, animal and soil health improvement occupying a unique position in cereal-based cropping systems (Bacchi *et al.*, 2010 and Yasin, 2015). Its ability in nitrogen fixation and carbon sequestration improves soil nutrient status, which intern provides sustainability in crop production systems (Abraham, 2015 and Yasin, 2015). The studied genetic variability, heritability, correlation and path analysis are helpful to the breeder to select superior parents and articulate selection criteria for improvement the yield-associated parameter (Khan *et al*, 2004 and Sakthivel *et al*, 2019). High heritability for days to flowering, plant height, no. of pods plant^{-1}, 100-seed weight and harvest index and moderate for seed yield plant^{-1} were obtained by Sharma and Singh (2014), Chowdhury *et al* (2019) and Vanave *et al* (2019). Lentil area and production is declining for the last years due to the low yield potential of lentil varieties. In the past few efforts have been made for genetic improvement of lentil crop. The available lentil germplasm in our area have not been evaluated for yield and yield related traits. The objectives of the present study were **a:** evaluate 22 lentil genotypes of diverse origin into three seasons, **b:** estimate phenotypic correlation coefficients for seed yield and related traits to provide the basis for planning more efficient selection programs and **c:** study the nature of association between seed yield and their contributing variables via path-coefficient procedure under overall seasons.

Materials and Methods

Twenty-two lentil genotypes including one as the check variety (Giza 9) were evaluated during three seasons *i.e.* 2017/2018, 2018/2019 and 2019/2020 at El-Mataana, Agricultural Research Station, Luxor governorate, ARC, Egypt. These genotypes were obtained from the same Station. The name and origin of these genotypes are shown in Table 1.

The trial was planted in a randomized complete block design with three replications. The sowing date was performed on the 15th of November for each season. The plot size of the trial was 9 m^2 (3×3 m) and seeds were drilled on ten rows with the rate of 300 seeds per plot. Spacing was 1 m, 0.5 m, 0.3 m and 0.1 m between replications, plots, rows, and plants, respectively. The recommended agronomical practices were followed along the three seasons. Observations were recorded on ten plants for each plot basis for each genotype for all traits under study as follows: Days to 50% flowering, plant height, number of pods/plant, 100-seed, seed yield/plant and harvest index.

Data analysis
The regular analysis of variance of RCBD design was performed for each trial according to Gomez and Gomez (1984). The homogeneity tests according Bartlett's test; 1973 demonstrated the validity of conducting the combined analysis of variance was performed by the MSTAT-C Computer program (Table 2). Genotypes were considered as fixed effects, whereas years and replications were taken as random effects in the statistical model. Differences among means were assessed by the revised least significant differences (LSD') at 5 and 1% levels of probability according to (El-Rawi and Khalafalla; 1980) as follow:

Table 1. The name, pedigree and origin of the used 22 lentil genotypes.

No.	Name	Pedigree	Origin
1	Giza-9	Widespread cultivar	Egypt
2	Giza-29	Landrace, high yield potential	Egypt
3	Sinea-1	Selection from Argentina variety precoz, early maturing	Argentina
4	X 5-1	Selection from hybrid line	ICARDA
5	X 5-6	Selection from hybrid line	ICARDA
6	XG 98-32	Selection from hybrid line	ICARDA
7	X2009-S-100	589517 × ILL 358	ICARDA
8	X2012-S-180	ILL 7978 × DPL 62	ICARDA
9	X2009-S-210	ILL 8178 × ILL 358	ICARDA
10	X2009-S-227	ILL 4404 × ILL 10241	ICARDA
11	X2012-S-291	ILL 8008 × (ILL 5888 × ILL 6002)	ICARDA
12	X2009-S-292	ILL 4402 × ILL 2590	ICARDA
13	Flip 81-17L	Cross-line mode in FLRS in Egypt	ICARDA
14	Flip 95-51L	Accession No. ILL7707	ICARDA
15	Flip 95-59L	Ill 6212 × ILL 298	ICARDA
16	Flip 2006-11L	SEL (ILL 4605)	ICARDA
17	Flip 2011-19L	ILL 8190 × ILL 7989	ICARDA
18	Flip 2003-37L	ILL723 × ILL7163	ICARDA
19	Flip 2010-79L	ILL 7620 × ILL 9836	ICARDA
20	Flip 2014-68L	ILL 7723 × ILL 5883	ICARDA
21	Flip 2012-148L	ILL 8072 × ILL 8114	ICARDA
22	Flip 2012-237L	ILL 9888 × ILL 9932	ICARDA

For each season: $$RLSD = t'_\alpha \times \sqrt{\frac{2MSerror}{r}}$$

For over seasons: $$RLSD = t'_\alpha \times \sqrt{\frac{2MSerror}{yr}}$$

Where t' from the minimum-average-risk table.

