



Selection of Lentil (*Lens culunaris* L.) Lines Grown at Different Sowing Dates for Their Precocity and Their Agronomic Performance under Semi-arid Climate of Tunisia

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ABSTRACT

Background: In Tunisia, water deficit and heat stress during the end of cycle are more frequent and causes significant yield losses. Selection of short cycle lines could be a good solution to escape the effect of heat and drought during the end of cycle. Furthermore, there is little published information on the effect of the sowing date on yield and its components in lentils. The aim of this study was to investigate the effect of the sowing date on yield and its components of some lentil lines. The best productive and early lines will be selected and therefore proposed for registration in the official catalog of plant varieties. The availability of these varieties to farmers could increase lentil production.

Methods: Sixteen genotypes of lentil out of which 14 were advanced lines and 2 were checks varieties were used in this study. The field experiment was conducted during the 2017-2018 cropping season at Kef research station located in a semi-arid zone in north western Tunisia. Genotypes were sown on December 15th, 2017 and February, 7th, 2018. Seventeen agro-morphological parameters were recorded.

Result: Based on agro-morphological analysis, lentil lines exhibited considerable genetic variability. Among the tested lines, L3 line seem to be the earliest lines. It showed high yield as well in timely and late sown dates. This line deserves more attention to develop short-cycle and high yielding variety.

Key words: Agronomic traits, Lentil (*Lens culinaris* L.), Precocity, Selection, Semi-arid, Sowing date.

INTRODUCTION

Lentil (*Lens culinaris* Medik) is a self-pollinated, annual, cool season and diploid legume with a relatively larger genome size of 4 Gbp (Arumuganathan and Earle, 1991). It is a good source of protein, dietary fibre and essential minerals and therefore, has the potential to be used as a staple food crop for eradicating the hidden hunger (Gautam *et al.* 2018). Furthermore, lentil contributes to the fertility and improvement of soil structure and to the enhancement of the productivity of cropping systems through the fixation of atmospheric nitrogen through the symbiotic relationship with the bacterium *Rhizobium leguminosarum*.

In Tunisia, lentils are cultivated in arid and semi-arid areas. In these areas, with low rainfall, this crop could constitute one of the cultural alternatives for enhancing the value of the farm's land. The average yield of this specie is low, fluctuating and remain insignificant. These fluctuations in yields are attributed to abiotic constraints which slow down its development, in particular water deficit during the end of cycle which is more frequent in Tunisia and which causes significant yield losses. Selection of short cycle lines could be a good solution to escape the effect of heat and drought during the end of cycle. Shrestha *et al.* (2006) reported that in Mediterranean zone, lentil is facing to an intermittent drought during the vegetative growth and terminal drought throughout their reproductive period when temperatures are ever-increasing and rainfall is declining. Shrestha *et al.* (2006) have shown that water stress during the reproductive

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phase negatively affects the yield components, in particular the number of flowers, the number of pods, the number of grains per pod as well as the harvest index.

In Tunisia, lentil acquires importance in the national legume improvement program by developing improved high yielding lentil varieties. In addition to varietal selection, research should be directed more towards the development of appropriate cultivation techniques for increasing lentil

yields, especially the date and density of sowing. Results of Sen *et al.* (2016) and Ugwuoke *et al.* (2021) showed that cultural practices in particular the sowing date and dose and planting distance and seed rate are among the parameters that affect the growth and yield of plants.

Matthews and Caffery (2011), show that an optimum sowing date can maximize yield potential and minimize disease levels. Sowing early can expose the crop to more rain, which can increase the risk of disease. Early sowing date also increases crop biomass, which subsequently increases the risk of lodging. Late sowing date can result in shorter plants, but can reduce vegetative water use and disease exposure. Furthermore, lentils are not competitive with weeds, therefore, the choice of the sowing date will be one of the solutions to solve this problem. The aim of this study was to investigate the effect of the sowing date on yield and its components of some lentil lines. The best productive and early lines will be selected and therefore proposed for registration in the official catalog of plant varieties.

