

RESPONSE OF RAINFED CHICKPEA (*Cicer arietinum* L.) TO TWEEN ROW SPATIAL ARRANGEMENT AT MULTIPLE DENSITIES

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Plant density and arrangement are important factors affecting rainfed chickpea yield. A field experiment was conducted under the Eastern Mediterranean conditions for two consecutive growing seasons (2009-2010 and 2010-2011) to evaluate the effects of plant density (20, 25, 35 and 55 plants per m²) and spatial configuration (conventional single 36-cm row width vs 18-cm twin rows spaced 72-cm between paired-rows). The experiment was laid out in a randomized complete block design in a factorial arrangement with three replications. Light interception (LI) and leaf area index (LAI) were significantly affected by plant density. Twin-row arrangement had higher light interception efficiency (LIE) than the single-row. Plants grown in the higher plant densities had greater LAI and LI; however, they had inefficient use of incident solar radiation. The number of primary branches was significantly affected by both planting patterns and plant densities, but the number of secondary branches was significantly affected only by the plant densities. The number of pods and seeds/plant decreased with the increasing plant density. The highest seed weight/plant was recorded at the lowest density (20 plants/m²) while the lowest one was recorded at the highest plant density (55 plants/m²). Seed weight and harvest index in the twin row were significantly higher in twin row than in the single row.

Keywords: Chickpea, seed yield, leaf area index, light interception, planting pattern

INTRODUCTION

Chickpea is an important grain legume in the world with a notable production quantity after beans (FAO, 2011) and is consumed by both human and animal. Its yield potential is not revealed due to varied environmental conditions and agricultural practices. Therefore, it is important to understand the growth dynamics of chickpea for development of suitable crop management.

Chickpea, like other crops, competes for such sources as light, nutrient and water. Light is one of the most important factors affecting agricultural production among them since growth is governed by the ability of a crop to intercept light and to convert the intercepted light into biomass (Confalone *et al.*, 2010). Moreover, dry mass production of a crop is linearly related to the amount of solar radiation intercepted by the crop under stress-free environments (Tesfaye *et al.*, 2006).

The solar radiation, used for photosynthesis, can be exploited more effectively (Salisbury and Ross, 1992; Mwanamwenge *et al.*, 1997) especially in chickpea genotypes with non-horizontal leaves, resulting in more yield per unit area (Ball *et al.*, 2000) if optimum plant density is achieved. The plant density above the optimum not only decreases the seed yield of the crop because of inter-plant competition but also cause wastage of seed. Furthermore, net photosynthesis is decreased at the dense foliage because of lacking solar radiation of basal leaves (Pearce *et al.*, 1965). On the other hand, the sparse densities

cause the seed yield per unit area to decrease and also promote growth and development of weeds. Therefore, determination of optimum plant density can lead to more effective usage of incident solar radiation for photosynthesis (Leach and Beech, 1988) because of a linear relationship between yield and dry matter production (Miah *et al.*, 2003; Thomson and Siddique, 1997), and long canopy duration (Gifford and Evans, 1981).

Planting geometry can also be an important factor affecting yield and yield components. The studies, which have been recently conducted with various crop plants, indicated that more seed yield per unit area could be achieved and easier management of crops in twin row arrangement (Lanier *et al.*, 2004; Janovicek *et al.*, 2006).

Plant density and geometry affect light interception (LI), light interception efficiency (LIE) and leaf area index (LAI). Delagrangé *et al.* (2006) reported greater LAI at the increasing plant densities. Board and Harville (1992) stated LAI is the prevailing aspect responsible for greater LI in narrow rows. However, more studies are required concerning row arrangement owing to insufficient data for chickpea.

