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Research Article
Evaluation of Some Lupin Genotypes Using Different Agro-morphological, Statistical and Chemical Methods

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Abstract

Background and Objective: Lupin (*Lupinus albus* L.) is an annual grain-legume widely harvest and cultivated in Egypt and also worldwide. Lupin seeds are utilized as food for the human and livestock nutrition. The objective of this investigation was to evaluate the performance of 50 lupin genotypes for yield, yield components and chemical compositions. **Materials and Methods:** Fifty lupin genotypes were collected from different regions in Egypt and Australia to evaluate and determine the relationships between lupin yield and yield components in a randomized complete blocks design (RCBD) with 3 replications and to show the efficiency of components on seed lupin yield by using different statistical procedures (correlation and cluster analysis). **Results:** Highly significant differences were found between the 2 seasons for number of pods/plant, number of seeds/plant, seed yield/plant, seed index and seed yield/plot), indicating wide variation among seasons and there were no differences between morphological characters (plant height and plant height from nod). The seed chemical analysis showed that the genotypes differed in their biochemical composition for moisture, protein, fat, fiber, ash and carbohydrate. Seed yield/plant was significantly and positively correlated with No. branches/plant (r = 0.609**), No. of pods/plant (r = 0.885**), No. of seeds/plant (r = 0.713**), seed index (r = 0.709**) and plot weight (g) (r = 0.884**). The cluster analysis showed that Fayed 3 and Abo-Soeir 2 genotypes were with very low seed yield/plant. And Sakolta, Edfo and X1/90/72 genotypes showed highest protein content. **Conclusion:** Based on the results, agreed upon that high lupin seed yield of genotypes could be obtained by selecting breeding materials with high number of seeds/plant, high number of pods/plant and genotypes with highly protein seed content for improving lupin breeding programs.

Key words: *Lupinus albus*, genotypes, yield, yield components, chemical compositions, correlation, cluster analysis

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Lupin (*Lupinus albus* L., 2n = 50) is a member of the Leguminosae family[1-3]. It is an annual grain legume crop widely grown in Egypt and other parts of the world. The genus includes over 300 species, with two geographically separated centers of diversity, the Mediterranean region and the Andean-Central American area[4-7]. The genetic diversity of lupin and other species of *Lupinus* has been characterized using morphological and agronomical attributes[8].

Lupin is an important grain legume because it has a high seed protein content compared to temperate legumes, which in some species is even higher than soybean[9]. About 85% of the world's lupin seeds are grown in Western Australia. To improve lupin crop and achieve the mentioned goals there is an essential need for a wide range of germplasm collection in addition to the available genotypes. Evaluation of such collected materials must be carried out and screened under different environmental conditions based on morphological, physiological, agronomical and auto ecological characteristics[10-12] and seed protein electrophoresis[13].

The species of the genus *Lupinus* probably have a polyploidy origin and they have different chromosomes numbers (*Lupinus angustifolius* 2n = 40, *Lupinus mutabilis* 2n = 48, *Lupinus albus* 2n = 50, *Lupinus luteus* 2n = 52)[14].

Yield is a complex character determined by several variables[15]. Hence, it is essential to identify the characters having the greatest influence on yield and their relative contributions in yield variation. That is useful in choosing selection criteria for breeding.

Lupin seeds are rich in protein, minerals and fibers. Protein content of white lupin seed (33-47%) is higher than other legumes and close to the soy protein content. Lupin proteins contain high amount of lysine and low amount of sulphur-containing amino acids[16]. The hull constitutes considerable part of the lupin seeds (20%) with a high content of dietary fiber and other valuable source of health promoting ingredients especially antioxidants[17]. Lupin seeds with 34.44-39.42% dietary fiber content (3.64-5.21% soluble and 30.80-34.22% insoluble) may also be a potential source for the production of dietetic food[18]. The present study was undertaken to investigate the relationship among lupin species collected from different region of Egypt using morphological and chemical traits and to evaluate yield, yield components of 50 important lupin genotypes grown under different Egyptian environmental conditions.

MATERIALS AND METHODS

Plant materials

Study area: The experimental genetic materials comprised of 50 lupin (*Lupinus albus* L.) genotypes from 10 Egyptian Governorates and Australia (44 Egyptian landraces and 6 Australian landraces), they were used as treatments and evaluated in the study compared with the improved commercial variety Giza 1 obtained from the Legumes Research Department in cooperation with Seed Technology Research department at Giza, Field Crops Research Institute, Agricultural Research Center, Egypt, from 2017/2018 and 2018/2019. The code number and origin of the genotypes are presented in Table 1.

Experimental design and cultivation practices: This investigation was carried out at the Experimental Farm of Giza Agricultural Research Station, Agricultural Research Center (ARC), Egypt, (30°02'N Latitude and 31°13'E Longitudes, Altitude 22.50 m), during the 2 successive growing seasons 2017/2018 and 2018/2019.

Two field experiments were carried out during 2017/2018 and 2018/2019 winter growing seasons. The randomized complete blocks design (RCBD) with 3 replications was used in each experiment. The experimental plot consisted of 3 rows, 60 cm apart and 3 m long (5.4 m^2 size), with single seeded hills, 20 cm apart in one side of ridge. Sowing dates were 8th and 9th of November in the 2 successive seasons, respectively. The crop was subjected to recommended package of agronomic and plant protection practices to obtain a healthy crop. Calcium super phosphate Fertilizer (15.5% P_2O_5) was applied during soil preparation at the rate of 30 kg fed^{-1} P_2O_5 and nitrogen fertilization was applied at a rate of 15 kg fed^{-1} as urea (46.5%).

