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Effect of Sowing Date and Plant Density on Yield and Yield Components of Lentil (*Lens culinaris* cv. Sistan)

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Authors' contributions

This work was carried out in collaboration between all authors. Author SGM designed the study and wrote the protocol and manuscript. Author MJS performed the statistical analysis and managed the literature searches. Author MRD managed the farm activity. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: This study was conducted to study the effects of sowing date and plant density on yield and yield components of lentil cv. Sistan.
Study Design: Experimental design was factorial based on randomized complete block with three replications.
Place and Duration of Study: The experiment was carried out in a personal farm in Zabol, Iran, in 2009.
Methodology: The factors included sowing date at four levels (November 21, December 5, December 19 and January 2) and plant density at four levels (18, 24, 36 and 71 plants. m^{-2}).
Results: The results of analysis of variance showed that sowing date significantly affected pod number per plant and per m^2, seed yield per unit area and per plant and harvest index, but its effect was not significant on seed number per pod, 100-seed weight and biological yield per unit area and per plant, while the change in plant density significantly affected all of them at 1% level. The interaction between sowing date and plant density did not significantly affect the measure traits. Means comparison showed that the delay in sowing

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from November 21 to January 2 decreased pod number per plant, pod number per m^2 and seed yield by 15.6, 14.7 and 10.3%, respectively. Also, with the increase in population from 18 to 72 plants. m^{-2}, pod number m^{-2} increased by 2.15 times and seed number per pod, seed yield and biological yield increased by 11.4, 104.4 and 178.9%, respectively, but pod number per plant and 100-seed weight decreased by 45.6 and 16.7%, respectively. The delay in sowing date as well as the increase in plant density/m2 significantly decreased harvest index.

Conclusion: In total, according to the results of the current study it is recommended to use sowing date of November 21 with the population of 72 plants. m^{-2} in order to realize optimum yield of lentil in Sistan, Iran.

Keywords: Lentil; plant density; sowing date; yield; yield components.

1. INTRODUCTION

The cultivation of lentil *(Lens culinaris*) and other pulses in semi-arid regions had many advantages because they partially supply their own N demand and the subsequent non-legume N demand by biological fixation of atmospheric N which reduces the required level of N fertilization [1,2]. Also, they break the life cycle of pests and diseases of cereals in single-cropping systems [3].

Given the importance of maximum utilization of environmental parameters during growth period, it is crucially important to choose an appropriate sowing date for any crop anywhere. Lentil planting at appropriate time allows its better-establishment before the commencement of growth-limiting temperatures.

Reference [4] was evaluated yield and yield components of some lentil genotypes to different planting dates in Zabol and concluded that grain yield, grain number per plant, pod number per plant, biological yield and harvest index were affected by planting dates.

Reference [5] reported that the best lentil sowing date was early-November in hot regions of Iran and early-March in Karaj, Iran and similar regions because of favorable weather. He studied the effect of sowing date and plant density on yield and yield components of lentil in Mashad, Iran, and observed that delayed sowing of spring lentil decreased its reproductive phase duration, seed yield, pod number per plant and seed number per pod because of the sudden increase in temperature during late-growing season. In a study on the effect of sowing date on lentil in Neishaboor, Iran, Reference [6] concluded that seed yield/ha, pod and seed number/plant and 1000-seed weight were higher at earlier sowing than those at later sowing dates.

Reference [7] studied some important agronomical traits of lentil in Karaj, Iran as affected by sowing date and plant density and found that the maximum yield and 100-seed weight were obtained at the first sowing date, i.e. early-December and the minimum ones were obtained at the last sowing date, i.e. early-February.

Reference [8] reported that out of three sowing dates of December 30, January 14 and February 3, the highest yield (1786 kg ha^{-1}) was obtained at the earliest sowing date. Additionally, delayed sowing decreased seed yield per plant, 1000-seed weight and pod number per plant. Also, Reference [9] mainly related the yield loss of lentil at delayed sowing to the decrease in pod number/plant, seed number/plant and 100-seed weight. The seed

yield loss of lentil as affected by delayed sowing was reported by Reference [10], too. Moreover, the decrease in biological yield of lentil at delayed sowing was confirmed by Reference [8] and Reference [11], too.

According to the report of Reference [11], delay in sowing of pea decreased its seed yield through shortening its growth period and the occurrence of drought and heat stress at the seed-filling stage. Also, delayed sowing of faba bean decreased yield and pod number per plant but did not significantly affect seed number per plant [12]. Also an increase in faba bean seed yield due to the production of more pods at earlier sowings was reported by Reference [13], too.

Appropriate plant density is another 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 [4].

In a study on the effect of population on the yield of pinto bean, Reference [14] showed that different plant densities had significant differences in their pod number per plant, seed number per plant, 100-seed weight and seed yield.