MATERIALS AND METHODS

Experimental procedure

Sixteen genotypes of lentil out of which 14 were advanced lines and 2 were checks varieties were used in this study. These lines were originated from crosses made at ICARDA and were subsequently selected in the national lentil genetic improvement program (Table 1). The field experiment was conducted during the 2017-2018 cropping season at Kef Research Station (INRAT) located in a semi-arid zone in north-western Tunisia. Experiment was laid out in a randomized split-plot design with three replications. Lines were sown at two sowing dates: Timely sown (December 15th, 2017) and late sown (February, 7th, 2018). The plot size was 4 rows of 4 m long and 0.5 m between rows. The climatic condition of the experimental station is presented

Table 1: Name and pedigree of the tested genotypes.

Genotypes	Pedigrees
FLIP2004-53L	ILL 4400 × ILL 6199
FLIP2012-244L	ILL7711 × ILL5480
FLIP2013-66L	ILL7121 × ILL 1005
FLIP2013-15L	ILL8066 × ILL6024
FLIP2014-25L	ILL9977 × ILL1005
FLIP2012-232L	LL7617 × ILL5883
FLIP2012-56L	ILL6024 × ILL8009
FLIP2014-60L	ILL4605 × ILL7723
FLIP2012-71L	ILL7949 × ILL8072
FLIP2003-55L	ILL6783 × ILL98
FLIP2013-70L	ILL7537 × ILL7711
FLIP96-15L	ILL 6209 × ILL 5671
FLIP2012-196L	ILL590 × ILL8113
FLIP2012-21L	ILL6129 × ILL1005
Siliana	ILL4400 × ILL5582
Kef	78S26002 (ILL5882)

in (Table 2). Seventeen agro-morphological parameters *viz.*, the plant height at flowering (PHF), biological yield per plant (BYP), number of branches per plant (NBP), number of productive branches per plant (NPBP), first pod level (FPL), number of pods per inflorescence (NPI), number of pods per plant (NPP), pods weight per plant (PWP), number of seeds per pod (NSPo), number of seeds per plant (NSP), grain yield per plant (GYP), straw yield per plant (SY), harvest index (HI), 1000 seed weight (1000SW), grain yield per ha (GY/ha), number of days until flowering (NDF) and number of days until maturity (NDM).

Data analysis

Data were subjected to analysis of variance. Relationships between traits was investigated using simple correlation coefficients. Data is subjected to a principal component analysis (PCA). These analyses were carried out by the XLSTAT software.

RESULTS AND DISCUSSION

To determine the magnitude of genetic variation, morphological evaluation is an important step in description and classification of genotypes (Zubair *et al.* 2007). Analysis of variance of agro-morphological traits showed significant differences between the tested lines for most of traits (Table 3). This indicated that in this set of materials considerable genetic variability exists, which has great significance to the plant breeder as it plays a crucial role in framing a triumphant breeding program as well as improvement of these traits through selection. Diversified germplasm possessing different desirable traits may prove useful for incorporation of these traits in the lentil improvement programme as confirmed by Gautam *et al.* (2014). Moderate to high variability was observed for the majority of the studied parameters *viz.*, number of days to flowering (87.3-119 days), number of days to maturity (117-166 days), plant height at flowering (19.3-35.3 cm), number of branches per plant (2-8), number of productive branches per plant (1.7-7 branches), first pod level (11-26.7 cm), number of pods per plant (10.7-53.7 pods), grain yield per plant (0.2-1.6 g per plant), straw yield per plant (1.3-6.7g per plant), 1000 seeds weight (29.3-60 g) and harvest index (10-44%) (Table 4). Furthermore, analysis of variance of agro-morphological traits showed significant effects of sowing date.

Regarding the phenological parameters, analysis of the variance of the number of days at flowering showed a highly significant genotype effect and a sowing date effect. In case of late sowing, the number of days until flowering and the number of days until maturity has been significantly reduced by 19.6 and 38 days, respectively, compared to early sowing. Among the tested lines, L3 line showed a high yield in both timely and late sowing. This line was also seems to be the earliest. This line deserves more attention and will be useful in the choice of parents in variety improvement programs aiming the selection of varieties simultaneously with high yielding and short-cycle. Similar results were observed by

Yannick *et al.* (2014) who showed that the sowing date influenced the number of days to flowering of a variety of cowpea (*Vigna unguiculata*). Analysis of the variance data showed highly significant genotype and sowing date effects on the number of days to maturity. The precocity of flowering or/and maturity is an important mechanism for escaping drought in a semi-arid climate such as in the Kef-Tunisia climate. This precocity is considered to be an important trait, which has an interesting effect on lentil yields, especially in areas where the distribution of rainfall and temperature variability affect the length of the development cycle. This was confirmed by Voisin and Salon (2004) who showed that in the Mediterranean climate, the plant must flower at the right time to avoid the damage caused by late spring frosts and by drought and high temperatures at the end of the cycle.

