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# Investigating Light Absorption and Some Canopy Properties in Monocultures and Intercropping Culture of Safflower and Chickpea

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***Abstract:*** **In order to compare various combinations of safflower(*Carthamus tinctorius* L.) and chickpea (*Cicer ariatinum* L.) intercropping, an experiment in the form of randomized complete block with three replications and 15 treatments was conducted in research farm of agriculture faculty of Ferdowsi University of Mashhad in crop season 1389. Treatments included three monocultures of safflower (12, 14 and 16 stands per square meter), three monocultures of chickpea (30, 40 and 50 stands per square meter) and nine treatment combinations for intercropping of the two crops with increasing method. Results indicated that leaf area index, received light percentage and chlorophyll content in intercropping were increased by 2.88, 37 and 11.94% compared to safflower monoculture and by 2.63, 30 and 9.27% compared to those of chickpea monoculture. Average canopy temperature in intercropping was 2.17°C and 2.88°C lower than that of safflower and chickpea monoculture; respectively. Among intercropping regimes, the treatment of 8 safflower stands and 50 chickpea stands was the best treatment regarding light received by canopy, leaf area index of canopy, chlorophyll and canopy temperature. It was revealed that land equilibrium ration (LER) value in various intercropping treatments was equal to one. The treatment of 12 safflower plant and 50 and 40 chickpea plants had the highest LER (1.97) indicating 97.5% increase in land usage compared to monocultures of the two crops; this shows superiority of intercropping over monoculture.**

***Keywords:*** **Canopy Temperature, Leaf Area Index, Chlorophyll, Land Equilibrium Ratio, Received Light**

## I. INTRODUCTION

By multiplication of global population during recent decades especially in Asia and Africa, demand for food and dwelling has greatly increased and on the other hand, available land for agriculture has been reduced. The most practical solution for this problem is to find a way enabling the highest possible production in smaller land. Intercropping is an option for enhancing food by maintaining cultivated area. However in modern systems of crop production, managerial methods practiced by farmers to achieve higher yield is being promoted. The most common approach in this regard includes enhancing use efficiency of resources such as water, nutrients, land area, sun light and atmospheric carbon dioxide. Some resources such as sun light are of greater importance (Koocheki et al, 2009). An accurate managerial method for crop production which results in enhancement of resource use efficiency is intercropping. Intercropping refers to simultaneous cultivation of two or more plant species in a given time and location (Vandermeer, 1989). Advantage of intercropping over monoculture includes enhanced use of light and moisture and increased resource use efficiency (Watuki et al, 1993). Light is an important competition factor in agronomic ecosystems since it can't be stored and is lost if not absorbed (Awal et al, 2006). Capacity of various plant species for better exploitation of light is determined by two factors namely light volume and its distribution for being received by mixture components and light use efficiency (beyshlag et al, 1990). If intercropping components have different efficacies in consumption of environmental resources, they will make better use of the resources and thus, yield is enhanced. Enhancement of light absorption and consumption is an advantage of intercropping compared to monoculture (Willy, 1979). Due to different ecological niches, intercropped plants are able to completely occupy all possible niches as fast as possible. This can explains enhanced light absorption in intercropping canopy compared to that of monoculture (Tsubo and Walker, 2004). If intercropped plants are of different heights so that higher plant is equipped with higher photosynthetic potential and wider leaves and the shorter species has lower photosynthetic potential and more horizontal leaves, higher level of light can be trapped by the intercropping system and is consumed in better manner (Willey, 1990). High leaf area index can promote leaf erection, vegetation photosynthesis and finally canopy growth (Mason et al, 1996). It has been reported that leaf area index in intercropping of safflower (Zea mays) and bean (Phaseolus vulgaris) is higher than that of their monocultures which leads to better use of the absorbed light and increased yield (Tsubo and Walker, 2004). Higher leaf area index is expected to enhance sun light absorption. Thus, determination of leaf area index can reveal its close relation with percentage of the light received by the canopy in monoculture and intercropping. The relation between leaf area index and light absorption has been reported bay many authors (Singer et al, 2006; Ahmadvand et al, ). According to Parsa and Bagheri (2008), nitrogen fixation by broad bean (*Vicia faba* L) is significantly enhanced in intercropping compared to monoculture. Therefore, enhancement of leaf chlorophyll content in intercropped plants is expected. Since there is a direct relation between leaf chlorophyll and its nitrogen content, it can be concluded that by increase in nitrogen availability, leaf chlorophyll is proportionally increased and the photosynthesis is promoted. Chickpea is a valuable crop that can be used as an important component of intercropping and in agro forestry in which shading is a limiting factor. Results of this experiment showed that leaf area index, soil surface cover, days to physiological maturation of seeds, seed weight and grain yield per unit area was higher in shading condition compared to full sunshine. It has been reported that the highest LER for grain yield as 1.37 was achieved in intercropping of forage millet (*Pennisetum americanum*) and bean (Hosseini et al, 2003). It has been also reported that relative yield of barley (Hordeum volgare) and broad bean (Vicia faba) was 0.85 and 0.35 and LER value was 1.23 (Agegnehu et al, 2006). In intercropping of barley and chickpea, Haugarrd Nielsen (2001) showed that LER was 1.05 to 1.23. According to this research, intercropping of chickpea and safflower is recommended for various locations due to exploiting numerous morphological and physiological traits and yield. The present study was carried out to determine the best combination of safflower and chickpea intercropping compared to monoculture in terms of light absorption and canopy advantages of intercropping under Mashhad climate.