The studies of Reference [15] and Reference [16] respectively on bean and soybean indicated that 100-seed weight did not significantly change as the plant density was changed but Reference [17] reported that 100-seed weight of mung bean was affected by plant density. In a study on pinto bean, Reference [18] showed that plant density did not significantly affect seed number per pod. On the contrary, Reference [17] reported that the increase in population significantly decreased seed number of grain legumes per pod.

The current study was carried out to study the effect of planting date and plant density n on yield and yield components of *lentil* (*Lens culinaris* cv. Sistan) in Zabol region, Iran.

2. MATERIALS AND METHODS

The study was carried out in a personal farm in Zabol, Iran (Long. 30º54´24˝ E., Lat. 61º40´28˝ N., Alt. 496 m) in 2009-2010. The soil texture was loam-sandy whose physic-chemical attributes are shown in Table 1.

Table 1. Physical and chemical properties of the soil in the research field

Sampling depth	E.C. (ds. m^{-1})	Saturated soil pH	Total N (%)	Absorbable P(ppm)	Absorbable K (ppm)	Soil particle percentage		
						Sand	Silt	clay
0-20	2.3	6.8	0.06	15	120	50	37	13
20-40	3.6	6.3	0.03	12	90	47	43	10

It was a factorial experiment based on a randomized complete block design with three replications. The sowing date was one factor at four levels of November 21, December 5, December 19 and January 2 and plant density was the other factor at four levels of 18, 24, 36 and 72 plants. m^{-2}. Each plot included six 6-m-long rows with inter-row spacing of 35 cm. Based on soil analysis; 200 kg ha^{-1} ammonium phosphate was manually applied before sowing. The seeds of lentil (*Lens culinaris* cv. Sistan) were manually sown at the depth of 3-4 cm in the desired dates. To measure the yield components, 10 plants were randomly

selected from the middle four rows at the time of harvest after eliminating two marginal rows. Then, their yield components including pod number per plant, seed number per pod, seed yield per plant and single-plant biomass were measured. Finally, in order to compare the yields, when 50% of pods became yellowish to brownish, 3 m^2 with respect border effects were harvested. Then, they were exposed to sun in cannabis bags to have their seed moisture decreased. Afterwards, they were manually winnowed and their seed and hay moisture was weighed to determine their biological yield. Then, the seeds were separated from hay by screening and weathering, and seed yield per unit area was measured. Hundred-seed weight was measured by mean weight of five 100-seed samples randomly taken from the winnowed seeds. The harvest index (HI) was determined by:

HI= (grain yield/ biological yield) ×100

At the end, the data were analyzed by software MSTAT-C and the means were compared by Duncan Multiple Range Test at 5% level.

3. RESULTS AND DISCUSSION

As the results of the analysis of variance showed, sowing date significantly affected pod number per plant and per m^2, seed yield per unit area and per plant, and harvest index, but its effect on seed number per pod, 100-seed weight and biological yield per unit area and per plant was not significant, whereas all these traits were significantly affected at 1% level as plant density was changed. The interaction between sowing date and plant density significantly affected none of them (Table 2).

3.1 Pod Number Per Plant

Means comparison indicated that pod number per plant decreased with the delay in sowing, so that the delay in sowing from November 21 to December 5, December 19 and January 2 decreased pod number per plant by 2.8, 7.6 and 15.6%, respectively (Table 3). The reason of this subject can be related to the loss of plant height and branch number per plant and the shortening of reproductive phase. These results are in agreement with the results of studies of Reference [12] on winter faba bean and Reference [4] and References [8] and Reference [19] on lentil.

The 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 18 to 24, 36 and 72 plants. m^{-2}, pod number per plant decreased by 14.1, 23.6 and 45.6%, respectively (Table 4).

This loss of pod number per plant at higher densities can be related to the intensified competition of plants and the decrease in over-ground space for light interception and branch-bearing. 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. Some researchers believe that intensified inter-plant competition on environmental factors [20] and the shading of lower parts of the canopy [21] at higher densities are the reasons for the decrease in pod number per plant of pulses.

Table 2. Results of analysis of variance for the yield and yield components of lentil as affected by different levels of sowing date and plant density

Sources of variation	df	Means of squares						
		Pod number per plant	Pod number per m^2	Seed number per pod	100-seed weight	Seed yield	Biological yield	Harvest index
Replication	2	123.721^{ns}	149977.289^{ns}	0.115^{ns}	0.008^{ns}	14870.536^{ns}	253.952^{ns}	25.389^{ns}
Sowing date(A)	3	692.687*	669438.795*	0.242^{ns}	0.049^{ns}	40009.635*	19391.401^{ns}	69.82*
Plant density(B)	3	7607.937**	18631312.7**	0.416**	1.004**	915468.08**	12860247.4**	288.631**
A × B	9	26.605^{ns}	17678.511^{ns}	0.161^{ns}	0.015^{ns}	1205.615^{ns}	13696.11^{ns}	1.841^{ns}
Error	30	178.854	161633.643	0.085	0.073	13512.724	294704.246	16.296
C.V (%)-		12.84	11.67	23.45	13.26	13.48	23.56	10.34