Data collection

Seed yield and its related characteristics: Data of seed yield and yield components were recorded on plants randomly selected from the middle row. Observations were recorded on ten randomly selected plants in each genotype/replication for the following traits: Plant height (cm), height of first nod (cm), number of branches/plant, number of pods/plant, number of seeds/plant, seed yield/plant (g), seed index (100-seed weight-g) and seed weight/plot (g).

Table 1: Code and the origin of studied lupin genotypes

No.	Genotype	Origin
1	Fakous 3	Sharkia-Egypt
2	Fakous4	Sharkia-Egypt
3	Meet Ghmer	Dakahlia-Egypt
4	Ismailia 1	Ismailia-Egypt
5	Ismailia 2	Ismailia-Egypt
6	Fayed 1	Ismailia-Egypt
7	Fayed 3	Ismailia-Egypt
8	Kantara 2	Ismailia-Egypt
9	Ismailia 3	Ismailia-Egypt
10	Abo-Soeir 1	Ismailia-Egypt
11	Abo-Soeir 2	Ismailia-Egypt
12	Algeerb 1	Ismailia-Egypt
13	Algeerb 2	Ismailia-Egypt
14	Badrashein	Giza-Egypt
15	El-Aiat	Giza-Egypt
16	Family 2	Giza-Egypt
17	Family 4	Giza-Egypt
18	Family 11	Giza-Egypt
19	Family 12	Giza-Egypt
20	Local 12	Giza-Egypt
21	Local 20	Giza-Egypt
22	Line 6	Giza-Egypt
23	Line 15	Giza-Egypt
24	Line 21	Giza-Egypt
25	X1/90/72	Giza-Egypt
26	Benisalh	Fayoum-Egypt
27	Beni-Suef 1	Beni-Suef-Egypt
28	Beni-Suef 3	Beni-Suef-Egypt
29	El-Minia	El-Minia-Egypt
30	Sohag	Sohag-Egypt
31	Sakolta	Sohag-Egypt
32	Quena	Quena-Egypt
33	Issna 1	Quena-Egypt
34	Issna 2	Quena-Egypt
35	Issna 6	Quena-Egypt
36	Issna 7	Quena-Egypt
37	Kous 1	Quena-Egypt
38	Kous 3	Quena-Egypt
39	Kous 4	Quena-Egypt
40	Kous 5	Quena-Egypt
41	Belbies 9	Quena-Egypt
42	Aswan 1	Aswan-Egypt
43	Edfo	Aswan-Egypt
44	Kiev Mutant	Australia
45	Butter Cup	Australia
46	Piscovij	Australia
47	75 B 15.17	Australia
48	75 B 9.15	Australia
49	P 20950	Australia
50	Giza 1	Egypt

Sources: Department of Food Legume Crops Research, FCRI, ARC, Egypt, Department of Seed Technology Research, FCRI, ARC, Egypt

Chemical characters: After harvest, chemical properties A.O.A.C. methods were followed for determinations of moisture content, protein (Kjeldahl method using a conversion factor of 6.25), ash, fiber and fat content of the seed samples[19]. The carbohydrate content was determined as the weight difference using moisture, total protein, lipids and ash content data. Each sample was analyzed in triplicate and the values were then averaged.

Statistical analysis: The analysis of variance (ANOVA) of the obtained data was carried out according to the procedure described by Snedecor and Cochran[20] for the randomized complete block design using MSTAT-C computer program (Michigan State University)[21]. The combined analysis of variance was done, for all traits, following the method described by Snedecor and Cochran[22], based on a randomized complete block design. Bartelett's test[23] was done before applying the combined analysis to test the homogeneity of variances of both seasons. The effect of genotypes and seasons and their interactions on lupin genotypes was measured. Duncan's multiple range test (DMRT)[24] at 5% level of probability was used to detect the significant differences among genotype means.

The estimates of simple correlation coefficients were computed among seed yield/plant and other studied characters according to Steel and Torrie[25].

Cluster analysis: Cluster analysis was performed using the package SPSSver. 18 statistical software. Clustering was done with the hierarchical Ward method. Data were standardized for clustering by choosing the "Standardize Data" option. In this study, seasons and varieties were clustered using seed yield/plant and protein content because genotypes were improved for dual purposes, as yield and protein content.

RESULTS

Mean performance: The agronomic performance of 50 lupin genotypes was compared in order to employ the most successful genotype(s) in a breading program for the improvement of new lupin cultivars (Table 2).

Firstly, the homogeneity of error terms over the 2 seasons, for all studied traits, indicated the validity of performing the combined analysis. The combined analysis of variance over the 2 seasons revealed significant differences among genotypes for all studied traits indicating wide genetic variation among genotypes. And this provides basis for selection among these genotypes. The combined analysis of variance (Table 2) for seed yield/plant and other agronomic traits showed significant genotype effects for agronomic traits. Also, indicating that lupin genotypes were highly variable in performance for agronomic traits during the 2 years trial.