Concerning the growth parameters, analysis of the variance of the plant height at flowering, the number of branches per plant and the first pod level showed significant genotype and sowing date effects. Furthermore, results showed that timely sown date produced significantly higher values of growth parameters. These results were confirmed by Abdel-Rahman *et al.* (2002) who showed that the sowing date affects the plant height and the number of branches per plant. Regarding the yield and its components, results showed significant genotype and sowing date effects for most of these parameters. In this study, the 1000 seed weight which is an important component of the yield, as well as the number of seeds per pod were greatly influenced by the sowing date. Similar results were observed by Turk *et al.* (2003) who showed that the date of sowing significantly

Table 2: The maximum and minimum temperatures and rainfall recorded at the NRAT-Kef station during the 2017/2018 cropping season.

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June
Rainfall (mm)	96.2	23.2	32.4	31.6	41.4	34.5	29	4.2
T min (°C)	6.5	3.7	4.6	3.5	6.6	9.1	12.2	15.3
T max	16.2	12.8	16.1	13.3	18.6	23.6	26.2	30.9

Table 3: Analysis of variance for lentil agro-morphological traits.

Source	NDF	PHF	NDM	FPL	BYP	NBP	NPBP	NPI	NPP
Genotype (G)	9.95**	5.33**	8.03**	4.20**	1.34 ^{ns}	2.056**	1.45 ^{ns}	1.54 ^{ns}	2.65*
Sowing date (SD)	1750.22**	202.31**	6172.03**	17.54**	1.98 ^{ns}	23.84**	18.29**	18.24**	0.57 ^{ns}
G* SD	2.067*	4.78**	3.13**	1.25 ^{ns}	1.02 ^{ns}	2.012*	1.59 ^{ns}	1.84*	0.69 ^{ns}
Source	PWP	NSPo	NSP	1000SW	GYP	GY/ha	SY	HI	
Genotype (G)	1.06 ^{ns}	2.39**	1.84*	53.75**	1.45 ^{ns}	6.76**	1.63 ^{ns}	2.09*	
Sowing date (SD)	0.05 ^{ns}	20.64**	1.05 ^{ns}	48.83**	1.72**	335.41**	2.56 ^{ns}	0.44 ^{ns}	
G* SD	0.62 ^{ns}	0.83 ^{ns}	0.79 ^{ns}	5.33**	0.73 ^{ns}	5.69**	1.37 ^{ns}	1.41 ^{ns}	

*, **Significant at 0.05 and 0.01 probability level, respectively. ns: non significant.

Table 4: Estimates of mean and range for 17 agro-morphological traits in elite lines of lentil sown at timely (TSD) and late sowing (LSD) dates.

Parameters	Mean		Range	
	TSD	LSD	TSD	LSD
Number of days until flowering (NDF)	111.2	91.6	87.3-99.7	108-119
Plant height at flowering (PHF)	28.1	21.9	19.3-25	22.3-35.3
Number of days until maturity (NDM)	160.4	122.3	157-166	117-130
First pod level (FPL) (cm)	18.1	14.9	11.3-26.7	11.3-20.8
Biological yield per plant (BYP)	3.6	4.3	1.95-8.1	1.6-6.4
Number of branches per plant (NBP)	3.8	2.6	2.3-8	2-3
Number of productive branches per plant (NPBP)	3.5	2.5	2.3-7	1.7-3
Number of pods per inflorescence (NPI)	3.2	2.7	2.3-3.7	2-3.7
Number of pods per plant (NPP)	27.2	29.8	14.3-44.3	10.7-53.7
Pod weight per plant (PWP)	1.3	1.2	0.6-1.8	0.4-2.1
Number of seeds per pod (NSPo)	1.5	1.1	1-2	1-1.7
Number of seeds per plant (NSP)	30.6	26.6	16-45.3	6-53.3
1000 seed weight (1000SW) (g)	39	44	29-56	35-60
Grain yield per plant (GYP) (g)	1.01	0.8	0.38-1.4	0.2-1.6
Grain yield per ha (GY/ha) (Kg)	522.8	117	66.3-848.3	9-258.7
Straw yield per plant (SY) (g)	3.2	2.5	1.5-6.7	1.3-4.6
Harvest index (%) (HI)	27	25	9-44	9-38