** shows significantly different at the 5% probability level, and ^{ns} is not significantly different.*

Table 3. Means comparison for yield and yield components of lentil as affected by different levels of sowing date

Sowing date	Pod number per plant	Pod number per m^2	Seed number per pod	100-seed weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
November 21	111.37 a	3671.2 a	1.28 a	1.99 a	927.03 a	2339.53 a	42.23 a
December 5	108.27 a	3574.6 a	1.24 a	2.02 a	831.13 ab	2333.58 a	39.38 ab
December 19	102.95 ab	3401.6 ab	1.23 a	2.06 a	849.06 ab	2289.73 a	37.94 b
January 2	94.03 b	3132.8 b	1.23 a	1.79 a	790.17 b	2253.93 a	36.61 b

**Means, in each column, followed by similar letter are not significantly different at the 5% probability level*

Table 4. Means comparison for yield and yield components of lentil as affected by different levels of plant density

Plant density (plants. m^{-2})	Pod number per plant	Pod number per m^2	Seed number per pod	100-seed weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
18	131.53 a	2367.5 d	1.15 b	2.15 a	587.28 d	1316.95 c	44.54 a
24	113.00 b	2712.0 c	1.20 ab	2.13 a	695.16 c	1731.13 c	40.20 b
36	100.53 c	3618.9 b	1.29 ab	2.07 a	966.30 b	2494.95 b	38.75 b
72	71.58 d	5081.8 a	1.32 a	1.79 b	1200.65a	3673.73 a	32.68 c

**Means, in each column, followed by similar letter are not significantly different at the 5% probability level*

3.2 Pod Number per m^2

Means comparison showed that delayed sowing led to the loss of pod number per m^2 and increased plant density per m^2 led to its increase, so that with a 42-day delay in sowing from November 21 to January 2, pod number per m^2 significantly decreased by 14.7% from 3671.2 to 3132.8 (Table 3). Higher pod number per m^2 at earlier sowing might be related to the swift establishment of plants and the extension of photosynthesizing area under optimum conditions. As a result, more assimilates are produced and longer growth period allows the plants to have enough opportunity for branch-bearing and producing more reproductive organs. Water availability at optimum growth conditions ensures the effective transfer and allocation of assimilates, so that all these factors bring about an increase in flower and pod number per plant. Also, Reference [8] reported that delayed sowing of autumn lentil decreased pod number per m^2.

In addition, as plant density was increased from 18 to 72 plants. m^{-2}, pod number per m^2 increased from 2367.5 to 5081.8, i.e. a 2.15 times increase (Table 4). In other words, it can be concluded that although the increase in population from 18 to 72 plants. m^{-2} significantly decreased pod no. plant-1by 45.6%, in total it increased pod number per m^2 by 114.6%. So, the increased number of plants per unit area compensated the decrease in pod number per plant and increased pod number per m^2. These results are in agreement with the results of study of Reference [22] on navy bean.

3.3 Seed Number per Pod

Means comparison showed that the increase in population from 18 to 72 plants. m^{-2} significantly increased seed number per pod (Table 4). Although seed number per pod is the most stable yield component of pulses [20] and is rarely affected by agronomical and environmental parameters [23], probably in the current study, the severe decrease in pod number per plant under higher densities and the resulting intra-plant competition for receiving assimilates was the possible reasons for the 11.4% increase in seed number per pod. These results are consistent with the results of the studies of Reference [24] on lentil.

3.4 100-Seed Weight

Although in a study on lentil in Karaj, Iran, Yazdi Samadi and Peighambari [6] found that the highest and lowest 100-seed weights were produced at the first (early-December) and last (early-February) sowing dates, respectively, Reference [4] studied the effect of sowing date on lentil genotypes in Zabol and showed that 100-seed weight was not affected by sowing date. Also, the studies of Reference [12] on faba bean did not show significant differences in 100-seed weight of different sowing dates which confirm the results of the current study.

As means comparison indicated, population increase from 18 to 72 plants. m^{-2} significantly reduced 100-seed weight from 2.15 to 1.79 g, i.e. a 16.7% loss (Table 3). However, it should be noted that the populations of 18, 24 and 36 plants. m^{-2} were ranked in a same statistical group. The loss of 100-seed weight at the density of 72 plants. m^{-2} can be associated with the increase in the respiration of plant community due to more shading, inadequacy of assimilates during seed-filling period and partial increase in seed number per pod at higher densities. Seemingly, inter-plant competition decreases and more assimilates are allocated to seeds which increases their weight. Also, Reference [23] believed that 100-seed weight was a variety-specific attribute which was profoundly affected by genetic parameters, but its

quantity was determined by the conditions at maturity period, so that these conditions could change 100-seed weight up to 20-30%.