Table 2: Effects of seasons and mean values of seed yield and its related characters as affected by lupin genotypes over 2017/2018 and 2018/2019 seasons

	Characters							
Variables	PLH (cm)	PLH from nod (cm)	Number of branch/plant	Number of pods/plant	Number of seeds/plant	Seed yield/plant (g)	Seed index (g)	Seed yield/plot (g)
Season								
2017/2018	124.53	54.53	3.07	17.60	52.78	23.93	34.67	651.46
2018/2019	124.49	54.97	3.39	19.29	57.58	29.67	36.53	662.80
Significance	ns	ns	*	**	**	**	**	**
Genotypes								
Fakous 3	130.70	60.80	3.70	20.00	60.40	27.00	31.30	239.30
Fakous 4	117.90	47.70	3.70	18.50	55.20	25.40	36.90	244.50
Meet Ghmer	123.80	54.60	3.40	17.20	62.00	28.00	33.60	549.90
Ismailia 1	108.10	38.60	2.50	15.10	40.70	19.60	28.10	259.80
Ismailia 2	125.00	55.00	4.30	16.20	51.30	20.50	33.40	274.50
Fayed 1	119.50	50.00	3.20	14.00	36.10	25.40	32.10	360.10
Fayed 3	124.90	55.20	3.30	13.00	28.30	14.00	26.20	604.10
Kantara 2	123.50	54.10	3.30	19.30	61.70	26.50	35.50	424.90
Ismailia 3	131.50	61.80	3.50	19.50	64.90	29.00	35.30	379.90
Abo-Soeir 1	124.10	54.60	3.00	14.20	42.40	22.40	33.40	364.90
Abo-Soeir 2	120.90	51.00	3.10	13.40	24.80	11.20	30.90	269.90
Algeerb 1	122.70	52.60	3.40	16.90	46.40	27.50	39.00	534.40
Algeerb 2	113.00	43.30	2.40	24.40	85.10	30.20	38.10	494.70
badrashein	118.30	48.30	3.20	16.80	79.70	31.60	33.70	860.30
El-Aiat	129.10	59.80	3.90	14.80	76.30	28.20	34.30	950.00
Family 2	132.30	62.40	3.30	25.00	63.40	39.40	36.10	729.60
Family 4	110.10	40.40	2.50	18.20	79.30	36.00	42.20	840.20
Family 11	123.40	53.40	3.30	18.80	41.80	23.00	35.10	965.10
Family 12	137.50	67.70	3.10	15.70	45.70	21.10	36.30	790.30
Local 12	114.20	44.70	2.50	14.00	51.50	30.70	38.70	959.80
Local 20	105.50	36.10	2.20	18.50	49.80	26.20	40.70	719.70
Line 6	103.10	33.60	2.20	16.20	43.60	21.70	40.80	1129.50
Line 15	107.50	37.70	1.80	15.40	47.70	28.60	37.40	829.90
Line 21	137.60	67.90	2.50	15.00	40.90	20.80	43.10	925.00
X1/90/72	139.10	69.40	3.20	18.30	38.70	19.30	38.70	945.00
Benisalh	141.40	71.20	4.00	17.50	51.10	30.00	36.20	810.40
Beni-Suef 1	135.00	65.70	4.00	21.00	58.00	32.00	40.70	638.30
Beni-Suef 3	127.00	57.10	3.30	24.00	41.00	25.30	38.50	689.90
El-Minia	117.30	47.70	2.90	19.60	47.90	27.60	38.60	865.30
Sohag	115.60	46.20	2.60	20.20	57.20	30.90	43.90	814.90
Sakolta	127.10	57.50	4.20	17.00	39.70	23.50	39.80	875.20
Quna	118.50	48.50	3.00	15.20	37.60	18.70	31.90	635.00
Issna 1	103.30	33.60	3.90	17.00	63.20	22.10	35.10	159.90
Issna 2	110.80	41.10	3.30	21.60	73.70	31.80	31.30	265.00
Issna 6	112.30	41.90	3.50	22.00	59.60	32.10	33.20	649.50
Issna 7	121.40	52.10	3.40	22.40	65.80	26.80	33.30	395.10
Kous 1	133.30	63.40	3.80	19.50	61.90	31.00	36.80	765.30
Kous 3	140.50	70.50	3.50	20.10	64.50	24.80	34.90	869.80
Kous 4	144.20	74.30	4.20	22.60	69.30	35.40	32.20	650.00
Kous 5	144.40	74.60	4.30	27.50	58.50	32.90	36.40	791.60
Belbies 9	136.50	66.80	3.40	17.00	72.10	30.20	34.10	550.20
Aswan 1	131.50	61.40	3.40	15.60	67.40	28.00	31.40	920.20
Edfo	123.30	53.40	3.70	16.20	60.70	32.90	33.20	508.00
Kiev Mutant	127.60	57.70	3.10	22.00	64.60	26.20	35.90	1087.80
Butter Cup	131.00	60.70	3.50	21.40	62.00	28.30	38.60	800.00
Piscovij	115.90	46.00	3.00	18.70	59.60	30.20	34.90	985.30
75 B 15.17	131.50	61.70	2.30	16.90	39.00	22.70	35.70	644.80
75 B 9.15	135.40	66.00	3.10	17.70	42.50	21.90	35.10	869.90
P 20950	139.30	69.40	3.70	22.00	66.10	25.20	35.30	770.10
Giza 1	118.60	48.60	2.20	19.40	58.60	36.70	32.10	199.80
Minimum	103.10	33.60	1.80	13.00	24.80	11.20	26.20	159.90
Maximum	144.40	74.60	4.30	27.50	85.10	39.40	43.90	1129.50
SD	10.98	10.93	0.60	3.25	13.66	5.61	3.64	259.93
CV (%)	8.81	19.96	18.51	17.61	24.75	20.91	10.22	39.55
Mean	124.50	54.80	3.20	18.50	55.20	26.80	35.60	657.10
$LSD_{0.05}$	2.278	2.407	0.670	2.502	3.613	2.292	2.259	39.28

ns: Non-significance, *,**Significance at 5 and 1% probability level, respectively

The range of measurements, their averages, standard deviation and coefficient of variation of yield and yield components across the 2 seasons are shown in Table 2. Based on the results of this study, no significant differences were found between seasons for plant height and plant height from nod, significant differences were found for number of branches/plant (3.07 and 3.39) and highly significant differences were found for number of pods/plant (17.60 and 19.29), number of seeds/plant (52.78 and 57.58), seed yield/plant (23.93 and 29.67), seed index (34.67 and 36.53) and seed yield/plot (651.46 and 662.80), indicating wide variation among seasons.