## II. Material And Methods

The present study was conducted in research farm of agriculture faculty of Ferdowsi University of Mashhad in crop year 1489-1390; the farm is located 10km east of Mashhad with 36° and 16' northern latitude, 59° and 36' eastern longitude and altitude of 985 above sea surface. The farm soil was of silt loam type. Average annual precipitation of Mashhad is 286mm and the maximum and minimum temperature of the city is 43°C and -27.8°C. The climate of Mashhad is dry and cold. Before initiation of the experiment, four soil samples were prepared from 20cm depth of various part of the farm and transferred to laboratory to determine physical and chemical properties of soil. The soil had silt loam texture and the results of soil chemical analysis are presented in table 1. The experiment was carried out in the context of randomized complete blocks with 3 replications and 15 treatments. Treatments include three monocultures of safflower (12, 14 and 16 stands per square meter), three monocultures of chickpea (30, 40 and 50 stands per square meter) and nine treatment combinations for intercropping of the two crops.

Table1. Result of soil analysis in Mashhad Ferdowsi University (2009-2010)

| PH | EC (ds/m) | T.N.V percent | N percent | P (mg/kg) | K (mg/kg) | OC percent |
|---|---|---|---|---|---|---|
| 7.74 | 0.96 | 15 | 0.042 | 28 | 250 | 0.38 |

The distance between crops in each row was 10cm, the rows were separated by 50cm, the distance between the blocks was 1m, between plots was 0.5m, margin as 1m, density of both species was 20 stands per square meter. The safflower and chickpea were planted on Isfand 20, 1389 by hand and as dry farming. Planting depth in both intercropping and monoculture was 10cm. Each plot was 6m long and 4m wide. The distance between the plots and between the blocks was 0.5m and 1m; respectively. Planting lines were separated by 0.5m and the crops on each line were separated from each other by 10cm. At the time of land preparation, 200kg/ha ammonium super phosphate and 150kg/ha urea fertilizer were applied. The first irrigation was practiced one day after sowing and irrigation period was 10 days. Irrigation was performed by siphon. Seed used for planting of safflower and chickpea was 25kg/ha and 40kg/ha; respectively. Thinning was practiced for chickpea in four leaf stage and for safflower in two leaf stage to achieve desired density which was 20 stands per square meter for both of the crops. After full establishment, weeding was carried out in two steps by hand weeding; the first one on 35 days after sowing and the second one on 70 days after sowing. Sampling for measurement of leaf area index and dry weight was repeated each 15 days in an area equal to $1m^2$. At the end of growth season, chickpea plants were harvested on 5/4/90 and safflower was harvested on 18/4/90 for measurement of final yield. Destructive sampling method was used for calculation of growth indices. To do this, half of each plot was devoted to sampling. Sampling location in each plot was selected randomly, so that a $25x25cm^2$ quadrate was used and the plants locating within this area were harvested and sent to laboratory. Leaf area of both species was measured using leaf area meter. To measure dry weight, the samples were placed in a pocket and incubated in 70°C oven for 48h and then dry weight of the dried samples was measured by a digital balance. Growth indices of chickpea and safflower were measured each 15 days during growth season. At the end of growth season, the plants of the other half of the plot, covering a $10m^2$ area, were harvested and final yield of chickpea and safflower was measured in unit area.