The results of the current study about the effect of plant density on 100-seed weight were consistent with the studies of Reference [7] on lentil and Reference [12] on faba bean.

3.5 Seed Yield

Means comparison showed that delayed sowing decreased lentil seed yield, so that seed yield decrease by 10.3% from 927 to 831.1 kg ha^{-1} with the delay in sowing from November 21 to January 2. In other words, it decreased by 2.28 kg ha^{-1} for each day delay in sowing (Table 2). The cause can be the decrease in branch number as well as yield components due to the shortening of growing season and the loss of photosynthetic potential of plants and also contemporaneous of growing period with long day. It appears that plants had longer growing season and longer period for utilizing solar radiation and nutrients at sowing date of November 21. Thus, they had the potential of producing more foliage which resulted in production of more assimilates. These assimilates were allocated to reproductive source and at the end, seed yield increased. In a study on the effect of sowing date on yield of lentil cultivars in India, Reference [9] concluded that one-month delay in sowing significantly decreased seed yield by 24.5%. The increase in seed yield at earlier sowing of lentil has been reported by Reference [25], Reference [8] and Reference [19], too.

Also, Reference [4] concluded that under delayed sowing of lentil, the plants did not have enough time for full establishment before the occurrence of chilling and also, they could not complete their full vegetative growth at the end of winter, when the hot season commenced, and necessarily started their reproductive growth which led to the loss of yield. Also, Acosta-Reference [26] indicated that delayed sowing of common bean reduced its dry matter production, leaf area index, leaf area duration, crop growth rate, net assimilation rate and hence, yield.

According to the results, as population was increased from 18 to 72 plants. m^{-2}, seed yield increased by 104.4% (Table 3). It appears that the increasing trend of seed yield with the increase in plant density was caused by effective utilization of solar radiation by biomass during growth period and photosynthetic capacity and production of more pods per unit area. In other words, it can be said that lentil seed yield has a direct relation with the number of pods per unit area so that as plant density is increased, seed yield increases in spite of the decrease in the number of pods per plant because of the increase in the number of pods per unit area. These results are in agreement with the results of the studies of Reference [4] on lentil and Reference [14] on pinto bean.

3.6 Biological Yield

Although the decrease in biological yield at delayed sowings has been confirmed by Reference [10], the results of this study showed non-significant effect of sowing date on lentil biomass production (in spite of the numerical decrease in biological yield as affected by the delay in sowing) (Table 2).

Means comparison showed that the increase in plant density increased biological yield, so that biological yield increased by 31.4, 89.4 and 178.9% as population was increased from 18 to 24, 36 and 72 plants.m^{-2}, respectively (Table 3). Higher biological yield at more densities can be related to greater number of plants 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. Reference [27] reported that out of the measured traits of lentil, biological yield had the greatest direct effect on its seed yield.

3.7 Harvest Index

Harvest index exhibited a decreasing trend with the delay in sowing, so that the highest harvest index (42.2%) and the lowest one (36.6%) were obtained at sowing dates of November 21 and January 2, respectively (Table 2). That is, more assimilates were allocated to reproductive organs at earlier sowings. The decrease in harvest index at delayed sowings could have been caused by the shortening of growing season and its impact on reproductive phase which brought about a decrease in the number of flowers and pods per plant.

Means comparison indicated that as plant density was increased, harvest index decreased, so that with the increase in population from 18 to 72 plants. m^{-2}, harvest index decreased from 44.5 to 32.7% (Table 3). It means that increase in plant density led to a decrease in the quantity of allocated assimilates to the seeds.

It seems that at higher populations, inter and intra-plant competition between vegetative and reproductive organs for assimilates intensifies and since reproductive buds are formed later than vegetative buds, the adverse effects of intensified competition impacts reproductive buds at the first place. On the other hand, the increased plant density increases respiration and decreases photosynthesis which leads to the decrease in the transfer of assimilates to seeds and consequently, harvest index loss. The studies of Reference [28] on corn suggested that although leaf area index and dry matter yield increased at higher densities, harvest index fell down because of the inter-plant competition.

4. CONCLUSION

It appears that the sowing date of November 21 had higher seed production potential than other sowing dates because of allowing the plants to complete their vegetative growth and to optimally use the resources as well as increasing their photosynthesis potential and dry matter accumulation. As well, the population of 72 plants. m^{-2} had higher seed production potential than other plant densities because of increasing the number of pods/m^2. Therefore, sowing date of November 21 with the plant density of 72 plants. m-2 is recommended for the cultivation of lentil cv. Sistan in Zabol, Iran.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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