The results in Table 2 showed a significant different response to the studied genotypes for plant height that ranged from 103.1-144.4 cm. Genotypes (Kous 5, Kous 4, Benisalh and Kous 3) exerted taller plants compared with other genotypes as well as the check variety. This was true in both seasons. Whereas, the shorter genotypes were Line 6, Issna 1, Local 20, Line 15 and Ismailia 1 genotypes. This indicates that the plant height was much under control of the genetic background of lupin genotypes.

Data in Table 2 indicated that the studied lupin genotypes exhibited significant differences in height from node which ranged from 33.6-74.6 g and genotypes Kous 5, Kous 4, Benisalh and Kous 3, showed the same response for plant height character that was highly significant differences with the other genotypes. On the other hand, also the shorter genotypes were Line 6, Issna 1, Local 20, Line 15 and Ismailia 1 genotypes that gave the shortest height of plant height from node (cm). The results showed significant differences for the number of branches/plant of lupin genotypes. Kous 5, Ismailia 2, Sakolta and Kous 4 genotypes appeared to have the highest number of branches/plant than the other genotypes, but the lowest number of branches was exhibited by Line 15, Local 20, Giza 1 and Line 6 (Table 2).

The results also showed wide averages of number of pods/plant differed widely among the tested genotypes ranging from (13.0-27.5) pods for Line Fayed 3 and Line Kous 5, respectively (Table 2). There was also a wide variation in number of seed/plant between lupin lines and check variety all over the 2 seasons. Line Algeerb 2 numbered the maximum seeds/plant recording 85.1, which differed significantly with other genotypes. On the other hand, lines Abo-Soeir 2 had the lowest number of seeds/plant recording 24.8 in both seasons.

The results in Table 2 showed that the lupin genotypes exhibited significant differences in seed yield/plant which ranged from (39.4-11.2 g). Family 2 significantly surpassed all the other lines and check variety. In the contrary, lines Abo-Soeir 2 recorded the lowest seed yield/plant.

Seed index (SI): Seed index (100-seed weight) showed that significant variation was found among genotypes in both seasons, indicating the existence of a wide genetic variation among these genotypes. Averaged values for this trait ranged from 26.2-43.9 g for Fayed 3 and Sohag, respectively.

Seed yield/plot: Results indicated also that there was a wide variation in seed yield/plot. Line 6 and Line Kiev Mutant yielded the maximum seed yield/plot recording 1129.5 and 1087.8 g, respectively which differed significantly with other genotypes. Line 6 and Kiev Mutant surpassed the remaining genotypes for all other yield.

Seed chemical composition: Chemical properties AOAC methods were followed for determinations of moisture, protein, ash (Kjeldahl method using a conversion factor of 6.25) and fat content of the samples. The gross seed chemical composition analysis (on dry matter basis) of 50 lupin genotypes under study is given in Table 3. All genotypes differed significantly in all seed chemical characters.

Moisture content (%): Results in Table 3 showed that moisture content in the seeds was in range 8.06-9.32%. The highest values were recorded by lines Kous 5, Badrashein and Family 12, while the lowest values for lines X1/90/72 and Fakous 3.

Protein content (%): The highest protein content was found in the lupin line X1/90/72 from EL-Giza (27.82%) and the lowest protein content recorded for Piscovij (20.40%) from Australia.

Fat content (%): The lowest fat content was found in the seeds of Beni-Suef 3 line (3.52%) and 75 B 15.17 line from Australia (3.69), while the highest fat content was in the Ismailia 2 lines and Belbies 9 (5.89 and 5.65%, respectively).

Fiber content (%): Results in Table 3 showed the fiber content (%) of the tested genotypes seeds. That the highest fiber content was found for lines Kous 1 and Belbies 9 (16.13 and 15.84%, respectively), whereas, the lowest fiber content values was recorded for Ismailia 2 line (11.22%) and Fakous 4 line (11.54%).