Components of variances

The phenotypic ($\sigma^2 p$) and genotypic ($\sigma^2 g$) variance were estimated according to Al-Jibouri *et al* (1958). According to Comstock and Robinson (1952), broad-sense heritability estimates for grain yield and related traits as the ratio of genotypic variance ($\sigma^2 g$) to phenotypic variance ($\sigma^2 p$).

Phenotypic correlation:

The Phenotypic correlation coefficient among different pairs of the studied traits was calculated according to Steel and Torrie (1980).

Path coefficient analysis
Path coefficient analysis was performed according to the procedure suggested by Dewey and Lu (1959) for seed yield and its components (Figure 1).

Variable of seed yield, which were considered to contribute to seed yield (S) were; 1- number of pods/plant, 2- 100-seed
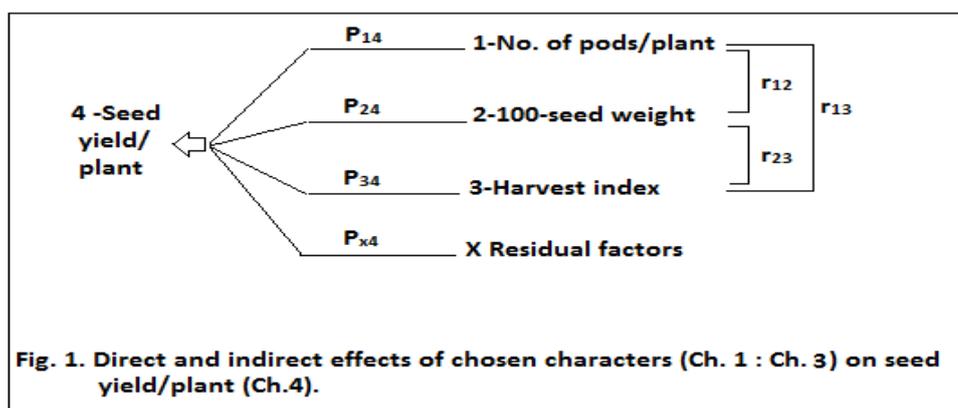
1- $r_{s1} = P_{s1} + r_{12}P_{s2} + r_{13}P_{s3}$

2- $r_{s2} = P_{s2} + r_{12}P_{s1} + r_{23}P_{s3}$

3- $r_{s3} = P_{s3} + r_{13}P_{s1} + r_{23}P_{s2}$

$1 = P^2_{4x} + P^2_{14} + P^2_{24} + P^2_{34} + 2P_{12}r_{12}P_{24} + 2P_{12}r_{13}P_{34} + 2P_{24}r_{23}P_{34}$

weight, 3- harvest index and (X) residual factors.

Fig. 1. Direct and indirect effects of chosen characters (Ch. 1 : Ch. 3) on seed yield/plant (Ch.4).

Results and Discussion

A. Performance for the studied traits

a₁. Analysis of variance

Separate and combined analyses of variances for three growing seasons of 22 lentil genotypes for days to 50% flowering, plant height, no. of pods plant⁻¹, 100-seed weight, seed yield plant⁻¹ and harvest index are illustrated in Table 2. Genotypic differences were found significant (P < 0.01) for all the studied traits in 2017/2018, 2018/2019, 2019/2020 seasons and over years. This indicates that the presence of inherent genetic variability among the genotypes, which gives an opportunity to select the superior ones or improve the target traits *i.e.* seed yield or quality in new verities or as a parents of hybridization programs.

Moreover, the combined analysis of variance over years for all traits under study revealed highly significant differences among years, reflecting the influence of climatic conditions on these traits. Besides, mean squares due to genotypes × years interaction for these traits were highly significant (P < 0.01). This reflects that the performance of tested genotypes varied from one year to another. Significant difference on lentil yield and its components were also reported by Raslan (2011), Neupane (2013), Abo Hegazy *et al.* (2013), Dugassa *et al.* (2014), Nath *et al.* (2014), Kumar *et al.* (2016), Gaad *et al* (2018), Adhikari *et al.* (2018), Sakthivel *et al* (2019) and Vanave *et al* (2019).