affects grain yield, seeds weight and number of pods per plant of lentils. Significant variation in the number of seeds per pod suggests that pod fertility is a predominant trait and appears to be under genetic control as suggested by Mathura *et al.* (2006) and Million (2012). Harvest index is defined as the degree of translocation of assimilate to seeds. It shows efficiency in distribution of photosynthetic products into grain in plants. Our study showed a genotype effect on the harvest index. The lowest harvest index was obtained in case of late-sowing date (for L1 and L2 lines).

Information on nature and magnitude of association among different traits can be helpful in indirect selection of desirable traits with low heritability, simultaneous selection of several traits (Singh, 1972) and to avoid undesirable correlated changes in desirable traits during selection (Tyagi and Khan, 2010). Correlation study between grain yield per plant and its components traits (Table 5) *viz.*, plant height at flowering ($r = 0.34$), biological yield per plant ($r = 0.35$), the number of branches per plant ($r = 0.4$), the straw yield per plant ($r = 0.23$) and the number of days to flowering ($r = 0.23$) were found major yield contributing traits and can be given due emphasis during development of improved genotypes of lentil for rainfed condition of Tunisia. This important correlation between yield and the various parameters indicates that the yield is a quantitative multi-gene trait. Indeed, the selection for yield can lead to different effects on the other characters, so the selection of one character induces that of the other. These correlations are therefore tools for selecting traits in varietal improvement program.

Principal component analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation and also identifies plant traits that contribute most to the observed variation within group of genotypes. Results showed that the first two axes of the principal component analysis (PCA1 and PCA2) explained 66.9% of the total variability, with respectively 44.21% and 22.71%. Based on the principal component analysis, lentil genotypes were divided to 4 groups (Fig 1). The first group is positively correlated with the first two axes. This group is composed by L2, L5, L6, L9 and L15 lines. The second group is positively correlated with the first axis and negatively correlated with the second axis. It is composed by L1, L13 and L14 lines. The third group, composed by L3, L7, L8, L10, L11 and L16 lines, is negatively correlated with the first axis and positively correlated with the second axis. The fourth group gathered L4 and L12 lines is negatively correlated with the first two axes.

Results presented in (Table 6) showed that axis1 is positively correlated to pod weight per plant (P8) ($r = 0.93$), grain yield per plant (P11) ($r = 0.93$), first pod level (P5) ($r = -0.89$), number of seeds per plant (P10) ($r = 0.89$), number of pods per plant (P7) ($r = 0.88$), number of days to flowering (P16) ($r = -0.87$), grain yield per ha (P15) ($r = 0.84$), the number of days to maturity (P17) ($r = -0.83$), the harvest index (P13) ($r = 0.78$), the plant height at flowering (P1) ($r = -0.5$), 1000 seeds weight (P14) ($r = -0.4$). Axis 2 is correlated to biological yield

Table 5: Correlation between traits.

	PHF	BYP	NBP	NPBP	FPL	NPI	NPP	PWP	NSPo	NSP	GYP	SY	HI	1000SW	GY/ha	NDF
PHF	1															
BYP	0.68**	1														
NBP	0.96**	0.68**	1													
NPBP	0.12	0.27**	0.13	1												
FPL	0.36**	0.41**	0.38**	0.42**	1											
NPI	0.33**	0.37**	0.36**	0.47**	0.92**	1										
NPP	0.41**	0.30**	0.40**	-0.15	0.09	-0.01	1									
PWP	0.37**	0.33**	0.39**	-0.01	0.09	0.14	0.36**	1								
NSPo	-0.17	-0.05	-0.13	0.51**	0.18	0.33**	0.34**	0.08	1							
NSP	-0.04	0.004	-0.001	0.49**	0.21*	0.34**	0.26*	0.09	0.86**	1						
GYP	0.34**	0.35**	0.40**	0.19	0.02	0.06	-0.03	0.02	0.03	0.12	1					
SY	0.002	0.12	0.06	0.53**	0.23*	0.37**	0.32**	0.07	0.90**	0.91**	0.23*	1				
HI	0.06	0.08	0.10	0.46**	0.25*	0.37**	0.25*	0.11	0.83**	0.94**	0.15	0.93**	1			
1000SW	0.14	0.28**	0.15	0.96**	0.38**	0.42**	0.08**	-0.05	0.41**	0.38**	0.18	0.43**	0.34**	1		
GY/ha	-0.11	-0.09	-0.18	0.008	0.03	-0.06	0.20	-0.07	-0.19	-0.06	0.26*	0.24*	-0.09	0.34	1	
NDF	0.62**	0.51**	0.69**	-0.01	0.21*	0.23*	0.14	0.25*	-0.06	0.08	0.23*	0.17	0.19	-0.03	0.34**	1
NDM	0.03	-0.06	0.04	-0.18	-0.059	0.03	-0.17	0.17	0.41**	0.51**	0.06	0.49**	0.61**	0.32**	-0.10	0.20*