Table 3: Seed chemical composition of lupin genotypes

	Characters content (%)					
Genotypes	Moisture	Protein	Fat	Fibers	Ash	Carbohydrate
Fakous 3	8.07	23.59	5.27	13.41	3.14	46.31
Fakous 4	8.27	24.22	5.02	11.54	3.92	47.01
Meet Ghmer	8.28	24.19	4.62	14.40	3.69	45.33
Ismailia 1	8.27	25.02	5.09	12.16	3.24	46.82
Ismailia 2	8.63	23.62	5.89	11.22	3.47	48.22
Fayed 1	8.52	22.02	4.46	13.16	4.16	47.96
Fayed 3	8.38	22.17	4.29	12.78	3.25	48.92
Kantara 2	8.61	23.21	4.57	14.22	3.82	46.08
Ismailia 3	8.31	23.69	4.89	12.25	3.41	47.85
Abo-Soeir 1	8.25	25.21	4.34	14.31	4.15	44.33
Abo-Soeir 2	8.30	24.67	5.61	13.10	3.65	44.64
Algeerb 1	8.62	23.24	4.28	14.27	3.25	46.74
Algeerb 2	8.29	21.43	4.13	14.14	3.54	48.57
badrashein	9.26	25.71	4.63	13.20	4.16	43.33
El-Aiat	8.68	23.19	3.81	15.27	3.87	45.21
Family 2	8.51	25.95	5.17	15.28	3.85	41.76
Family 4	8.21	22.94	4.94	15.13	3.44	45.54
Family 11	8.17	24.73	3.81	12.96	3.34	47.36
Family 12	9.10	23.72	4.32	13.28	3.17	47.00
Local 12	8.50	23.68	4.97	12.87	3.34	47.68
Local 20	8.35	25.68	4.24	13.44	3.38	45.11
Line 6	8.17	22.12	4.71	13.14	3.75	48.11
Line 15	8.32	23.89	5.08	12.40	3.19	47.92
Line 21	8.55	23.04	5.31	15.75	3.94	44.01
X1/90/72	8.06	27.82	4.99	15.12	3.87	40.24
Benisalh	8.50	24.17	4.27	13.25	3.59	46.61
Beni-Suef 1	8.23	25.33	4.30	14.53	2.78	45.54
Beni-Suef 3	8.19	22.17	3.52	13.19	4.18	48.75
El-Minia	8.44	23.24	4.44	15.33	3.80	45.12
Sohag	8.56	24.34	4.30	12.67	2.85	48.04
Sakolta	8.45	26.79	5.08	15.38	2.64	44.13
Quna	8.23	25.26	4.99	15.37	3.41	43.35
Issna 1	8.43	22.25	4.94	13.30	3.64	48.17
Issna 2	8.40	24.21	5.38	15.20	3.38	44.05
Issna 6	8.76	24.30	4.77	14.93	3.21	44.61
Issna 7	8.40	25.38	4.43	14.51	3.71	44.22
Kous 1	8.52	24.07	4.84	16.13	2.83	44.68
Kous 3	8.55	24.35	4.35	15.73	4.23	43.57
Kous 4	8.21	21.50	3.93	13.30	3.80	49.83
Kous 5	9.32	23.27	4.21	14.28	3.62	45.89
Belbies 9	8.85	21.45	5.65	15.84	3.55	44.89
Aswan 1	8.56	25.30	4.23	15.65	2.93	44.04
Edfo	8.28	26.87	4.72	15.59	3.84	41.07
Kiev Mutant	8.30	24.20	4.42	14.31	3.52	45.54
Butter Cup	8.17	22.10	4.31	12.40	4.24	49.53
Piscovij	8.39	20.40	4.57	14.89	2.79	49.37
75 B 15.17	8.57	25.99	3.69	13.55	3.25	45.55
75 B 9.15	8.67	25.80	4.35	13.32	3.96	44.73
P 20950	8.48	24.74	4.36	14.36	4.33	44.20
Giza 1	8.26	22.90	5.30	14.53	3.46	45.87
Minimum	8.06	20.4	3.52	11.22	2.64	40.24
Maximum	9.32	27.82	5.89	16.13	4.33	49.83
SD	0.27	1.56	0.52	1.22	0.42	2.16
CV (%)	3.16	6.49	11.19	8.72	11.88	4.72
Mean	8.45	23.98	4.64	14.01	3.55	45.87
$LSD_{0.05}$	0.315	0.598	0.352	0.561	0.218	0.826

ns: Non-significance, *,**significance at 5 and 1% probability level, respectively

Ash: Seed mineral elements content (%) of lupin genotypes under this study is presented in Table 3. Results showed that the lowest value of mineral elements content was found in line Sakolta (2.64%) while, the highest values were observed in lines P 20950 from Australia (4.33%), buttercup from Australia also (4.24%) and Kous 3(4.23%).

Total carbohydrates: Higher carbohydrate content of lupin genotypes under this study was observed in lupinline Kous 4 (49.83%), Butter cup (49.53%) and Piscovij (49.37 %), however, the lowest carbohydrate content (%) was found in the seeds of lines X1/90/72 and Edfo (40.24 and 41.07%, respectively) (Table 3).

Correlation coefficients: Correlation coefficients between the studied characters are presented in Table 4 that showed the most important relationships were those between seed yield/plant and each of number of branches/plant (r = -0.609**), number of pods/plant (r = 0.885**), number of seeds/plant (r = 0.713**), seed index (r = 0.709**) and plot weight (r = -884**). Plot weight had highly significant positive correlation with all agronomic characters except number of branches/plant has a significant correlation (r = -0.157*). The relationships between seed chemical composition, only protein and carbohydrate contents showed highly significant negative correlation (r = -0.716**), fiber and ash showed significant and negative correlation (r = -0.189*). Highly significant and positive correlation was observed between number of moisture and fat and ash (r = 0.272** and 0.375**, respectively) and positive significant correlation between fat and ash (r = -0.1.4*). The partitioning of these correlations showed that pods/plant, seeds/plant and seed index exhibited high direct effects on seed yield/plant and seed yield/plot.

Cluster analysis: Since the aim of the present study was to evaluate the 50 genotypes regarding their yield, yield components and chemical composition, seed yield/plant (g) and protein content (%) were chosen and utilized in the cluster analysis, the cluster analysis, on the basis of selection indices, was used to classify genotypes into different groups.