Mean of the studied traits

a₂₁- Days to flowering

Regarding days to 50% flowering (Table 3), it varied from 55.33, 52.67, 56.00 and 54.67 for the genotype X 5-6 to 81.00, 72.33, 84.33 and 79.22 for the genotype Flip 2014-68L with an average of 61.47, 58.89,

Table 2. Separate and combined analysis of variance for the studied traits of 22 lentil genotypes for 2017/2018, 2018/2019 and 2019/2020 seasons.

S.O.V	df	Mean squares					
		Days to heading	Plant height (cm)	Number of pods/plant	100-seed weight (g)	Seed yield/ plant	Harvest index %
2017/2018							
Reps	2	7.56	4.21	1.65	0.04	0.03	6.34
Genotypes (G)	21	127.26**	57.45**	510.94**	0.11**	3.12**	139.69**
Error	42	5.31	6.91	20.89	0.01	0.12	9.57
2018/2019							
Reps	2	22.97	4.11	7.11	0.01	0.22	8.88
Genotypes (G)	21	90.36**	113.92**	783.39**	0.38**	5.07**	48.49**
Error	42	9.49	13.23	15.11	0.02	0.47	10.38
2019/2020							
Reps	2	7.11	62.55	6.47	0.07*	0.60*	25.78
Genotypes (G)	21	85.01**	361.27**	441.73**	0.22**	2.40**	74.86**
Error	42	3.93	34.30	10.39	0.01	0.17	10.24
Combined							
Years (Y)	2	163.05**	10080.81**	1620.40**	0.70**	24.31**	695.77**
Error (a)	6	12.55	23.62	3.38	0.04	0.29	13.67
Genotypes (G)	21	230.98**	319.70**	911.51**	0.60**	3.43**	135.59**
Y × G	42	35.83**	106.47**	484.11**	0.06**	3.18**	63.72**
Error (a)	126	6.24	18.15	36.46	0.01	0.25	10.06
$\sigma^2 g$	-	21.68	23.69	47.49	0.060	0.033	7.99
$\sigma^2 p$	-	23.76	29.74	51.54	0.063	0.61	9.11
h^2_b	-	0.91	0.80	0.92	0.95	0.54	0.88

**; Significant at 0.01 level of probability.

61.74 and 60.70 days in the first, second, third and over seasons, respectively. This reveals that the genotype X 5-6 was the earliest in the three seasons, reflecting that this genotype had accumulated desirable alleles for earliness and could be used in future breeding programs. On the other hand, the genotype Flip 2014-68L was the latest under all seasons, indicating that this genotype had accumulated favorable alleles for lateness. Significant difference on combined analysis indicates the existing variation among genotypes for days to flowering among the evaluated lentil genotypes. Bicer and Sakar (2004), Ezzat et al (2005), Raslan (2011), Abo-Hegazy et al (2012), Neupane (2013), Dugassa et al. (2014), Sharma and Singh (2014), Yadav et al (2016), Darai et al (2017), Gaad et al (2018), Adhikari et al. (2018), Sorechi and Daba (2018) and Vanave et al (2019) have also reported the performance of the genotypes differed significantly in days to 50% flowering.

Table 3. Separate and combined averages of days to 50% flowering, plant height and number of pods plant[-1] for the studied lentil genotypes in 2017/2018, 2018/2019, 2019/2020 and over the growing seasons.

