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Impact of row spacing and seeding rate on yield components of lentil (*Lens culinaris* L.)

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Abstract - In Tunisia lentil (*Lens culinaris* L.) which is an annual grain legume, is included in cropping systems throughout the semiarid region but information on optimum plant population density was not well developed for this region. This study was conducted in kef (Northwest Semi-Arid region of Tunisia) in order to determine the impact of row spacing and seeding rate on yield and yield components of lentil. 'Siliana' lentil cultivar was sown at 17 and 34cm cm row spacing, and at three seeding rates (80, 120, 160 seeds/m^2). Analysis of variance showed that the effect of row spacing, plant seeding rates and interaction between them was significant on all traits show that was significant on all measured parameters except for 100- seed weight. Results show that 34cm row spacing and seed rate of 120 seeds/m^2 was found to be the best for lentil production in terms of biological and grain yields with 2119,2 and 903,9 kg/ha respectively. On the other hand, 17cm row spacing and 160seeds/m^2 affects negatively the yields and components.

Keywords: Lentil, *Lens culinaris* L, row spacing, seedling rate, yield, yield components.

1. Introduction

In Tunisia, lentil (*Lens culinaris* L.) is commonly grown under rainfall condition during winter on soils that conserve moisture from the preceding monsoon. This crop as characterized by its ability to enter into a symbiotic relationship with the *bactrium Rhizobium leguminosarum* in the fixation of atmospheric nitrogen. It helps in reducing the amount of added nitrogenous fertilizer to the plants. Total production of lentil in Tunisia in the year 2011-2012 was 1300 tons from an area of 3168acres with an average yield of 4.1 qx ha-1 (ONAGRI 2012). In Tunisia, lentil is grown in arid areas (Southeast) and semi arid. For this reason, it is exposed to less biotic stresses than other legumes. It is increasingly recognized that lentil offers most practical means of solving the protein malnutrition which has necessitated giving more efforts to improve and increase its production in the country. Seeding rate can have a major impact on production of lentil. Recommended seeding rates differ based on cultivar and seed size, location, soil moisture, and environmental conditions such as rainfall and temperature (McKenzie and Hill 1995). Boquet and Walker (1980) reported that sowing at a seed rate that result in optimal plant population density may reduce seed costs, lodging, and ameliorate disease problems. Too low and high plant population beyond a certain limit often adversely affects the crop yield. Number of plants per unit area influences plant size, yield components and ultimately the seed yield (Beech and Leach 1989). Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis. Optimum plant population density is an important factor to realize the potential yields as it directly affects plant growth and development. Many studies show that lentil yields are remarkably stable over a wide range of population densities. The plants are able to fill available space by initiating lateral branches and,

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thus, can compensate for poor emergence and thin stands (Morrison and Muehlbauer 1986). Silim et al. (1990) found that lentil yield increased up to 300 plants/m^2 after which it decreased. Seed rate is one of the main factors that have an important role on growth, yield and quality of lentil. Optimum spacing can ensure proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, water, land as well as air spaces. Spacing for line sowing is recommended to maintain the required number of plant population and to undertake intercultural operations for harvesting a higher yield. Seed rate has a major bearing on the yielding ability of any crop. Substantial yield increase of lentil can be achieved by using optimum seed rate (Malik and Singh 1996).Therefore, the present experiment was undertaken to study the effect of method of sowing and seed rate on the yield and yield components of lentil. The choice of sowing rate is an important agronomic practice influencing plant density and crop establishment. Lopez et al. (2005) reported that plant density can affect canopy development, radiation interception, dry matter production, and evaporation of water from the soil under the crop, weed competition, the development of fungal and viral diseases, podding and harvesting height, seed yield, and, ultimately, the probability of a crop in the farming system. There is limited information published on the optimum sowing rate and plant density for lentil in Tunisia. So, the objectives of this study were to determine optimal plant population densities for siliana Tunisian lentil variety grown in the Tunisia semiarid region.

2. Materials and methods

A field trial was carried out at Kef research station (INRAT) located in a semi-arid zone (36°14'N 8°27'E) in north-western Tunisia. Each trial was laid out in a randomized split-plot design with three replications. The main treatments were the susceptible row spacing widths (17 and 34cm) and the subplot treatments were seeding rates (80, 120, 160 seeds/m^2). Each row was 4m long. At full maturity, three sample plants were uprooted for data collection from each plot. The collected data for 6 different characters (plant height (P.H), pod number per plant (PN/P), grain number per plant (GN/P), biological yields per ha (BY/Ha), grain yields per ha (GY/ha), straw yields per ha (SY/ha), 100- seed weight (100 SW) were recorded. Finally, statistical analyses were performed by using ANOVA procedure in statistica software.