The purpose of the current study was to determine the response of rainfed chickpea to the twin row arrangement and multiple plant densities in a Mediterranean-type environment

MATERIALS AND METHODS

Culture and experimental design: The study was carried out at the experimental farm of Mustafa Kemal University during 2009-2010 and 2010-2011 growing seasons. The experimental area is located at the South of Turkey, with a geographical coordinates of 36°15'N 36°30'E. The chickpea variety "Cevdetbey 98" was sown 4 cm deep at four plant densities on November 24, 2009 and November 30, 2010. Treatments were arranged in a randomized complete block design with three replications. The experiment had two factors, namely planting arrangement (single and twin row) and plant density (20, 25, 35 and 55 plants per m²). Single rows were spaced 36 cm apart and twin rows were spaced 18 cm apart on 72 cm centers. Each plot comprised 8 rows with dimension of 2.88 m X 5 m and was fertilized by commercial fertilizers in the ratio of 30 kg N and 50 kg P₂O₅ per hectare. Plants were harvested on June 5, 2010 in the first growing season and June 10, 2011 in the second. The soil of experimental area was clay loam with a pH of 7.4 and with a low concentration of available phosphorus (15.6 kg/ha) and low organic matter content (0.32 %).

Data collection and calculations: At the full maturity, ten plants were selected randomly from the central six rows in each plot taking primary branches per plant, secondary branches per plant, pod number per plant, seed number per plant, seed weight per plant and harvest index. Harvest index was calculated as the ratio of seed dry weight to the total aboveground biomass.

LAI, incident and transmitted PAR (0.4–0.7 µm wavelength) were measured at the beginning of pod set by using the Sun Scan Canopy Analysis System, BF3 type (Delta-T Devices, UK). The instrument comprised two parts, viz., 1 m long probe to measure transmitted PAR and BF3 to measure incident PAR. To measure transmitted PAR, the probe was placed at right angle to the crop rows at the soil surface. The PAR measurements for each plot were taken five times near the solar noon when unimpeded by clouds. Light

interception (LI) was calculated as the percentage of the light intercepted by the canopy. Light interception efficiency (LIE) was calculated by dividing LI by LAI (Board and Harville, 1992).

Data were analyzed using analysis of variance in the general linear model procedure (PROC GLM) of SAS statistic software (1998) as combined over two years. Duncan multiple comparison test at $P \leq 0.05$ was performed to separate means. Figures were built using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Light interception, light interception efficiency and leaf area index: LI and LAI were significantly affected by plant densities (Table 1).

As shown in Figure 1, LI increased with the increasing plant density. The least and the highest LI was obtained from the lowest and highest plant densities, respectively. The higher interception of light in higher plant densities was mainly due to more LAI. As noted by Figure 2, the plant densities having the higher LAI values had also higher LI. The positive and significant correlation coefficient ($r^2=0.82$) between LAI and LI supported these inferences. On the other hand, LIE was significantly decreased with the increasing plant densities and LAIs (Fig.1 and Fig.3). This is because denser canopy and greater leaf area or LAI at the increasing plant densities increased overlapping and self-shading of leaves (Delagrange *et al.*, 2006). These results were in agreement with those of Board and Harville (1992), who studied the effects of narrow and wide row spacing on the light interception of soybean, and those of Sedghi *et al.* (2008), who stated increasing LAI resulted in sharp decrease in LIE of soybean. Ayaz *et al.* (2004) also stated similar conclusion in their experiment, which contained four grain legumes, namely *Cicer arietinum*, *Lens culinaris*, *Lupinus angustifolius* and *Pisum sativum*.

Table 1. Summary of analyses of variance combined over two years

Sources of Variation	LI (%)	LAI	LIE	Pri. branches/p lant	Sec. branches/p lant	Pod number/ plant	Seed number/ plant	Seed weight/ plant (g)	Harvest index (%)
Year (Y)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting pattern (P)	NS	*	NS	*	NS	NS	NS	*	*
Plant density (S)	*	*	*	*	*	*	*	*	*
Y*P	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y*S	NS	NS	NS	NS	NS	NS	NS	NS	*
P*S	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y*P*S	NS	NS	NS	NS	NS	NS	*	*	NS
CV (%)	11.9	26.3	15.7	11.1	15.6	20.1	11.0	10.2	11.8

NS: Not significant at the level of $p < 0.05$; *: Significant at the level of $p < 0.05$

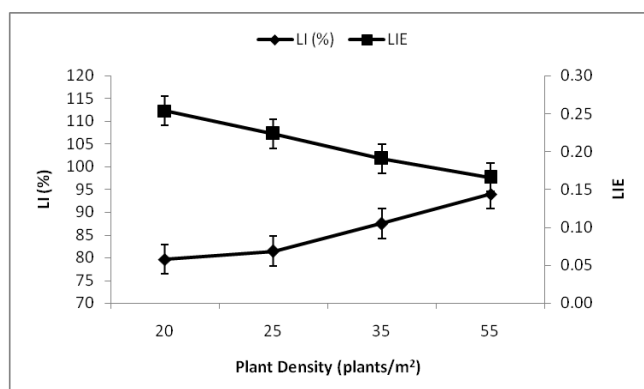


Figure 1. Light interception (%) and light interception efficiency at four plant densities of chickpea