No.	Genotypes	Days to 50% flowering (days)				Plant height (cm)				Number of pods plant[-1]			
		2017/2018	2018/2019	2019/2020	Combined	2017/2018	2018/2019	2019/2020	Combined	2017/2018	2018/2019	2019/2020	Combined
1	Giza-9	59.00	59.67	60.00	59.56	50.00	71.67	71.00	64.22	62.33	73.33	76.00	70.55
2	Giza-29	58.33	59.67	63.33	60.44	49.30	78.67	79.33	69.10	62.33	77.67	58.33	66.11
3	Sinea-1	57.00	57.00	61.00	58.33	38.83	66.33	65.67	56.94	57.33	60.67	59.00	59.00
4	X 5-1	58.33	56.67	59.00	58.00	52.20	69.33	69.33	63.62	51.33	69.67	63.33	61.44
5	X 5-6	55.33	52.67	56.00	54.67	43.80	73.67	72.67	63.38	62.33	65.00	65.00	64.11
6	XG 98-32	58.67	56.67	60.33	58.56	46.80	78.00	78.33	67.71	47.33	41.67	50.67	46.56
7	X2009-S-100	60.00	56.67	59.33	58.67	45.33	65.67	65.67	58.89	42.00	72.33	65.67	60.00
8	X2012-S-180	58.33	63.67	62.00	61.33	46.33	75.00	75.33	65.56	58.00	49.67	46.67	51.45
9	X2009-S-210	60.00	58.00	60.67	59.56	58.33	65.33	62.67	62.11	33.33	55.33	63.67	50.78
10	X2009-S-227	59.33	56.00	61.00	58.78	44.87	66.00	65.67	58.84	53.00	51.67	66.00	56.89
11	X2012-S-291	58.33	57.00	61.67	59.00	44.33	65.67	64.00	58.00	65.67	84.67	82.00	77.45
12	X2009-S-292	57.67	56.00	61.33	58.33	50.00	75.67	75.00	66.89	35.33	52.67	45.67	44.56
13	Flip 81-17L	58.33	59.33	60.67	59.44	52.07	80.00	83.00	71.69	50.00	64.33	69.67	61.33
14	Flip 95-51L	59.67	55.00	59.00	57.89	48.60	78.67	90.00	72.42	72.67	91.67	71.33	78.56
15	Flip 95-59L	58.33	60.67	62.67	60.56	48.33	72.67	69.33	63.44	31.67	63.67	63.00	52.78
16	Flip 2006-11L	61.67	55.00	59.33	58.67	49.27	70.33	69.67	63.09	43.33	66.00	69.00	59.44
17	Flip 2011-19L	60.67	53.67	59.00	57.78	44.20	65.67	46.03	51.97	51.67	50.33	53.33	51.78
18	Flip 2003-37L	58.67	55.00	61.33	58.33	47.47	75.33	75.33	66.04	77.67	91.67	80.67	83.34
19	Flip 2010-79L	65.00	54.67	60.33	60.00	44.80	65.33	44.33	51.49	46.00	44.67	52.67	47.78
20	Flip 2014-68L	81.00	72.33	84.33	79.22	47.67	63.33	63.67	58.22	62.33	58.67	40.33	53.78
21	Flip 2012-148L	74.00	71.00	62.67	69.22	43.00	59.67	53.67	52.11	48.67	45.33	44.00	46.00
22	Flip 2012-237L	74.67	69.33	63.33	69.11	56.00	60.33	60.00	58.78	77.00	98.00	79.33	84.78
Mean		61.47	58.89	61.74	60.70	47.80	70.11	68.17	62.02	54.15	64.94	62.06	60.38
RLSD0.05		3.48	4.86	3.00	2.18	4.13	5.73	9.23	3.72	1.81	5.74	4.87	5.07
RLSD0.01		4.64	6.53	4.00	2.91	5.54	7.69	12.38	4.96	2.41	7.64	6.50	6.77

a$_{22}$. Plant height

Results in Table 3 demonstrated that the average of plant height differed widely among the tested genotypes and ranged from 38.83 (Sinea 1) to 58.33 (X2009-S-210) with an average of 47.80 cm, from 59.67 (Flip 2012-148L) to 80.00 (Flip 81-17L) with an average of 70.11 cm and from 44.33 (Flip 2010-79L) to 90.00 (Flip 95-51L) with an average of 68.17 cm in 2017/2018, 2018/2019 and 2019/2020, respectively (Table 3).

The combined mean in Table 3 displayed that the plant height varied from 51.49 (Flip 2010-79L) to 72.42 (Flip 95-51L) with an average of 62.02 cm. Over all growing seasons, comparing all genotypes with the check variety (Giza 9) recorded that three genotypes *i.e.* Giza-29, Flip 81-17L and Flip 95-51L were significantly taller than the check variety (Giza 9). The genotypes, which showed taller, erect and lodging resistance, are desirable for mechanical as well as manual harvesting. These results are similar with those of Bicer and Sakar (2004), Ezzat *et al* (2005), Singh *et al* (2006), Bayoumi (2008), Raslan (2011), Abo-Hegazy *et al* (2013), Neupane (2013), Dugassa *et al* (2014), Meknnen *et al* (2014), Sharma and Sing (2014), Yadav *et al* (2016), Gaad *et al* (2018), Adhikari *et al* (2018), Sorechi and Daba (2018) and Vanave *et al* (2019).

a$_{23}$. Number of pods plant^{-1}

A large range of variation was observed for this trait among twenty-two lentil genotypes. The number of pods/plant is very important in determining yield performance of lentil. The average number of pods/plant for the genotypes in 2017/2018 was 54.15 g, which ranged from 31.67 (Flip 95-59L) to 77.67 (Flip

2003-37L). Otherwise, it varied from 41.67 (XG 98-3-2S) to 98.00 (Flip 2012-237L) with an average of 64.94 g and from 40.33 (Flip 2014-68L) to 82.00 (X2012-S-291) with an average of 62.06 g in 2018/2019 and 2019/2020 seasons, respectively (Table 3).