Seed yield/plant (g): Fifty genotypes in this study (Fig. 1) were divided into 4 separate groups which involved 31, 13, 4 and 2 genotypes, respectively. The 1st group consisted of genotypes No. 40, 43, 27, 35, 14, 34, 41, 46, 26, 30, 37, 20, 9, 23, 12, 29, 3, 42, 15, 45, 2, 6, 28, 49, 38, 21, 44, 8, 36 and 1 in A section of the cluster diagram with average 20.07 g/plant. The 2nd group consisted of genotypes No. 33, 48, 22, 18, 47, 10, 31, 5, 24, 19, 4, 25 and 32 in B section of the cluster diagram with average

Table 4: Simple correlation coefficients among studied characters derived from 50 lupin genotypes, evaluated across 2 consecutive seasons (2017/2018 and 2018/2019)

Parameters	Plant height	Plant height from nod	Number of branches/plant	Number of pods/plant	Number of seeds/plant	Seed yield/plant	100-seed weight	Plot weight	Moisture	Protein	Fat	Fibers	Ash	Carbohydrate
Plant height	1.000	0.997**	0.542**	0.261**	0.032	0.069	0.022	0.214**	0.169*	0.126	-0.197*	0.027	0.148*	-0.223**
Plant height from nod		1.000	0.542**	0.269**	0.035	0.073	0.036	0.215**	0.166*	0.127	-0.203*	0.018	0.145*	-0.225**
Number of branches/plant			1.000	0.270**	0.611**	0.609**	-0.147*	0.157*	0.149*	0.049	-0.042	0.116	0.058	-0.062
Number of pods/plant				1.000	0.780**	0.885**	0.752**	0.840**	0.010	-0.084	-0.216**	-0.034	0.055	0.010
Number of seeds/plant					1.000	0.713**	0.724**	0.905**	0.116	-0.202*	-0.036	-0.091	0.046	-0.050
Seed yield/plant						1.000	0.709**	0.884**	0.094	-0.128	-0.067	-0.044	-0.070	-0.036
100-seed weight							1.000	0.447**	-0.017	0.003	-0.126	0.090	-0.055	0.028
Plot weight								1.000	0.113	0.071	-0.340**	0.072	-0.042	-0.096
Moisture									1.000	0.100	0.272**	-0.050	0.375**	-0.004
Protein										1.000	0.122	0.136	0.038	-0.716**
Fat											1.000	0.125	0.140*	-0.153*
Fibers												1.000	-0.189*	-0.082
Ash													1.000	-0.065
Carbohydrate														1.000