Light received by upper and lower parts of the canopy was measured using photometer device (Sun scan, ΔT model, England). Light estimation was performed on a sunny day between 11 a.m and 14 p.m in safflower flowering time which coincided with chickpea grain filling time. Light measurement in each plot was carried out at the upper part and bottom of the canopy with three replications perpendicular to planting rows. Final light absorption by monoculture and intercropping canopies was calculated by estimating the difference between upper and lower parts of the canopy (Tesfaye et al, 2006). Leaf area index was calculated by the same device (Sun scan, ΔT model, England) used for measuring absorbed light. At the same time, canopy temperature was measured by thermometer in upper, intermediate and lower parts of the canopy. Canopy temperature was calculated by estimating the average temperature of these three parts at 11 a.m. and 14 p.m. leaf chlorophyll content was measured by chlorophyll meter (SPAD-502, Molinta Inc) in development phase of safflower and chickpea. Measurement was carried out at upper, intermediate and lower parts of the two crops in the canopy, and also from tip, intermediate and lower parts of mature leaves of both

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crops. Chlorophyll content was calculated by estimating the average of the three values and recorded for each crop separately.

Data related to sampling during and at the end of growth season for dry matter, yield and yield components (grain, pod number, head number and 100grain weight) were analyzed and mean comparison was conducted by Duncan test. Significance level in all analyses was 0.05. Data analysis and graph drawing were performed using EXCEL and MSTAT-C software. To assess efficiency of various treatments, land equilibrium ratio was calculated using formula 1:

$$LER=\sum (Y_I/Y_I^{//})$$

Where, $Y_1$ stands for crop yield in intercropping (in unit area) and $Y''_1$ indicates yield of the same crop in monoculture (in unit area)

## III. Results and Discussion

### *3.1. Leaf area index of canopy*

According to ANOVA results, leaf area index of canopy in monoculture and intercropping of chickpea and safflower was significant ($p<0.01$) (table 2).

Table 2- Analysis of variance for measured traits of sole and intercrop safflower at different safflower and chickpea densities

| S.O.V | df | Chlorophyll index | Canopy temperature | Light interception | Leaf area index |
|---|---|---|---|---|---|
| Replication | 2 | 0.591 | 0.004 | 9.8 | 50906.652 |
| Treatment | 14 | $98.008^{**}$ | $9.144^{**}$ | $569.533^{**}$ | $734267.533^{**}$ |
| Error | 28 | 0.838 | 0.09 | 10.276 | 8017.502 |
| CV (%) | | 11.99 | 9.32 | 23.53 | 33.21 |

intercropping was higher than that of monocultures of the two crops. Leaf area index in densities of 14 and 16 stands of safflower in monoculture was 1.35% higher than that of chickpea monocultures showing that canopy leaf area index in safflower monoculture was larger than that of chickpea monoculture. In the other words, safflower leafrea index was more affected by various treatments of intercropping compared to chickpea.

Canopy leaf area index in chickpea/safflower. By increase in densities of chickpea and safflower in intercropping, canopy leaf area index was significantly enhanced. The highest leaf area index was achieved by 16 safflower stands and 50 stands of chickpea, which is significantly different from other treatments (table 3).