Overall years, average number of pods/plant of all genotypes was 60.38 g. Among the genotypes, Flip 2012-237L produced maximum number of pods/plant (84.78 g), which is statistically at par with Flip 2003-37L (83.34 g), minimum number of pods/plant (44.56 g) was produced by the genotype X2009-S 292 (Table 3).

Comparing all genotypes with the check variety (Giza 9) for each season and overall years (Table 3), it was recorded that four genotypes *i.e.* X2012-S-291, Flip 95-51L, Flip 2003-37L and Flip 2012-237L had significantly higher values of number of pods/plant than the check variety (Giza 9). In agreement with this finding, variation due to genotypes were also reported Bayoumi (2008), Raslan (2011), Abo-Hegazy *et al* (2013), Neupane (2013), Dugassa *et al* (2014), Nath *et al* (2014), Kumar *et al* (2016), Adhikari *et al* (2018) and Vanave *et al* (2019).

a$_{24}$. 100-seed weight

The seed weight is a very important influence for the determination of crop yield. Results in Table 4 indicated that the averages of 100-seed weight differed widely among the tested genotypes. The average of 100-seed weight for the genotypes showed that the heaviest averages were 2.73, 3.60, 3.43 and 3.26 g for the genotype X2012-S-291, but the lightest averages were 1.83, 1.93,

Table 4. Separate and combined averages of 100-seed weight, seed yield plant^{-1} and harvest index for the studied lentil genotypes in 2017/2018, 2018/2019, 2019/2020 and over the growing seasons.

No.	Genotypes	100-seed weight (g)				Seed yield plant^{-1} (g)				Harvest index (%)			
		2017/2018	2018/2019	2019/2020	Combined	2017/2018	2018/2019	2019/2020	Combined	2017/2018	2018/2019	2019/2020	Combined
1	Giza-9	2.30	2.53	2.63	2.49	2.87	4.97	4.83	4.22	26.03	20.54	27.89	24.82
2	Giza-29	2.33	2.20	2.70	2.41	2.43	5.43	3.50	3.79	27.85	26.42	26.19	26.82
3	Sinea-1	2.33	2.40	2.50	2.41	3.40	3.93	3.93	3.76	24.22	19.42	29.02	24.22
4	X 5-1	2.10	2.10	2.40	2.20	2.43	3.70	4.50	3.54	24.69	17.52	27.30	23.17
5	X 5-6	2.30	1.93	2.40	2.21	2.47	4.80	3.70	3.66	32.91	27.08	28.87	29.62
6	XG 98-32	2.20	2.20	2.60	2.33	2.43	3.17	4.87	3.49	24.68	21.91	24.29	23.63
7	X2009-S-100	2.50	2.43	2.53	2.49	5.80	3.80	3.90	4.50	39.75	25.58	26.88	30.74
8	X2012-S-180	2.30	2.30	2.47	2.36	4.20	2.37	2.17	2.91	23.28	17.25	17.14	19.22
9	X2009-S-210	2.20	2.10	2.20	2.17	1.57	4.03	3.43	3.01	18.04	25.40	27.82	23.75
10	X2009-S-227	2.20	2.40	2.50	2.37	3.60	2.83	4.17	3.53	27.14	20.30	29.09	25.51
11	X2012-S-291	2.73	3.60	3.43	3.26	4.17	5.23	5.43	4.94	19.76	27.13	29.30	25.40
12	X2009-S-292	2.20	2.10	2.40	2.23	2.70	3.30	2.93	2.98	32.94	25.12	29.51	29.19
13	Flip 81-17L	2.30	2.50	2.60	2.47	2.50	4.73	4.63	3.96	31.36	17.88	25.61	24.95
14	Flip 95-51L	2.40	2.60	2.43	2.48	2.57	5.93	3.93	4.14	30.64	25.13	29.02	28.26
15	Flip 95-59L	2.27	2.23	2.30	2.27	1.37	4.33	4.03	3.24	22.96	24.05	25.74	24.25
16	Flip 2006-11L	2.10	2.00	2.10	2.07	3.63	3.07	4.20	3.63	36.39	17.54	31.67	28.53
17	Flip 2011-19L	2.20	2.10	2.30	2.20	3.43	2.83	4.13	3.47	36.63	21.86	40.62	33.04
18	Flip 2003-37L	2.70	2.80	2.67	2.72	1.70	6.57	5.50	4.59	23.34	28.15	33.04	28.18
19	Flip 2010-79L	2.20	2.30	2.30	2.27	3.67	2.10	3.77	3.18	30.44	17.81	29.31	25.85
20	Flip 2014-68L	1.83	1.93	2.10	1.96	3.07	2.70	2.30	2.69	22.35	15.62	19.80	19.25
21	Flip 2012-148L	2.20	2.37	2.60	2.39	2.30	2.70	2.63	2.54	18.21	17.12	17.78	17.70
22	Flip 2012-237L	2.40	2.40	2.53	2.44	1.97	6.20	3.27	3.81	21.64	24.92	25.43	24.00
Mean		2.29	2.34	2.49	2.37	2.92	4.03	3.90	3.62	27.06	21.99	27.33	25.46
RLSD0.05		0.19	0.19	0.19	0.09	0.52	1.08	0.64	0.46	0.95	5.65	5.04	2.90
RLSD0.01		0.26	0.25	0.26	0.12	0.69	1.45	0.85	0.62	1.27	7.78	6.76	3.89