*,** Significance at 0.05 and 0.01 probability levels, respectively

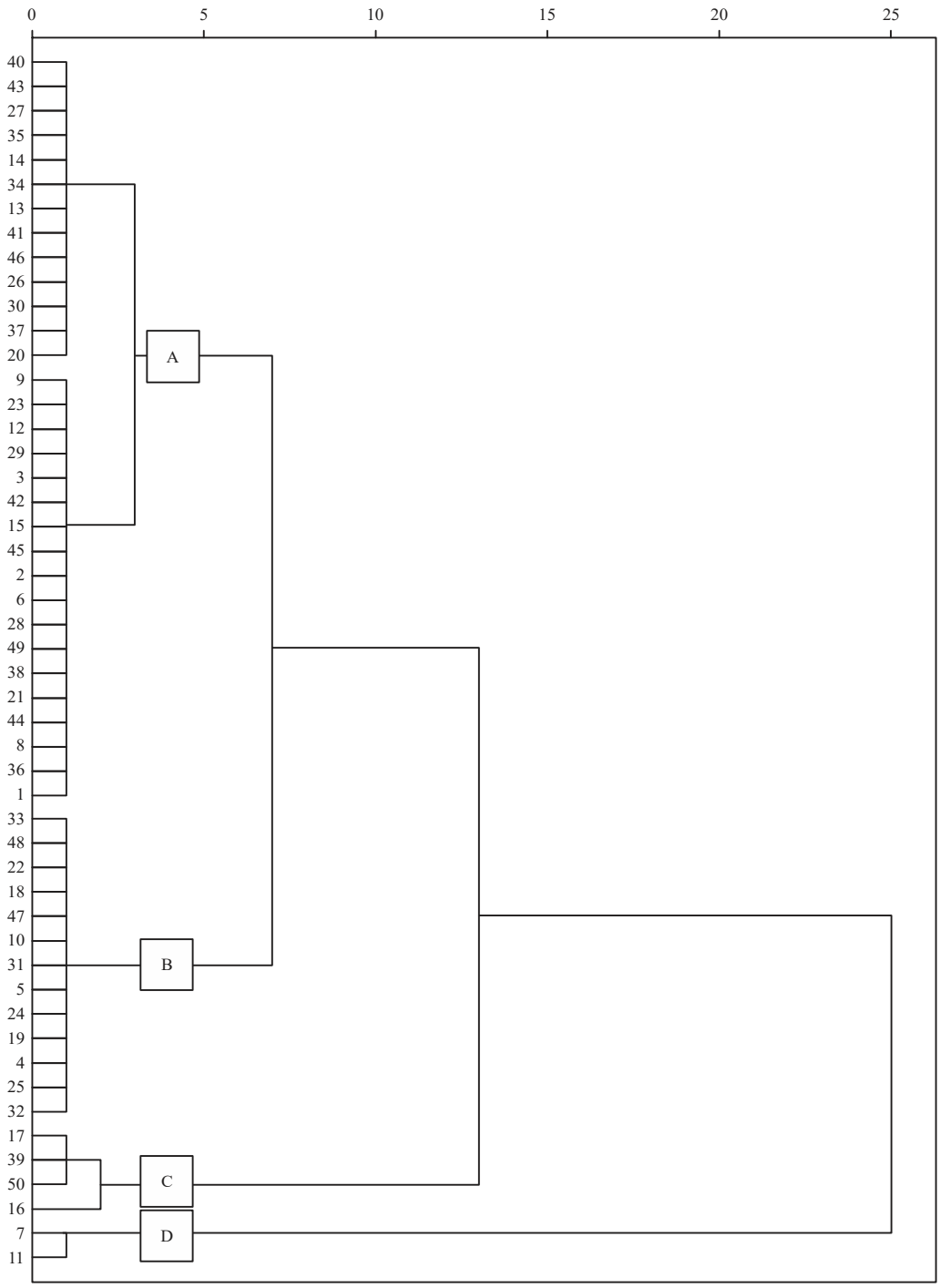

Fig. 1: Dendrogram from cluster analysis based on seed yield/plant of 50 lupin genotypes in both seasons 2017/2018 and 2018/2019

17.31 g/plant. The 3rd group consisted of genotypes No. 17, 39, 50 and 16 in C section of the cluster diagram with the highest average 22.20 g/plant. The 4th group consisted of genotypes No. 7 and 11 in D section with lowest seed yield/plant all over the 2 seasons with average 14.18 g/plant.

Protein content (%): Fifty genotypes in this study (Fig. 2) were divided into 4 separate groups, which involved 26, 9, 11 and 3 genotypes, respectively and ungroup genotype No. 46. The 1st group consisted of genotypes No. 12, 29, 40, 8, 15, 17, 50, 24, 1, 5, 9, 20, 19, 23, 18, 49, 11, 30, 38, 35, 3, 44, 2, 34, 26 and

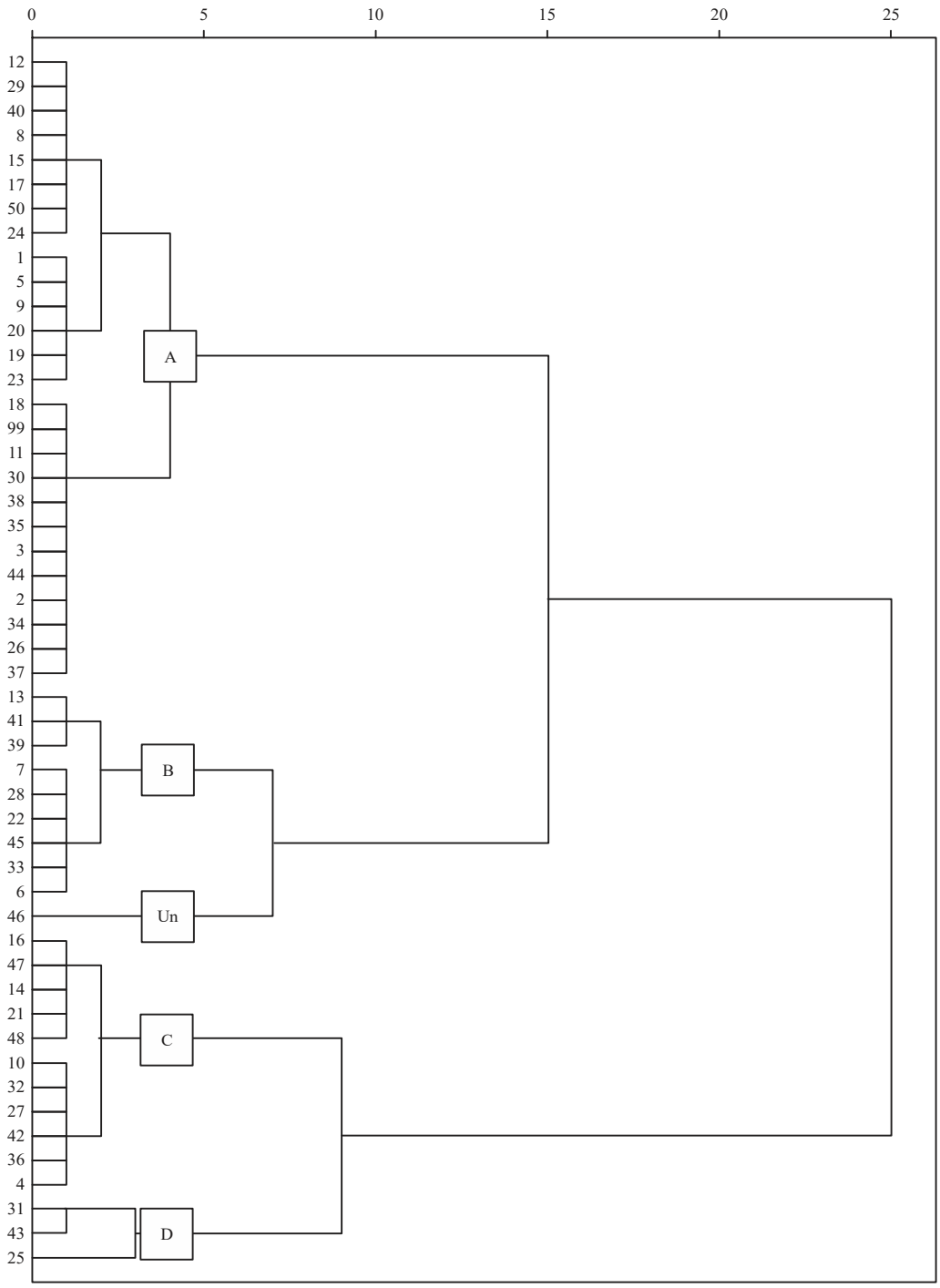

Fig. 2: Dendrogram from cluster analysis based on seed protein content of 50 lupin genotypes in both seasons 2017/2018 and 2018/2019

