Effect of planting density and row spacing on light extinction coefficient, light interception and grain yield of corn (single cross704) in Esfahan

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ABSTRACT
An experiment was done in 2014 in research station Islamic Azad University in Isfahan Branch (Khorasgan) in order to study the effect of planting density and row spacing on light extinction coefficient, light interception and grain yield of corn (single cross704) in Esfahan. Experiment was arranged in strip plots in randomized complete blocks design with three replications. Vertical factor was interrow space (50, 60, and 75 cm) across blocks and horizontal factor was density (6, 8, 10, and 12 plants per square meter) along blocks. This research results showed that the effect of density and row spacing on maximum level of leaf area index became significant. The most leaf area index was obtained in 12 density in square meter. The 50 cm space obtained the most leaf area index. The effect of density on light absorption percentage was significant and the most amount of light absorption in 10 density in square meter was obtained. The 50 cm row spacing also achieved the most leaf area index. The effect of density on light absorption percentage became significant and the most amount of light absorption was obtained in 10 density. The interrow space had not a significant impact on light absorption percentage, however, 50 cm distance showed the most amount of light absorption. The density impact on grain yield, the weight of 100 grains, the number of row in maize, the number of grain in row and the number of grain in maize was significant. In fact, the density affected on yield and grain yield components through influence on the amount of received light. The interrow space had not a significant impact on grain yield, the weight of 100 grains, the number of row in maize, the number of grain in row and the number of grain in maize.

KEY WORDS: Density, Inter row space, light absorption, light extinction coefficient

INTRODUCTION
The grain yield is always influenced by interspecific and intraspecific plant competition for access to production factors. Therefore, minimizing these two competition and attainment the maximum product, selecting desirable extent of plant density and the method of distributing bush in unit level through adjusting planting pattern is very much important. The effect of bush steady distribution in unit level on received light's appropriate distribution is appeared within herbal coverage. In the case of reducing planting row space and approaching to square pattern of planting in which ration of rows distance to bushes distance on planting row is close to one, light distribution will be steady. In such arrangement of bushes, farm canopy has been steady and the competition between adjacent bushes in order to absorb growth effective factors will be reduced. (Costa et al., 2001). Light is one of the necessary factor for plant growth and light extinction coefficient is a concept which indicates the amount of light penetration rate inside canopy. The study of growth and biomass accumulation in has shown than biomass production is dependent to leaf area index and the amount of photosynthetic active radiation received during growth period. (Yano et al., 2007. Asseng et al., 2004. Wolf et al., 2002). Successful modeling of plant growth are very much related to complete description of leaf area index, light extinction coefficient and light use efficiency. (Ocannell et al., 2004). Photosynthetic active radiation Reception by plants and its consumption in biomass production shows the fundamental processes which control agricultural plants (Purcell et al., 2002). The manner of photosynthetic active radiation reception by plant shading is considered as one of the most important factor in determining shading photosynthesis and agricultural plants yield. (Stewart et
al. 2003). The amount of absorbed light by plant canopy and light extinction coefficient are dependent to different factors. One of the most important factor is planting arrangement and plant density which the amount of absorbed light and light extinction coefficient in plant community can be greatly changed through changing these two factors. Many studies have shown that grain yield will be greatly increased through plant density increase and after it, the yield is will be fixed in a range of density and through more increase in plant density due to intense competition between plants decreases the yield (Pandey and Gardner, 1999). Through density increase, the size of maize and the weight of grains of one maize decreases. This production reduction is due to the decrease in Nutritional space which is available for plant. Because noting to amount of absorbed light by canopy in order to reaching to higher photosynthesis and consequently higher yield and computing light extinction coefficient in constructing climate and predictive models of production is applicable, in this regard, the aim of this research is to study the effect of density and row spacing on light extinction coefficient, radiation absorption and grain yield of corn (single cross704) in Esfahan.