2.10 and 1.96 g for the genotype Flip 2014-68L in 2017/2018, 2018/2019, 2019/2020 and the combined mean, respectively (Table 4). The average 100-seed weight for all the genotypes was 2.29, 2.34, 2.49 and 2.37 g in the first, second, third and over seasons, respectively (Table 4).

Comparing all genotypes with the check variety (Giza 9) over seasons, it was found that the genotype X2012-S-291 had a significantly heavier in 100-seed weight and seed yield/plant than the check variety. But thirteen genotypes were significantly lighter in 100-seed weight than the check variety. The rest of the genotypes were comparable to the check variety in 100-seed weight. These results are in conformity with to result obtained by Sing *et al* (2006), Bayoumi (2008), Raslan (2011), Abo Hegazy *et al* (2013), Meknnen *et al* (2014), Yadav *et al* (2016), Adhikari *et al* (2018), Gaad *et al* (2018), Sakthivel *et al* (2019) and Vanave *et al* (2019).

a_{25}. Seed yield plant^{-1}

Variance analysis exhibited that the presence of genetic variability on studied lentil genotypes for seed yield (Table 2). Seed yield is a function of combined effect of gene controlling yield components and influence of growing seasons and agricultural practices applied. Consequently, any variation or change in both them is responsible to bring a change in attained yield. Results in Table 4 indicated that there was a large variation in seed yield. In 2017/2018 season, mean of seed yield for the genotypes under

investigated was 2.92 g, which ranged from 1.37 (Flip 95-59L) to 5.80 g (X2009-S-100). During this season, the genotype X2009-S-100, which is followed by X2012-S-180, X2012-S-291, Flip 2010-79L, Flip 2006-11L, X2009-S-227, Flip 2011-19L, Sinea-1 and Flip 2014-68L produced 5.80, 4.20, 4.17, 3.67, 3.63, 3.60, 3.43, 3.40 and 3.07 g, respectively. All these genotypes were high significantly yielders than the check variety, except the genotype Flip 2014-68L was at par with the check variety (Giza 9).

Average seed yield in 2018/2019, all genotypes produced seed yield varied from 2.10 (Flip 2010-79L) to 6.57 (Flip 2003-37L) with an average of 4.03 g. The genotype Flip 2003-37L produced higher seed yield/plant (6.57 g), which was followed by Flip 2012-237L (6.20 g), Flip 95-51L (5.93 g), Giza-29 (5.43 g) and X2012-S-291 (5.23 g), however these genotypes were at par with the check variety (Giza 9), except Flip 2003-37L and Flip 2012-237L, which produced significantly higher than the check variety. In 2019/2020 growing season, results showed that the average of seed yield/plant ranging from 2.17 (X2012-S-180) to 5.50 (Flip 2003-37L) with an average of 3.90 g. In this season, data exhibited those genotypes Flip 2003-37L, X2012-S-291 and XG 98-3-2S were higher yielding genotypes produced mean yields of 5.50, 5.43 and 4.87 g, respectively. However, these genotypes were at par with the check variety, except Flip 2003-37L, which produced significantly higher than the check variety. On the reverse, the remainder genotypes were lower significantly yielding genotypes except three genotypes (X 5-1, Flip 81-17L and Flip 2006-11L) were at par with the check