3. Results and Discussion

The effect of plant row spacing, plant seeding rates and interaction between them was significant on all measured parameters except for 100- seed weight (Table 1). Indeed, the vegetative (plant height) and reproductive yield (number of pods and seeds per plant, biological yields/ha, grain yields/ ha and 100- seed weight) were affected by plant population.

Table 1 Analysis of variance of plant height (P.H), pod number/ pl (PN/P) , grain number/ pl(GN/P), biological yields/ha (BY/Ha) , grain yields/ ha (GY/ha), straw yields/ha (SY/ha) and 100- seed weight (100 SW).

Characteristics	Row spacing (A)		Seeding rates (B)		Interaction A*B	
	M.S.	F value	M.S.	F value	M.S.	F value
P.H	21,125	13,703**	20,514	13,306**	7,292	4,730*
PN/P	20,056	15,696**	15,167	11,870**	8,389	6,565*
GN/P	24,5	17,640**	17,056	12,280**	11,167	8,040**
BY/Ha	1285811,7	31,930**	482687,03	11,986**	269733,813	6,698*
GY/ha	269014,18	24,419**	132140,01	11,994**	45897,523	4,166*
100SW	0,0089	0,1684ns	0,0622	1,1789ns	0,0089	0,1684ns

*, ** significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant (P>0.05). M.S. = Mean square.

3.1 Plant Height

Table 2 show that the average plant height was 24.9 and 27.1 respectively for 17cm and 34 cm. Indeed the average plant height was decreased 8.5 % as the row spacing was increased from 17 cm to 34cm.

Table 2 Mean comparisons of plant height, seed yield and yield components at row spaces treatments.

Row spacing (A)	P.H (cm)	PN/P	GN/P	BY/ha Kg/ha	GY/ha Kg/ha	100 SW (g)
A1 (17 cm)	27,1^b	7,8^a	8,6^a	1235,4^a	636,5^a	6,6^a
A2 (34 cm)	24,9^a	9,9^b	10,9^b	1769,9^b	881^b	6,7^a

Values within the same column followed by the same letters are not significantly different according to Duncan's multiple range test (*P* =0.05).

Table 3 show that plant height were increased by 10.8 % and 15.1 % as the seeding rate was increased from 80, 120 and 160 seeds/m^2 respectively. The data confirmed that changing the row spacing had shining influences on plant height at harvest, where it was increased by decreasing space between plants. This increase in plant height could be justified on the bases of increase in the number of plants per unit area coupled with high plant competition for light, resulting in taller plants as reported by Mekkei (2014). These results are consistent with the results of Habbasha et al. (1996) and Singh et al. (2003) who reported that increasing plant density increased plant height.

Table 3 Mean comparisons of plant height, seed yield and yield components at seeding rates treatments.

Seeding rates (B) (cm)	P.H (cm)	PN/P	GN/P	BY/ha Kg/ha	GY/ha Kg/ha	100 SW (g)
B1 (80 seeds/m^2)	23,9^a	8^a	8,7a	1180,4^a	587,7^a	6,5^a
B2 (120 seeds/m^2)	26,5^b	10,7^b	11,7^b	1613,1^{ab}	853,4^b	6,7^a
B3(160 seeds/m^2)	27,5^b	7,8a	8,8a	1714,5^b	835,1^b	6,7^a

Values within the same column followed by the same letters are not significantly different according to Duncan's multiple range test (P =0.05).

Table 4 show the average of plant height at different row spaces and seeding rates interactions treatments. Results show that the highest plant height was obtained at (17 cm row spacing and120 seeds/m^{2}combination) with 29,8cm and the lowest plant height (23.7cm) was produced at (34cm row spacing and 80 seeds/m^2 combination).

Table 4 Mean comparisons of plant height, seed yield and yield components at different row spacing and seeding rates treatments.

Row spacing (A) X Seeding rates (B)	P.H (cm)	PN/P	GN/P	BY/ha Kg/ha	GY/ha Kg/ha	100 SW (g)
A1xB1	24,2^a	8a	8,7a	986,3^a	491,1^a	6,7^a
A1xB2	27,2^b	8,3a	9^b	1106,9^{ab}	803^{cd}	6,7^a
A1xB3	29,8^c	7a	8^a	1613^{cd}	615,5^{ab}	6,5^a
A2xB1	23,7^a	8a	8,7a	1374,6^{bc}	684,3^{bc}	6,8^a
A2xB2	25,8^{ab}	13^c	14,3b	2119,2^e	903,9^{de}	6,7^a
A2xB3	25,2^{ab}	8,7a	9,7a	1816de	1054,8^e	6,5^a

Values within the same column followed by the same letters are not significantly different according to Duncan's multiple range test (P =0.05).