MATERIAL AND THE METHODS

An experiment was done in 2014 in research farm of Islamic Azad University in Isfahan Branch (Khorasgan) of in order to study the effect of density and the row spacing on light extinction coefficient, light absorption and grain yield of corn (single cross704) in Esfahan. This research station was located ten kilometer of East of Isfahan and it has been located In terms of geographical coordinates, it is located within 32 degrees latitude and within 40 minutes north and located at the longitude 51 degrees 48 minutes East. Experiment was arranged in strip plots in randomized complete blocks design with three replications. Vertical factor was interring row space (50, 60, and 75 cm) across blocks and horizontal factor was density (6, 8, 10, and 12 plants per square meter) along blocks. In order to prepare land of experiment place which was as fallow in last year, at first one 25 to 30 cm deep plow was ploughed and then one perpendicular plowing was performed on first plowing. Fertilization of one third of the Nitrogen as before planting took place according to soil analysis results in amount of 100 kg per hectare of Nitrogen from Urea resource and immediately it was mixed with soil by disk and then land surfacing was performed. Each experimental plot had 4 planting line in 6 meter length. Planting was done manually at a depth of 5 -6 cm as a pile. Setting the considered plant density by respect to distance between row obtained by setting bushes distance on the row by the use of metal ruler. The first Irrigated was immediately done after planting and second irrigated took place 4 days later in order to steady growth. In 6 leaf stage, thinning operation was performed to access to appropriate density. In order to control farm’s weeds, by the use of Herbicide 2.4.D, broadleaf weeds were controlled and Narrow leaf weeds were mechanically controlled. For measuring light absorption rate, the deluxe photometer in model LX 101 which Manufactured in Taiwan Lutron factory was used. For this purpose, one day before dry material measuring, in that part of plot which dry weight sampling performed, light measuring was done. Therefore, the measurement was performed every 15 days between the times of 11 up to 13 hours of real noon. In this manner that in one sunny and clear day , light absorption rate was measured 30 measuring below canopy and 10 measuring above it. (Optical spectra: 400 -700 Nm).

Light extinction coefficient and light absorption percentage were calculated through below relations:

\[ \ln(\frac{I}{I_0}) = -KLAI \]

\[ I_{ab} = \frac{(I_{0}-I)}{I_{0}} \times 100 \]

In which

I₀ = Photosynthetic Active radiation rate above canopy
I = Photosynthetic Active radiation rate below canopy
LAI= Leaf area index.
K= Light extinction coefficient
I_{ab} light absorption percentage

In each radiation rate measuring, leaf area index was determined. The maximum leaf area index was determined in 50% of pollination stage. The measuring of grain yield and yield’s components was performed in physiologic maturity stage in the manner that bush sampling was done in a surface equals to one square meter by observing edge effect in each subordinated plot and the number of row in maize, the number of grain in row and the number of grain in maize was determined based on 14% humidity. 4 number of a sample of 100 number from each one’s plot was randomly selected in order to determine the weight of 100 number of grain. And their weight were computed based on 14% humidity. In order to statistically analyze and drawing diagram some software such as M-STAT C, Excel and Stat Graph respectively was applied and average comparison was done through the method of Duncan multi-range Test in possibility level of 5%.
RESULTS AND DISCUSSIONS

The effect of density on leaf area index in possibility level of 1% was significant according to table of Variance analysis (Table 1). The most leaf area index in density of 12 bushes per square meter (4.400), and the lowest one in density of 6 bushes per square meter (2.800), was computed (Table 2). The effect of row spacing on leaf area index in possibility level of 5 % was significant. The most leaf area index was computed in 50 cm space (4.200) and the lowest one was obtained in 75 cm space (2.97), (Table 2). The interaction effect of density and row space on leaf area index was not significant (Table 1). The effect of density on the maximum light absorption in canopy in possibility level of 1 % was significant. The most light absorption rate in density of 10 number of bushes per square meter was obtained (89.1%) and the lowest one in density of 6 bushes per square meter was computed (83.2%) (Table 2). The results indicate that light absorption rate has been significantly increased through the increase in plant density up to 10 bush per square meter. But light absorption rate has been decreased through the increase in plant density up to 12 in spite of the fact that light absorption rate has not been significantly changed. Flent and his co-workers in 1996 stated that through the increase in leaf area index because of the increase in plant density, the light absorption percentage will be increased. The effect of row spacing on the maximum light absorption was not significant in canopy. However, the most light absorption rate was computed in lower row distance (Table 2). The interaction effect of density and row space on leaf area index was not significant. The procedures of light absorption percentage changes in different densities during growth season indicates that procedure of light absorption percentage changes grows at the beginning of season and it is slow and then it will grow as ascending and it receives to its space rows during growth s

of 6 bush per square meter (Figure 1). The light absorption percentage changing procedure in different row space rows during growth season indicates that light absorption percentage changing procedure in all the treatments grow at the beginning of season and it is slow and then it will grow as ascending and it receives to its maximum amount during 47 days after germinating. In this time, 50 cm distance absorb nearly total of light and