variety. Regarding the combined mean for seed yield, the genotype X2012-S-291 yielded the maximum seed yield recording 4.94 g and surpassed significantly the check variety (Giza 9) followed by Flip 2003-37L (4.59 g) and X2009-S-100 (4.50 g) which were at par with the check variety. However, these genotypes were at par with the check variety (Giza 9), except X2012-S-291, which differed significantly with the check variety and rest genotypes, excluding Flip 2003-37L and X2009-S-100. On the basis of seed yield, seed weight, flowering period, number of branches/plant, biological yield/plant and number of pods/plant, the genotype X2012-S-291 was found promising and could be new lentil varieties for Upper Egypt conditions. In agreement with this finding, variations on grain yield due to genotypes were also reported by Bicer and Sakar (2004), Ezzat *et al* (2005), Singh *et al* (2006), Bayoumi (2008), Raslan (2011), Abo-Hegazy *et al* (2012), Meknnen *et al* (2014), Sharma and Singh (2014), Yadav *et al* (2016) Gaad *et al* (2018), Adhikari *et al* (2018), Sorechi and Daba (2018), Abbas *et al* (2019), and Vanave *et al* (2019) have also reported the performance of the genotypes differed significantly in seed yield.

a_{26}. Harvest index

The average performance of different genotypes exerted more variation for harvest index (Table 4). It ranged from 18.04 (X2009-S-210) to 41.83 (Sinea-1) with an average of 27.86, from 15.62 (Flip 2014-68L) to 28. 15 (Flip 2003-37L) with an average of 21.99 and from 17.14 (X2012-S-180) to 40.62 (Flip 2011-19L) with an average of 27.33% for 2017/2018, 2018/2019 and 2018/2019, respectively.

Combined mean, harvest index ranged from 17.70 (Flip 2012-148L) to 33.04 (Flip 2011-19L) with an average of 25.46% (Table 4).

Comparing all genotypes with the check variety (Giza 9) over years (Table 4), the genotype Flip 2011-19L was registered the highest significantly in harvest index compared to the check variety and other genotypes except X2009-S-100, which was at par with it. In addition, five genotypes (X 5-6, X2009-S-292, Flip 95-51L, Flip 2006-11L and Flip 2003-37L) produced mean of 29.62, 29.19, 28.26, 28.53 and 28.18%, respectively, however, these genotypes which produced significantly higher in harvest index than the check variety (Giza 9). Similar results were obtained by Sharma and Singh (2014), Dugassa *et al* (2014), Sakthivel *et al* (2019) and Vanave *et al* (2019) who found the performance of the genotypes differed significantly in harvest index.

B. Variance components

Results in Table 2 illustrated that the phenotypic variance was higher than genotypic ones for all traits under study. The small difference between $\delta^2 g$ and $\delta^2 p$ was observed for days to 50% flowering, plant height, number of seeds plant^{-1}, 100-seed weight and harvest index, reflecting that there was little influence of environmental factors on their phenotypic expression. Consequently, heritability values in the broad-sense (h^2_b) were high for these traits. The phenotypic variance is a good index of genotypic variance in these traits. Selection is also easy for these traits. On the other hand, the large difference between $\delta^2 g$ and $\delta^2 p$ observed for seed

yield plant[-1], revealing that there was large influence of environmental factors on their phenotypic expression. A moderate heritability estimate was found for this trait and the selection should take announcement to the yield components that estimated high heritability and correlated positively with seed yield. Similar results were also reported by Raslan (2011), Sharma and Sing (2014), Chowdhury *et al* (2019), Get *et al* (2019), Sakthivel *et al* (2019) and Vanave *et al* (2019).

C. *Phenotypic correlation*

Seed yield plant[-1] was positive correlated with each of plant height, number of pods plant[-1], 100–seed weight and harvest index over the three growing seasons (Table 5). These results indicate to importance of these traits for improvement seed yield through selection. In contrast, seed yield plant[-1] showed negative significant correlation with days to 50% flowering (Table 5). These results were agreement with those obtained by Abo-Hegazy *et al* (2012), Dugassa *et al* (2014), Sharma and Singh (2014), Kumar *et al* (2017), Hussan *et al* (2018), Adhikari (2018) and Chowdhury *et al* (2019).