Shahram et al. (2012) reported that when plant density is too high, it encourages interplant competition for resources. Then, plant height will be affected by less light penetration in the crop canopy as well as increase in the competition for available nutrient which will affect plant branches. The plants which received less light increased the height of the main stem to compensate for this deficiency and to achieve more radiation. Ganjali and Majidi (2000) and Cho et al. (2004) also reported similar results, and they noted that plant height is increased under too high plant density due to competition for light interception. In this study, plant height was taller in higher plant population treatments due to more competition for light. Similar observations had been reported by Jasinska and Kotecki (1995); Felton et al. (1996); Khan et al. (2001) and Sharar et al. (2001). These authors noted that plant height increase with high densities.

3.2 Pod number per plant

Number of pods/plants, an important primary yield component, is the more unsteady attribute among yield components of legumes. Number of pods/plant, was affected significantly by different row spacing and seeding rate and their interaction (Table 1).Means comparison indicated that pod number per plant increased with the row spacing, so that the increase of row spacing from 17cm to 34cm increased pod number per plant by 35.5% (Table 2). On the other hand, number of pods and seeds/plant were tending to increase with increasing plant density up to a density threshold beyond which the number of pods/plants decreases. Indeed, results revealed that the increase in plant density led to the loss of pod number per plant, so that with the increase in population from 80 and 120 seeds/m^2, pod number per plant increased by 48.6%. However, at plant density higher than optimal (160 seeds/m^2) pod number per plant decrease (Table3). Similarly, Momoh and Zhou (2001) stated

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that the number of effective branches and pods per branch decreased with increasing plant density. These authors confirmed that the higher branching observed in wide row spacing was a major cause of the increased number of pods per pod. Results show that the maximum pod number per plant (13pods/plant) was recorded for 34cm row spacing and 120 seeds/m^2 interaction while the minimum average was recorded (5.7pods/plant) for 17cm row spacing and 160 seeds/m^2 combination. This loss of pod number per plant at lower row spacing and higher densities can be related to the intensified competition of plants and the decrease in over-ground space for light interception and branch-bearing as confirmed by Seyyed et al. (2014). This can be explained by the dominant effect of terminal bud lessens at lower densities and plants produce more auxiliary branches. So, they have better conditions for utilizing environmental conditions and produce more flowers. Consequently, pod number per plant increases. Habibzadeh et al. (2006) and Zabet et al. (2005) showed that intensified inter-plant competition on environmental factors and the shading of lower parts of the canopy at higher densities are the reasons for the decrease in pod number per plant of pulses. Our results are consistent with the results of the studies of Seyyed et al. (2014) on lentil. The effect of seedling rate on pod number per plant might be due to greater number of plants per unit row length, which might have adversely affected the pod development, hence, pods formation were comparatively less than that of low seeding rate which resulted in greater competition for light, space and nutrients. Idris (2008) indicated that increasing plant spacing increased number of pods per plant and consequently gave the highest seed yield.

3.3 Seed number per plant
The seeds number per plant is closely correlated with the number of pods per plant, and is, therefore, an important yield attribute. Seed number per plant increased by 31% when row spacing increased from 17cm to 34cm (Table 2). In parallel, different plant densities had significant differences in seed number per plant. Indeed, means comparison of seed number per plant showed that the increase in seedling rate from 80 and 120 seeds/m^2 increased seed number per plant by 49.3% (Table 3). Means comparison indicated that pod number per plant increased as the row spacing and seedling rate were increased. From a density threshold of 120seeds/m^2, number of pods/plant decreases (Table3). The highest number of grains per plant (14.7 seeds/ plant) obtained by row spacing of 34cm and seedling rate of 120 seeds/m^2 ,while the lowest average was recorded (6.7 seeds/ plant) for 17cm row spacing and 160 seeds/m^2 combination. Competition between lentil plants affects not only the pod number per plant, but also seed number per plant. This can be due to the limited light interception in high plant population density which caused increasing height and decreasing fertile nodes witch can has negative impact on seed number per plant. These results were agree with those of Wells (1993) who reported that plant spacing affects leaf area, light interception, and canopy apparent photosynthesis. Edwards et al. (2005); Boquet (1990) reported that light energy efficiency in photosynthesis depends on the plant density and transition of light to plant canopy.