| Table 1: Variance analysis of studied Trait leaf area index, light absorption percentage, the number of rows in maize, number of grains in maize, the weight of 100 grain, seed yield in different density and row spacing. |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Source of Variation | Mean of Square | Degrees of freedom | Source of Variation |
| Seed yield weight of 100 grain | Number of grain in maize | Number of row in row | Number of row in maize | Light absorption percentage | Maximum leaf area index |
| 168910.0 | 10.753 | 7763.840 | 32.168 | 0.771 | 71.633 | 0.05 | 2 | Replication |
| 973896.2 | 48.934 | 31661.729 | 82.715 | 1.648 | 61.141 | 7.462 | 3 | Density |
| 15637.7 | 7.816 | 360.729 | 5.319 | 0.363 | 1.164 | 0.030 | 6 | Error (a) |
| 146367.6 | 34.351 | 12734.090 | 8.960 | 2.583 | 33.034 | 0.981 | 2 | Inter row space |
| 112717.6 | 18.020 | 3447.090 | 4.918 | 0.542 | 15.145 | 0.063 | 4 | Error (b) |
| 182456.9 | 14.387 | 6142.351 | 37.492 | 0.176 | 23.673 | 0.098 | 6 | Density * Inter row space |
| 105131.7 | 8.599 | 4133.535 | 20.732 | 0.579 | 11.989 | 0.051 | 12 | Error (c) |
| Significant at 1% and 5% probability level respectively** and * |

| Table 2: Mean comparison + of studied Trait leaf area index, light absorption percentage, the number of rows in maize, number of grains in maize, the weight of 100 grain, seed yield in different density and row spacing |
|-----------------|----------------|----------------|----------------|----------------|----------------|
| Source of Variation | Mean of Square | Source of Variation |
| Seed yield weight of 100 grain | Number of grain in maize | Number of row in row | Number of row in maize | Light absorption percentage (%) | Maximum leaf area index |
| Density (plant/m²) | 2398.8 | 34.5 | 692.3 | 49.8 | 13.9 | 83.3 | 2.80 | 6 |
| 1989.7 | 32.0 | 622.0 | 47.1 | 13.2 | 87.1 | 3.43 | 8 |
| 1907.8 | 31.1 | 611.5 | 46.1 | 13.2 | 89.1 | 4.00 | 10 |
| 1600.4 | 28.9 | 547.5 | 42.5 | 12.9 | 88.5 | 4.40 | 12 |
| Inter row space (Cm) | 2101.1 | 32.8 | 625.8 | 46.6 | 13.4 | 88.4 | 4.20 | 50 |
| 1900.1 | 32.3 | 582.6 | 45.5 | 12.8 | 87.4 | 3.80 | 60 |
| 1921.4 | 29.7 | 646.5 | 47.1 | 13.7 | 85.2 | 2.97 | 75 |

There is no significant difference at 5% probability level between means of each Column which have at least one Colume letter 

After this time, light absorption process will be decreased because of leafs shading on each other and aging the below leaves. When the density increase, the light absorption will be increased in whole growth season. The most light absorption rate was obtained in density of 12 bush per square meter and the lowest one was in density of 6 bush per square meter (Figure 1). The light absorption percentage changing procedure in different row space rows during growth season indicates that light absorption percentage changing procedure in all the treatments grow at the beginning of season and it is slow and then it will grow as ascending and it receives to its maximum amount during 47 days after germinating. In this time, 50 cm distance absorb nearly total of light and
then light absorption percentage start to reduce. Light absorption percentage reduction. Intensity will be very much increased in 53 days after germinating (Figure 2). Andrade et al showed that radiation absorption will be increased by reducing the row space.

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**Fig. 1:** Light absorption percentage changing procedure in different planting densities.

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**Fig. 2:** Light absorption percentage changing procedure in different inter row space.

The rate of light extinction coefficient during growth season is actually slope of this relation: \( \ln I/I_0 = -KL_{AI} \).

The results indicates that light extinction coefficient will be decreased by increasing plant density. The most light extinction coefficient in density of 6 bush was obtained \( (K=-0.7856) \) and the lowest one in density of 12 bush was obtained \( (K=-0.6262) \). Because \( \ln I/I_0 = -3 \) shows 95% light absorption and 5% light passing to plant flooring. Therefore, the leaf area index in confront of it is the critical leaf area index whose rate were respectively 3.08, 3.85, 4.53 and 4.9 for plant density of 6, 8, 10 and 12 which this reaction shows that critical leaf area index will be increase through the increase in plant density.
Fig. 3: The relationship between light passing from canopy and leaf area index in different densities of planting.