Table 3- Experimental treatments ,Leaf area index, Light interception, Canopy temperature, Chlorophyll index of Safflower and Chickpea at the different intercropping treatments

| Treatments | Sanfflower Density (plants.m2) | Chick pea Density (plants.m2) | Light interception (%) | Canopy temperature © | Chlorophyll index (spad ) | Leaf area index |
|---|---|---|---|---|---|---|
| ( Monocropped Safflower) | | | | | | |
| Monocropped Safflower(a1) | 12 | 0 | $56^{e}$ | $31.5^{a}$ | $33^{hi}$ | $3^{h}$ |
| Monocropped Safflower(a2) | 14 | 0 | $60^{d}$ | $31.6^{a}$ | $35^{g}$ | $3.5^{j}$ |
| Monocropped Safflower(a3) | 16 | 0 | $60^{d}$ | $31.8^{b}$ | $38^{g}$ | $3.5^{j}$ |
| ( Monocropped chickpea) | | | | | | |
| Monocropped chickpea (b1) | 0 | 30 | $48^{f}$ | $31.9^{a}$ | $33^{i}$ | $2.2^{k}$ |
| Monocropped chickpea (b2) | 0 | 40 | $52^{ef}$ | $31.6^{a}$ | $35^{i}$ | $2.4^{ik}$ |
| Monocropped chickpea (b3) | 0 | 50 | $56^{e}$ | $31.8^{a}$ | $37^{h}$ | $2.8^{hi}$ |
| Intercropping | | | | | | |
| Intercropping (A1b1) | 12 | 30 | $70^{c}$ | $29.2^{c}$ | $37^{f}$ | $5^{f}$ |
| Intercropping (A1b2) | 12 | 40 | $68^{c}$ | $29.1^{c}$ | $39^{e}$ | $5.2^{de}$ |
| Intercropping (A1b3) | 12 | 50 | $70^{c}$ | $29^{c}$ | $40^{d}$ | $5.6^{cd}$ |
| Intercropping (A2b1) | 14 | 30 | $78^{a}$ | $28.8^{cd}$ | $40^{cd}$ | $5.8^{bc}$ |
| Intercropping (A2b2) | 14 | 40 | $79^{ab}$ | $29^{cd}$ | $42^{abc}$ | $5.6^{cd}$ |
| Intercropping (A2b3) | 14 | 50 | $80^{ab}$ | $29.2^{cd}$ | $43^{a}$ | $6^{c}$ |
| Intercropping (A3b1) | 16 | 30 | $84^{a}$ | $29.1^{cd}$ | $40^{bc}$ | $6.2^{b}$ |
| Intercropping (A3b2) | 16 | 40 | $80^{ab}$ | $28.9^{d}$ | $43^{a}$ | $6.3^{b}$ |
| Intercropping (A3b3) | 16 | 50 | $82^{ab}$ | $28.8^{d}$ | $42^{d}$ | $7^{a}$ |

Results showed that canopy leaf area index in intercropping treatments was 2.63% and 3.88% higher than that of safflower and chickpea monocultures; respectively. This can be due to nitrogen availability via biological fixation by chickpea and better distribution of light by safflower canopy. Thus, combination of complementing and facilitating effects of safflower and chickpea can enhance leaf area index of each crop. In intercropping of safflower and soybean, it was revealed that the highest leaf area index was obtained when vegetative growth was stopped and male inflorescence of safflower emerged (Keyhan et al, 1999).