37 in A section of the cluster diagram with average 23.82% protein. The 2nd group consisted of genotypes No. 113, 41, 39, 7, 28, 22, 45, 33 and 6 in B section of the cluster diagram with average 21.91 (%) protein. The 3rd group consisted of genotypes No. 16, 47, 14, 21, 48, 10, 32, 27, 42, 36 and 4 in C section of the cluster diagram with protein average 25.51%. The fourth group consisted of genotype No. 31, 43 and 25 in D section of the cluster diagram with protein content (26.79, 26.87 and 27.72%, respectively) in D section with highest protein content (27.16%) all over the 2 seasons.

DISCUSSION

The results indicate that lupin genotypes were highly varied in performance for agronomic traits during the 2 season trial. The presence of variability in crop is important for genetic studies and consequently improvement and selection programs. It is clear magnitude as a parent in lupin development breeding programs. These results are in agreement with those reported by Julier *et al.*[26], Raza and Jqrnsgard[27] and Lara-Rivera *et al.*[28].

Lupin is a good source of nutrients, not only proteins but also lipids, fiber, minerals and vitamins. There are variations in the protein content between species and cultivars as a result of the characteristics of the growing conditions and soil types[29] from 28-48%. The mean value of fat in *L. albus* grown in different parts of the world[30] is 13%. Protein content of dry seed was not affected by growing environment, growing environment had significant effects on contents of total sugar, amino acids, oil, fatty acids and minerals[31]. Significant variation existed among 12 lupin genotypes for various traits when composition of seed produced in Virginia was evaluated.

According to literature, lupin seed protein has a relatively good amino acid profile with high content of arginine amino acid (4.10-11.20 %), leucine (7.50-9.40%), lysine (4.30-5.20%) and phenylalanine (3.00-6.80%). Among pulses, lupin ranked the 3rd one in protein quality after soybean and chickpea[32]. The results of the seed chemical composition of lupin genotypes under this study are in agreement with those reported by Naczk *et al.*[33], Martínez-Villaluenga *et al.*[34] and Lara-Rivera *et al.*[28], who found the corresponding protein content (dry basis) ranged from 28.4-36.6%. Similar results of protein content were reported by Porres *et al.*[35] The least content of protein was observed for line Piscovij from Australia (20.40%).

Lupinus mutabilis sweet seeds are one of the richest in fats (13-23%), whereas, the content of fat in other species such as *L. albus* (5-14%), *L. luteus* (5-7%) and *L. angustofilius* (4-8.5%) was found to be lower[36]. In general, the content of fat in lupin is relatively high and only a few pulses like soybean exceed lupin in this respect. The content of fat in lupin is ranked third after ground nut and soybean among the legumes. The high fat content confers a high energy value on lupin meal as food and feed. As dietary oil, lupin compares favorably with soybean and rape seed oils[37].

For fiber content results are in agreement with those reported by Phan *et al.*[30] However, Sujak *et al.*[38] reported crude fiber values similar to those found in the present study (11.6-14.1%), when evaluating 8 distinct genotypes of lupin, in Poland. It means that we can use the introductions in improvement breeding programs. Results of the seed chemical composition of lupin genotypes under study are in agreement with those reported by and Lara-Rivera *et al.*[30], who found the ash content ranged from 3.1-3.5%. The results for carbohydrate concentration reported in this study are similar to those reported for other cultivars of *L. angustifolius* (41.0-51.0%)[38,39].

Therefore, this study showed that selection for yield in lupin may be done through number of pods/plant, number of seeds/plant, seed index and seed yield/plant characters that may be considered as practical selection criteria for improving lupin cultivars in breeding programs. These results are in agreement with Herbert[40], Huyghe[41], López-Bellido *et al.*[42], Naguib[43]. From the results of correlation coefficients it can be concluded that indirect selection for any character with a significantly positive correlation with yield would improve the productivity of lupin crop.

The cluster analysis, on the basis of selection indices, was used for to classify genotypes into different groups[44]. These results show that the cluster analysis can segregate separately the exact genotypes in yield potential and protein content of both seasons and has the ability to distinguish all genotypes. Cluster analysis on the basis of evaluation new cultivars indices was used by some researchers[44,45] in evaluating lupin genotypes for yield and yield components.

CONCLUSION

Wide agro-morphological and biochemical differences among lupin genotypes were recorded, it will be useful to identify promising genotypes for yield potential and quality to use direct as new cultivars or introduce in breeding program. The lupin selected genotypes demonstrated significant differences and showed superiority in most of the studied characters except PLH and PLH from node, the highest seed yield genotypes were Family 2, Giza 1, Family 4 and Kous 4. While the highest seed protein content genotypes were X1/90/72, Edfo, Sakolta, 75 B 15.17and Family 2. This indicates the potential of such genotypes in lupin breeding programs. These genotypes provide a basis for development breeding programs of locally-adapted lupin cultivars in Egypt.

SIGNIFICANCE STATEMENT

This study reveals some of the most promising genotypes of lupin that can be used in breeding programs in the Arab Republic of Egypt to produce new cultivars, either this study will help the researcher to improve the lupin cultivars through selection or hybridization programs.

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