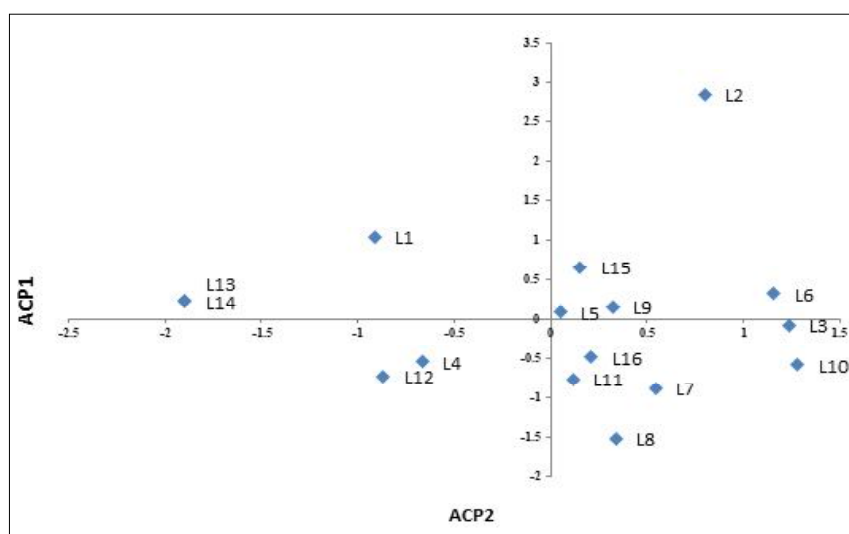


Fig 1: Distribution of lentil lines according to axes 1 and 2 of the principal component analysis.

Table 6: Correlation coefficients for principal components.

Parameters	Axe 1	Axe 2
PHF	-0.50	0.33
BYP	-0.03	0.86
BYP	0.06	0.86
NBP	0.39	0.79
FPL	-0.89	-0.08
NPI	0.23	-0.31
NPP	0.88	0.22
PWP	0.93	0.10
NSPo	0.02	-0.56
NSP	0.89	0.09
GYP	0.93	0.11
SY	-0.26	0.84
HI	0.78	-0.48
1000SW	-0.40	0.27
GY/ha	0.84	-0.22
NDF	-0.87	-0.01
NDM	-0.83	-0.31

per plant (P2) ($r = 0.86$), number of branches per plant (P3) ($r = 0.86$), straw yield per plant (P12) ($r = 0.84$), number of productive branches per plant (P4) ($r = 0.79$), number of seeds per pod (P9) ($r = -0.56$) and number of pods per inflorescence (P6) ($r = -0.31$). Sharma *et al.* (2020) also reported the lentil characters that had the highest weight in component first were plot yield, yield per plant, pods per plant, crop growth rate, biomass per plant, leaf area index and plant height.

CONCLUSION

Based on agro-morphological analysis, lentil lines exhibited considerable genetic variability. The provided information on the variability of the tested material allows us to conclude that the plant material contains a significant potential for

improvement. The L2, L3 and L13 lines were shown to be early. They can serve as a source of parents to improve the precocity of varieties. Among the tested lines, L3 line seem to be earliest lines. It showed high yield as well in timely and late sown dates. This line deserves more attention to develop short-cycle and high yielding variety. It will be tested for several years at different sites before being registered in the official catalog of plant varieties. The availability of this early material could increase lentil production and offers the producer an profitable benefit in their cropping systems.

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