Increase of leaf area index in intercropping compared to monoculture has been reported by other authors (Rostami et al, 2009; Koocheki et al, 2009). Results in the present study indicated that leaf area index in intercropping was higher than that of monoculture and this can have a positive effect on absorbed light percentage; by safflower shading on chickpea especially in higher densities, the latter enhances its leaf area to absorb more light and this situation results in increased leaf area index of chickpea and thus, enhanced canopy leaf area index. On the other hand, this increased leaf area index leads to retention of more moisture and decrease of temperature which ultimately results in increased relative moisture of the canopy. Thus, adjustment of canopy microclimate can cause increase in canopy leaf area index in intercropping compared to monoculture. The difference between absorbed light percentage in monocultures and intercropping of safflower and chickpea was significant ($p<0.01$; table 2). Absorbed light percentage in safflower/chickpea intercropping treatments was higher than that of monocultures of the two crops. Light absorption in safflower monocultures with density of 14 and 16 plants was 13% higher than that of chickpea monocultures. Increase of chickpea density in each level of safflower density had significant effect on increase of light absorbed by the canopy. The highest percentage of light absorption was obtained in density of 16 safflower stands and 30 chickpea stands which is significantly higher than density combinations of 16/40, 16/50, 14/40 and 16/50 (safflower/chickpea; table 3). Results showed that average rate of light absorption in intercropping was increased by 30% and 37% compared to monocultures of safflower and chickpea; respectively. This can be due to increased leaf area index in higher densities which closes the canopy and reduces waste of the light penetrating the canopy. Light absorption by canopy was higher in intercropping compared to monoculture which can be due to alteration of safflower and chickpea canopy structures when the crops are planted in juxtaposition. Presence of chickpea under safflower canopy results in absorption of wavelengths transferred and reflected by safflower canopy which causes enhancement of canopy light absorption of intercropping compared to monoculture. Conducting an experiment on intercropping of wheat (*Triticum aestivum* L) and wild oat (Avena fatua), Ahmadvand et al (2006) showed that by increasing nitrogen fertilizer from 25 to 100kg/ha, total light absorbed by the canopy was increased from 80% to 90%; and light absorption in wach height of canopy was higher in larger rate of nitrogen fertilizer compared to lower rate of the fertilizer; the authors attributed this increase to increased leaf area and leaf area durability in every layer of canopy. Increase of absorbed light percentage in intercropping has been reported by other investigators (Li et al, 1999; Shikata et al, 2003). Increased density of chickpea and difference in leaf shape and angle of the two crops and coverage of blank spaces can result in optimal consumption of light in intercropping. The main difference between absorption of light and other resources is that light can't be stored. Thus, as system is more successful in light absorption that has the highest consumption of the light arrived in canopy and the receiver areas are more durable. Thus, canopy closure speed is directly related to light consumption rate. A leaf or canopy even in suitable densities of monoculture can't fully use available light (Keating and Carbery, 1993). Intercropping of two species with different height and leaf arrangement absorbs more light than monoculture qualitatively and quantitatively (Awal et al, 2006). Indeed, a part of photosynthetic radiation is lost in monoculture due to presence of empty spaces within the canopy. Rate of this loss in intercropping cultures is reduced by higher coverage of soil surface and so, total absorption of radiation is enhanced compared to monoculture; and this can enhance the yield by itself. It has been reported that intercropping of oat and vetch had 20% higher light absorption compared to average absorption of monocultures and this was due to reduced light reflection (Mariotti and Masoni, 1997). Effective photosynthetic light may not be used because of low safflower growth in early season and chickpea aging at the end of growth period. The light is more efficiently used by intercropping of the two crops. It has been reported that broad bean and wheat intercropping is more successful in absorption of sun light due to difference in growing time, leaf arrangement and canopy shape (Keating and carbety, 1993). According to various studies, higher light use efficiency in intercropping is a major advantage, and by adopting suitable crops and favorable combination, maximal light use can be achieved in intercropping.

### *3.2.Temperature inside the canopy*

Inside canopy temperature in intercropping and monocultures of safflower and chickpea was significant ($p<0.01$; table 3). Inside canopy temperature of intercropping was lower than that of monocultures of the two crops. Moreover, this parameter in monoculture of safflower with density of 16 stands was lower than those observed in 12 and 14 safflower plants and chickpea monoculture (table 3). Results indicated that average temperature inside the canopy of intercropping was 2.17 and 2.88°C lower than that of safflower and chickpea; respectively. Plant density, quality of received light, planting direction and wind affect canopy temperature. It was revealed in intercropping of safflower and cauliflower that canopy temperature in favorable densities is reduced as a result of safflower shading (Jaya et al, 2008). Canopy temperature is reduced in intercropping due to positive effects of two crops including increased land coverage, higher retention of soil moisture, reduced evaporation from soil surface, enhanced water use efficiency and increased relative moisture of canopy (Anthony and Rene, 2008). Based on the present study and previous ones, it can be concluded that microclimate temperature of canopy in intercropping is lower than that of monoculture. Higher transpiration enhances relative humidity and the energy penetrating the canopy is used for photosynthesis and production processes and thus, the amount of energy devoted to air heating is reduced. These factors cause relative coldness of microclimate and since microclimate temperature, to some extent, depends on relative humidity of canopy, humid air retains canopy temperature of intercropping in a moderate level and, therefore, canopy temperature in intercropping is colder than that of monoculture. By addition of chickpea densities to safflower canopy, reduction of canopy temperature was larger in higher densities compared to lower ones which is probably due to enhanced relative humidity of canopy, increased shading and reduced light loss. Perhaps it can be concluded that adopting a favorable density balances canopy temperature in intercropping and this phenomenon can results in enhancement of leaf area, higher light absorption and increase of yield.