3.4 Biological yields per hectare
Biological yield is sum total of all dry matter produced through physiological and biochemical processes occurring in the plant system. Data given in Table 1 showed that row spacing and seedling rate and their interaction significantly affected the biological yield. Table2 showed that maximum biological yield (1769.9 kg/ ha) was recorded in 34cm row spacing. While the lowest biological yield (1235.4 kg/ ha) was recorded in 17cm row spacing. Indeed, plants are able to fill available space by initiating lateral branches and, thus, can compensate for height row spacing. Different plant densities had also significant differences in biological yields per hectare. Indeed, Biological yields increased incrementally as seeding rates increased. Results of table3 showed that the increase in seedling rate from 80, 120 and 160 seeds/m^2 increased seed number per plant by 36.6 and 45.2 % respectively (Table 3). At densities higher than optimal, biological yield decrease. Indeed, with 34 cm row spacing, increasing in density caused an increasing at first of the biological yield and then decreasing at high density. The 34cm row spacing and seed rate of 120 seeds/m^2 was found to be the best for lentil production in terms of biological yields per hectare (Table4). Optimum plant population density is an important factor to realize the potential yields as it directly affects plant growth and development. When plants are widely spaced, biological yields tend to increase linearly with increase in plant density due to no or minimum competition between the adjoining plants. In this study, total biomass

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could be achieved through more plants with increasing plant population density. Similar result was also reported by Hosseini et al. (2001) in soybean. Application of low distances for planting rows or high plant densities increase speed of canopy closure and amount of solar radiation interception and therefore improves growth speed as reported by Neda and Mehrdad (2015). Ramroodi et al. (2008) showed that appropriate plant density is an important parameter affecting the yield of crops. In addition, optimum plant density is important considering the point that too much reduced plant density may reduce total yield due to reduced number of plant per unit area. Seemingly, the increase in plant density increased dry matter accumulation per unit area because of higher leaf area index and greater absorption of solar radiation.

3.5 Grain yields per hectare

Results showed that an increase in row spacing led to significantly higher Grain yields per hectare. Means comparison indicated that grain yields per hectare increased with the row spacing. The close row spacing of 34cm gave the maximum seed yield of 881 kg/ha. Indeed, on average, 34cm row spacing produced about 38.4 % higher seed yield than 17cm row spacing. Different plant densities had also significant differences in grain yields per hectare. Indeed, grain yields increased as seeding rates increased. Results of table3 showed that the increase in seedling rate from 80, 120 and 160 seeds/m2 increased seed number per plant by 45.2 and 40.1 % respectively (Table 3). At densities higher than optimal, biological yield decrease. Indeed, with 34 cm row spacing, increasing in density caused an increasing at first of the biological yield and then decreasing at high density. Substantial yield increase of lentil can be achieved by using optimum seed rate. Indeed, the 34cm row spacing and seed rate of 120 seeds/m2 was found to be the best for lentil production in terms of grain yields per hectare (Table 4). Optimum plant population density in lentil is an important factor to realize the potential yields as it directly affects plant growth and development (Turk et al. 2003; Saleem et al. 2012). Generally, grain yield was tending to decreasing with increasing sowing rates. The high yield resulted from higher number of pods and seed per unit area produced. However, the higher sowing rate causes higher inter-plant competition and results in poor individual plant as reported by BİÇER (2014). Selim (1999) reported that high plant density may lead to competition among plants and increase risk of disease and lodging of the crop, resulting in reduced grain yield. On the other hand, Salem et al. (2012) reported that low plant populations are unable to utilize the resources efficiently and often produce low yields. Parveen and Bhuiya (2010) reported that seed rate is one of the main factors that have an important role on growth, yield and quality of lentil. An optimum spacing can ensure proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, water, land as well as air spaces. Spacing for line sowing is recommended to maintain the required number of plant population and to undertake intercultural operations for harvesting a higher yield. The yield values obtained in the present study are lower than the average potential seed yields of this variety. This result was possibly due to the late sowing dates.

3.6 100- Seed weight (100 SW)

The results revealed that row spacing, plant seeding rates and interaction between them were statistically non- significant on 100- seed weight (Table 1). However, row spacing showed positive association with 100- seed weight. Maximum 100- seed weight (6.7g) was recorded in 34cm row spacing (Table 2). On the other hand, plant seeding rates showed positive association with 100- seed weight. Maximum 100- seed weight (6.7g) was recorded in both 120 and 160/m2 seeding rates (Table 3). Singh et al. (2003) reported that with the increase of seed rate 1000-seed weight decreased which is contradictory to the findings of the present study. This character 100 seed weight may be non susceptible to environmental conditions due to high heritability by comparison with plant height, number of pods per plant and seeds per plant as confirmed by Stoilova and Pereira (1999). 1000-seed weight was influenced significantly by the seeding densities. There has been a consistent decrease in the seed weight with increased seeding densities (Sharar et al. 2001).

4. Conclusion

The yield of lentil can be improved by planting of optimum density. In total, according to the results of the current study it is recommended to use 34 row spacing with the population of 120seeds/m2 in order to realize optimum yield of lentil in kef.

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