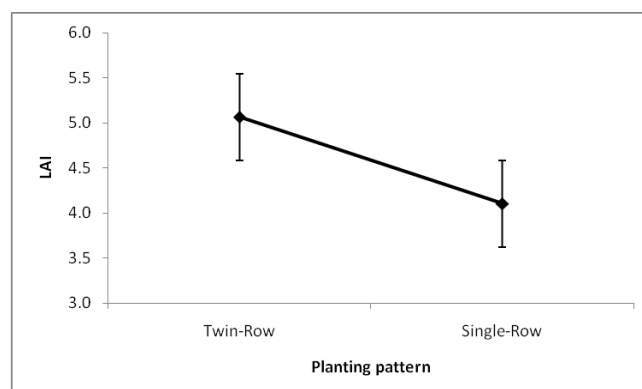


Figure 4. Leaf area index of chickpea sown at two planting patterns

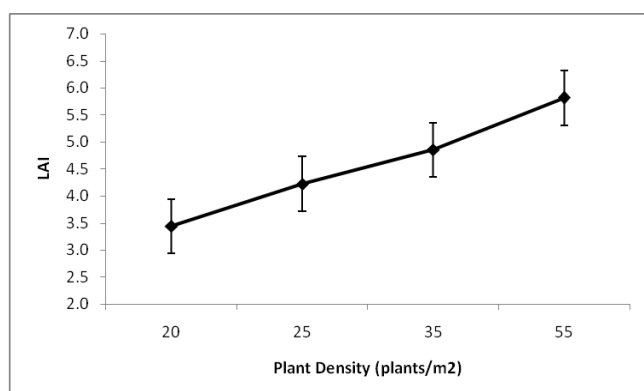


Figure 2. Leaf area index at four plant densities of chickpea

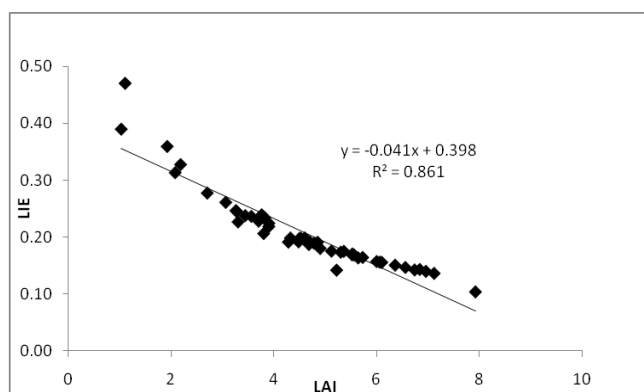


Figure 3. Relation between leaf area index and light interception efficiency, using data combined over two years

The effect of planting pattern on the LAI is presented in Figure 4. As shown, twin-row arrangement produced more LAI than single-row since decreased row widths allow the crop to utilize sunlight more efficiently due to increased leaf area (Balkcom *et al.*, 2011; Robles *et al.*, 2012).

Primary and secondary branches per plant: Different planting patterns and plant densities had significant effect on the number of primary branch/plant (Table 1). As indicated in Figure 5, single-row planting arrangement had more primary branches (3.2) than twin-row (2.9). On the other hand, the number of primary branch decreased as plant density increased (Fig.6), which was in agreement with that of Biabani (2011) and Cokkizgin (2012). This might be due to competition for light, space and nutrients between the plants.