Calculating light extinction coefficient during growth season in different row space, shows that light extinction coefficient is increased by the increase in distance. The most light extinction coefficient rate in 75 cm space was obtained ($K = 0.9337$) and the lowest one in 50 cm space was obtained ($K = 0.6847$). The critical leaf area index rate for the row space 50, 60 and 75 cm are respectively 4.07, 3.46 and 3.02. This reaction shows that critical leaf area index rate has increase by reducing in row space. Some scholars have believed that light extinction coefficient is decreased through reducing row space. (Duncan, 1973; Nielson et al, 1988. Pandey and Gardner, 1999).
Fig. 4: The relationship between light passing from canopy and leaf area index in different rows spacing.

The effect of density on the number of row in maize in possibility level of 5% was significant (Table 1). The most number of row in maize in density of 6 bush was obtained 13.9 and the lowest one in density of 12 bush was obtained 12.9 (table 2). The number of row in maize decreased through the increase in density. The effect of row space on the number of row in maize was not significant (table 1). However, the most number of row in maize was obtained 13.7 in 75 cm space and the lowest one was obtained 12.8 in 60 cm space (table 2). Interaction effect of density and row spacing on number of row in maize was not significant (table 1). The effect of density on number of grain in row in possibility level of 1% was significant according to table of Variance analysis (table 1). The most number of grain in row in density of 6 bush per square meter was obtained 49.8 and the lowest one in density of 12 bush was 42.5 (Table 2). In fact, the number of grain in row will be decrease through the increase in density. These results are consistent with the results of Tetio and Gardner Test in 1988. The effect of row space on the number of grain in row was not significant (table 1). However, the 75 cm space has the most number of grain in row (table 2). Interaction effect of density and row space on number of grain in row was not significant (table 2). The effect of density on number of grain in maize in possibility level of 1% was significant according to table of Variance analysis (table 1). The most number of grain in maize in density of 6 bush per square meter was obtained 692.3 and the lowest one in density of 12 bush was 547.5. There is not statistically a significant difference between density of 8 and 10 bush per square meter (table 2). In fact, the number of grain in maize was decreased through increasing in density in unit level. Density is increased through the decrease in light absorption at below parts of canopy and because of existence of shading and more distance between pollination period and overall tassels in high densities, the fewer ovule is inoculated and the number of grain in maize in this density will be decreased (Hashemi et al., 2005). The effect of row space on the number of grain in maize was not significant (table 1). However, the most number of grain in maize was obtained in 75 cm space (table 2). Interaction effect of density and row space on number of grain in maize was not significant (table 1). The effect of density on weight of 100 number of grain in possibility level of 5% was significant according to table of variance analysis (table 1). The most weight of 100 number of grain in density of 6 bush per square meter was obtained 34.5 g and the lowest one in density of 12 bush was 28.9 g (table 2). In fact, the weight of 100 number of grain is decreased through increase in density in unit level. The effect of row space on the number of weight of 100 number of grain was not significant (table 1). However, the most weight of 100 number of grain was obtained 32.8 g from the 50 cm space which it show an increase of 10% compared with the 75 cm space (table 2). Interaction effect of density and row space on weight of 100 number of grain was not significant (table 1). Effect of density on seed yield in possibility level of 1% was significant according to table of variance analysis (table 1). The most seed yield in density of 6 bush per square meter was obtained 2398.8 kg/hectare and the lowest one in density of 12 bush was 1600.4 kg/hectare (table 2). Through the increase in density, seed yield showed a decreasing process. The effect of row space on seed yield was not significant (table 1). However, the most seed yield was obtained in 50 cm space which it show an increase of 11% and 10% compared with the 60 cm and 75 cm row space (table 2). Interaction effect of density and row space on seed yield was not significant (table 1). The seed yield will be increased through reducing the inter row space and the increase in plant distance on the row in the manner that their distribution is steady in unit level. The conducted studies also emphasized this fact (Scarbrook and Doss, 1988. Ottman and welch, 1989).

According to the results obtained from this research, we can conclude that leaf area index has been increased through the increase in plant density and decrease in row space. In fact, by adjusting density and planting arrangement, the allocated growth space for each plant will be more suitable and the plant will apply of this more suitable space in the best manner, it will product more leaf area index and the canopy will be closed with more speed. Because light absorption is an obedient of leaf area index, light absorption will be increased through the increase in leaf area index and consequently light extinction coefficient will be decreased. These
conditions increase the share of photosynthetic material of grain compared with other organs and it improve its yield and components.

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