3- *Path coefficient analysis*

Path analysis exhibiting the direct and indirect effects of the number of pods/plant, 100-seed weight and harvest index on seed yield/plant over seasons is given in Table 6 and Figure 1. 100-seed weight was had the highest positive direct effect (0.663) on seed yield/plant followed by Number of pods/plant (0.389). Abo-Hegazy *et al* (2012), Mekonnen *et al* (2014) and Sharma *et al* (2014) also observed positive direct effects of number

of pods/plant on seed yield/plant. Chowdhury *et al* (2019) indicated positive direct effect of number of pods/plant and 100-seed weight on seed yield/plant. Harvest index showed negative direct effect on seed yield. Alok Kumar *et al* (2017) and Sakthivel *et al* (2019) found that harvest index displayed highest positive direct effect on seed yield/plant. From these results, it noticed that direct selection of number of pods/plant and 100-seed weight for the improvement of seed yield/plant in lentil would be more effective. Indirect effects of number of pods/plant via seed index and harvest index were 0.109 and – 0.049, respectively. 100-seed weight showed indirect effects on seed yield/plant via number of pods/plant and harvest index were 0.064 and – 0.126, respectively. However, indirect effects of harvest index on seed yield/plant via number of pods/plant and seed index were 0.075 and 0.335, respectively.

In this study, the residual effect (0.683) showing that the previous traits contributed less 40% of variability in seed yield/plant studied in the current path analysis. In addition, the remainder traits were had low correlation with seed yield/plant. This may be due to many causes such as may be other causal factors (traits) that not involved in the analysis contribute more towards yield and sampling error. Das and Sarma (2015) and Sakthivel *et al* (2019) stated that the residual effect of phenotypic path was 14.94%, indicating major contribution of the traits under study toward the causal relationships, and hence most of the variation in yield.

Table 5. Phenotypic correlation coefficient between each pairs of six traits over the three growing seasons.

Traits	Days to heading	Plant height	No. of pods plant[-1]	100-seed weight	Seed yield plant[-1]	Harvest index
Days to heading	-	- 0.471	- 0.516	- 0.196	- 0.465	- 0.992
Plant height		-	0.719	0.397	0.141	0.323
No. of pods plant[-1]			-	0.164	0.449	0.194
100-seed weight				-	0.601	0.505
Seed yield plant[-1]					-	0.161
Harvest index						-

Table 6. Path coefficient analysis of seed yield/plant and its components over the three seasons.

Effect	Combined over seasons
Correlation between no. of pods/plant and seed yield/plant	0.449
Direct effect of no. of pods/plant on seed yield/plant	0.389
Indirect effect of no. of pods/plant on seed yield/plant via seed index	0.109
Indirect effect of no. of pods/plant on seed yield/plant via harvest index	- 0.049
Total	0.449
Correlation between seed index and seed yield/plant	0.601
Direct effect of seed index on seed yield/plant	0.663
Indirect effect of seed index on seed yield/plant via harvest index	0.064
Indirect effect of seed index on seed yield/plant via no. of pods/plant	- 0.126
Total	0.601
Correlation between harvest index and seed yield/plant	0.161
Direct effect of harvest index on seed yield/plant	- 0.250
Indirect effect harvest index on seed yield/plant via no. of pods/plant	0.075
Indirect effect of harvest index on seed yield/plant via seed index	0.335
Total	0.160
Residual effect	0.683

Conclusion

In this investigation, the genotypes showed a wide genetic diversity for all traits under study. The genotypes X2012-S-291 and Flip 2003-37L were found promising and could be take steps as new lentil varieties for Upper Egypt based on seed yield/plant, 100-seed weight, number of pods/plant and flowering. Phenotypic correlation showed that seed yield/plant was positive correlated with plant height, number of pods/plant, pod weight, 100-seed weight, seed yield/plot and harvest index, indicating that these components are most analysis 100-seed weight and number of pods/plant were the most important traits for seed yield improvement.

important of yield. However, most of traits such as days to flowering and maturity, plant height, no. of pods/plant, 100-seed weight, seed yield/plot and harvest index registered high heritability, reflecting low environmental effects. Number of branches/plant, pod weight and seed yield/plant showed moderate heritability, in addition, biological yield/plant recorded low heritability, showing high environmental effects on These traits. Therefore, selection based on these yield contributing traits . might be fruitful in lentil breeding program.

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