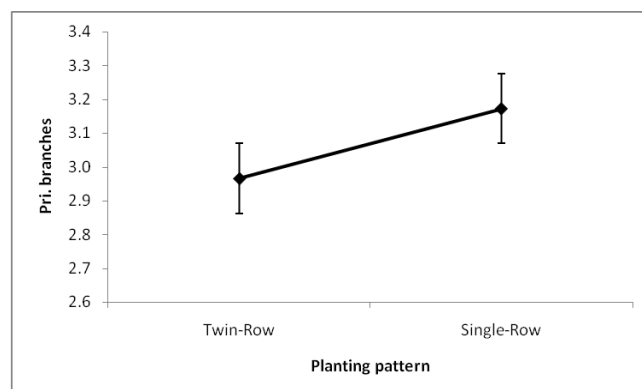


Figure 5. Number of primary branches per plant at different planting pattern, using data combined over two years

Number of secondary branches/plant changed significantly only by the plant density (Table 1) and decreased as the plant density increased from 20 to 55 plants m⁻² like primary branches/plant (Fig. 6). Plants grown at the lowest density (20 m⁻²) had more secondary branches (approximately 28%) than those grown at the highest plant density (55 m⁻²). These differences were presumably due to plant to plant competition for such resources as light, water and nutrients. Naik *et al.* (2012) also reported greater number of branches at the lower plant density. The decrease in number of

secondary branches in response to plant density was sharper than in number of primary branches.

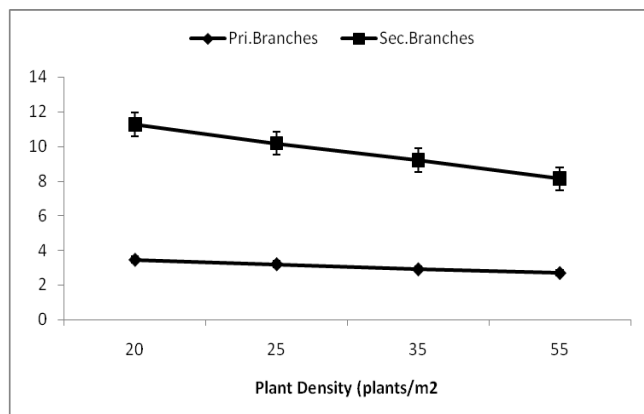


Figure 6. Number of primary and secondary branches per plant of chickpea sown at different plant densities, using data combined over two years

Pod and seed number per plant: Plant density had a significant influence on the number of pods and seeds/plant, while neither the planting pattern nor the interactions affected these characters (Table 1). The results concerning number of pods and seeds/plant versus plant density are shown in Figure 7.

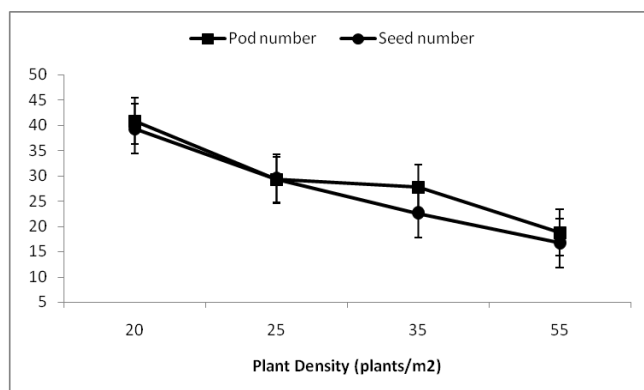


Figure 7. Number of pods and seeds per plant of chickpea sown at different plant densities, using data combined over two years

Both number of pods and seeds/plant decreased in parallel to increasing plant density. These yield components were positively and remarkably correlated ($r^2=0.85$). These results may suggest the competition between vegetative and reproductive structures of chickpea plants. Goyal *et al.* (2010) reported that they observed maximum number of pods/plant from the treatment “22 plants m⁻²” and did not find any significant seed number between plant densities. Liu *et al.* (2003) stated similar results in their study involving four population densities and three chickpea types.

On the other hand, in a study conducted in Pakistan, Khan *et al.* (2010) reported the effect of planting pattern, plant density and their interactions on the pod number/plant and seed number/pod were significant. They obtained maximum pods/plant from 45 cm single row and by 15/45 cm paired rows. Hence, it was suggested that optimal planting pattern and plant density might be changed under different ecological conditions.

In case of dense population, the production of flower or pod presumably decreased because of competition for assimilates between the vegetative parts and the developing reproductive sink (Khanna-Chopra and Sinha, 1987).