### *3.3.Chlorophyll index*

Chlorophyll index in monocultures and intercropping was significant ($p<0.01$; table 2). Chlorophyll index in intercropping was higher than that of monocultures of chickpea and safflower. Similar to leaf area index and absorbed light percentage, densities of 14 and 16 stands in safflower monoculture had higher chlorophyll index compared to chickpea monoculture, so that chlorophyll index in safflower monoculture was 4% higher than that of chickpea monoculture in average. In intercropping cultures, chlorophyll index was increased by increase in chickpea and safflower densities. The highest chlorophyll index was obtained in density of 16 safflower stands and 40 chickpea stands per square meter which was not significantly different from that observed in 16/50, 14/50 and 14/40 densities (safflower/chickpea; table 3).

Since chlorophyll content, photosynthesis rate and dry matter production are related to each other, higher chlorophyll content in higher densities can enhance yield and dry matter production. Leaf chlorophyll index in intercropping treatments was 9.27% and 11.94% higher than that of safflower and chickpea monocultures; respectively (table 3).

In intercropping of soybean and sorghum, chlorophyll content of sorghum in intercropping was always higher than that of monoculture which was attributed to shading of the two crops on each other and nitrogen fixation by soybean (Ghosh et al, 2006). Increased chlorophyll content of safflower in higher densities of chickpea can be due to enhanced consumption of nitrogen fixed by chickpea and soil nitrogen. Plant leaves have often higher chlorophyll concentration in intercropping compared to monoculture (GHosh et al, 2006).

### *3.4. Effect of intercropping on land equilibrium ratio (LER)*

LER value in all intercropping treatments was higher than that of monocultures of the two crops (table 4).

Results show that the highest LER value was achieved in safflower density of 12 plants and chickpea densities of 40 and 50 plants (LER=1.97) which is equal to 97.5% increase in agricultural profitability compared to monocultures of two crops. The lowest LER as 1.22 was obtained in 8 safflower stands and 30 and 40 chickpea plants. In this case, intercropping has land profitability increase as 0.22 hectare. Reduction of LER in higher densities can be due to inter-competition between chickpea and safflower. Intercropping is profitable when grain yield is higher than that of monoculture. This increase in yield can be due to better use of resources by the two crops, physiological and morphological difference between them and lower level of weeds in intercropping. In an experiment conducted on cumin and lentil intercropping, Hamayati et al (2002) observed the highest LER in row intercropping.

Table 4- Relative yields (RY), land equivalent ratio (LER) for grain yields of Safflower and Chickpea at the different intercropping densities

| Treatments | Safflower (RY) | Chickpea (RY) | LER |
|---|---|---|---|
| (a1b1) | 0.74 | 1.17 | 1.91 |
| (a1b2) | 0.78 | 1.19 | 1.97 |
| (a1b3) | 0.78 | 1.19 | 1.97 |
| (a2b1) | 0.63 | 1.19 | 1.82 |
| (a2b2) | 0.63 | 1.10 | 1.73 |
| (a2b3) | 0.65 | 0.78 | 1.43 |
| (a3b1) | 0.64 | 0.58 | 1.22 |
| (a3b2) | 0.64 | 0.58 | 1.22 |
| (a3b3) | 0.64 | 0.7 | 1.34 |

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