Seed weight per plant and harvest index: The effects of plant density and planting pattern on the seed weight/plant and harvest index were significant (Table 1). As noted from Figure 8, the highest seed weight per plant was recorded at the lowest density (20 plants m⁻²) while the lowest one was recorded at the highest plant density (55 plants m⁻²).

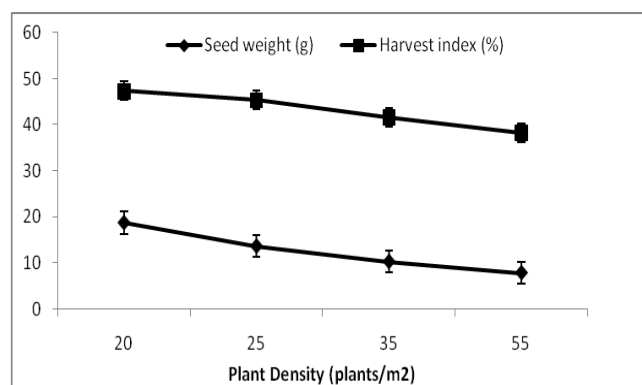


Figure 8. Seed weight per plant and harvest index of chickpea sown at different plant densities, using data combined over two years

There was a great gap between the highest and the lowest plant density because the latter was approximately 42% of the first one. It can be noted that lowest plant density produced more secondary branches (28%) than highest one; however, it could produce much more seed weight/plant. This confirmed that branch number in leguminous plants is an important determinant of grain yield (Jeuffroy and Ney, 1997). The differences in the seed weight/plant might be due to the fact that the increases in light interception with increasing LAI caused increases in net photosynthesis up to a critical LAI value (Pearce *et al.*, 1965). Furthermore, the availability of solar radiation defines a maximal limit to crop yield as intercepted solar radiation provides the energy for photosynthetic fixation of CO₂ (Sinclair, 1994). From the viewpoint of this physiological approach, although the higher plant densities in this study had more LAI and LI, the opposite trend of LIE could cause inefficient use of incident solar radiation.

The finding was in agreement with that of Goyal *et al.* (2010) and Liu *et al.* (2003), who reported a linear decrease in the seed weight/plant in response to increasing population density. On the contrast, Biabani (2011) did not find any significant differences in the pod number per plant, using three row and plant spacing.

Plant density had a significant effect on the harvest index in a similar manner as the seed weight/plant. However, harvest index was more stable than seed weight/plant in response to varying plant densities. Apart from the effect of interactions, the results in this study were in accordance with those of Khan *et al.* (2010), who reported the effect of planting pattern, plant density and their interactions on the seed yield/hectare and harvest index were significant. The seed weight and harvest index of the plants in the planting pattern of twin row in this study was significantly more than in the single row (Fig. 9) whereas they obtained maximum seed yield and harvest index from 45 cm single row. The greater LAI in twin row in this study (Fig. 4) might be the reason for these differences.

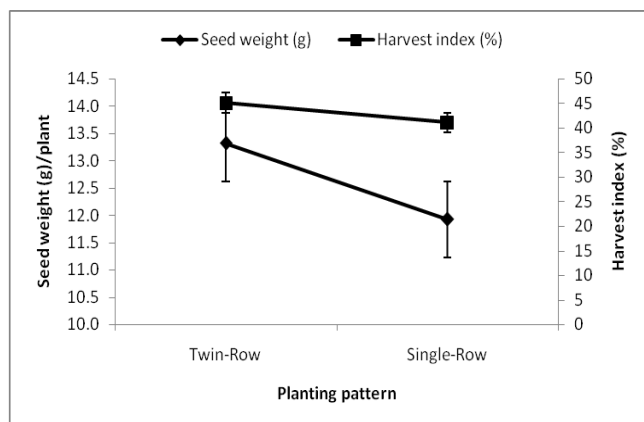


Figure 9. Seed weight per plant and harvest index of chickpea sown indifferent planting pattern, using data combined over two years

Conclusion: Twin-row chickpea production may be a profitable practice due to optimizing LAI. Twin-row planting can facilitate the use of required cultivation such practices as herbicide or insecticide application and hoeing after emergence, which single-row can't enable. Therefore, twin-row planting may be the most feasible practice to increase chickpea production without yield loss. The current study provides a basis for new planting pattern recommendations for rainfed chickpea production in the Eastern Mediterranean type of environments.

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