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Evaluation of plant density on light distribution and interception in canopy of mungbean genotypes

Tohidi Mahmood[1*], Falahi Rahim[2], Mokhtarpoor Asghar[3]

[*]Department of Agronomy, Islamic Azad University, Dezful Branch, Dezful, Iran
[2,3]Agricultural Researcher, Islamic Azad University, Dezful Branch, Dezful, Iran

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ABSTRACT

In order to evaluate the effect of plant density on light interception and efficiency in mungbean genotypes, a research was conducted in summer 2011in agricultural research farm of Islamic Azad University of Dezful. The experiment was performed factorial based on Randomized Complete Block Designs (RCBD) with three replications. The research included 12 treatments including four levels of plant density (plant spacing 5, 10, 15, and 20 cm) and three genotypes of mungbean were Parto, KPS, and CN95.The results showed that treatments of plant spacing on the row and genotypes and their interaction had significant effects on light interception, Radiation Use Efficiency (RUE), Leaf Area Index (LAI), and grain yield. For the highest and lowest light interception(95.3 and 71.1%), RUE was 2.55 and 1.63 g/mj, and LAI was 95.3 and 71.1%, on interaction of plant spacing 10 and 20cm on row were related to Parto and KPS genotypes, respectively. This study demonstrated that achieving desirable yield depends on light interception, radiation use efficiency and high leaf area index so that the highest and lowest grain yield, 2573 and 1358 kg/ha on interaction of plant spacing on row 10 and 20cm were related to Parto and KPS genotypes, respectively.

KEYWORDS: Plant density, Light absorption, Radiation use efficiency, Mungbean genotype.

I.INTRODUCTION

The main objective in crop management is to achieve maximum light interception by crop canopy. Agricultural professionals think that reduction in radiation penetration into vegetation reduces crop yield, and in order for solar radiation to be used by plant character, maximum radiation should be absorbed by the plant so any factor that increases radiation will increase plant yield. The mainspring for crop management is to maximize light interception by plant canopy, and also maximum and optimized operation of all growth factors such as water, nutrients, radiation, and CO_2have been considered in order to achieve high yield. Radiation is one of the most important climate factors that directly and indirectly affect all plant life functions. Having optimized plant characteristics including LAI, better leaf distribution in the plant (source), producing larger reproductive organs(reservoir), and efficiency of favorable environmental conditions are affected by cultivar, optimized density, productivity, height of plant, and planting pattern that allow maximum crop yield to be achieved. Absorption of radiation by plants and its application for conversion of light energy into heat energy and as a result, its accumulation as plant biomass indicates the fundamental processes that control crop growth and yield. One of the methods for evaluating plants functions is measurement of the radiation received by plant and calculation of the efficiency of converting it into dry matter. Purcell et al. (2002) and Soltani et al. (2006) mentioned that RUE constitutes the amount of dry matter produced in terms of gram for one mj solar energy received. Beheshti et al. (2002) stated that spacing arrangements of respiratory organs in plant affects the amount of absorption of radiation received by vegetation during different stages of plant life cycle. In addition to photo-synthetically active radiation (PAR), increased output of converting PAR into dry matter and RUE also affect dry matter production and are among prerequisites to achieve high yield, providing optimized conditions to use solar radiation in order to produce photosynthesis materials in the highest efficiency. Idinoba et al. (2002) reported that RUE is one of the first parameters applied in most stimulation models of plant growth that is used to analyze plant production in different regions and to improve management planning and techniques especially in heterogeneous environments like arid regions. Yano et al. (2007) stated that the study of growth and accumulation of biomass in different crops indicated that biomass production depended on LAI and radiation rate received during growth period. Ekmel and Johnson (2004) suggested that the environmental factors and management operations such as planting, plant density, cultivar, climate changes and soil productivity, and especially available nitrogen affected RUE because they played specific roles in photosynthesis. Mungbean is one of cereals that have long been used as one of the most important protein resources in most people's diet. Mung bean is a thermophilic plant and it needs high heat, and beside wheat and barley, it could be cultivated easily under climate conditions of Khuzestan. Considering the effective role of the plant on soil productivity, crop frequency, cultivability as forage and green fertilizer in order to improve quality of the soil reveal the

*** Corresponding Author:** Tohidi Mahmood, Department of Agronomy, Islamic Azad University, Dezful Branch, Dezful, Iran. mahmoodtohidi@yahoo.com

necessity of conducting comprehensive researches on the plant to achieve the best crop management. One of the main objectives in agriculture is the necessity for determination of the best plant density to get the optimal yield. The optimized density is achieved when vegetation has maximum leaf area at the beginning of reproductive stage to receive radiation. In very large densities, mortality increases due to competition and at low densities, radiation penetration into vegetation will be reduced and these changes will lead to reduced yield. The increased crop yield in any region and selecting the appropriate cultivars that are adjustable with the climate of that region are the most important objectives. Applying the appropriate cultivars that are adjustable with climate of north Khuzestan is necessary for production to be increased and for the effective characteristics on seed yield to be examined. This research was conducted to introduce the genotype(s) appropriate and adjustable with climate of the region and to determine the effect of the plant density to achieve maximum radiation by canopy of mungbean crop.

2. MATERIALS AND METHODS

This research was conducted in 2012 at agricultural research farm of Islamic Azad University of Dezful that is located at north Khuzestan, with the altitude of 82m, the latitude of 32°22′N, longitude of 48°32′S, and the average annual precipitation of 250mm, without summer precipitation and with semi-arid climate. According to the soil science experiments, soil is the place for sand loamy research with PH=7.8. This research was conducted with 12 treatments including four plant densities (plant spacing 5, 10, 15, and 20cm) and three mungbean genotypes (Parto, KPS, CN95) in factorial randomized complete block design in three replications. The operation of soil preparation including plaguing was done by plow, two perpendicular discs, and a trowel. Chemical fertilizers of urea 50kg (starter) and that of phosphorus 120kg as P_2O_5 and potash fertilizer 120kg as K_2O and critical level of the elements were calculated separately after soil test and after these three fertilizers were completely combined, they werespread and then the discs were used and some streams and stacks were made with 50cm spacing. After determining the viability, mungbean seeds were cultivated manuallyon rows more than the expected plant density by dry planting method. Irrigation was performed immediately after planting and the other irrigations were peformed depending on needs. In order to determine plant density levels (plant spacing) accurately after making sure that the germination in the farm is uniform, the additional plants during 2-3 leaves stage with respect to spacing between two plants according to the desired treatments, stronger and healthier seedlings equal to other plants were made sparse and weeding was done manually.

1.2 Measurement of radiation use efficiency and absorption

In order to measure radiation received, 20 days after planting, once every seven days, the light on top and bottom of the canopy was measured by PAR measuring digital device LP-80, and at the same time sampling was performed to determine dry matter and leaf area. The measurements was performed in four points of any terrace and intervals of 11-13 hours and perpendicular to row directions and the average measurement was used as the radiation received for plant community. Sampling in any terrace was performed randomly from three plants to calculate and measure LAI and dry weight produced while measuring light. Light interception (LI) was calculated by using the equation $LI\% = (1-I_1 \times I_0) \times 100$, where$I_1$ and I_0 are radiations at bottom and top of the plant community, respectively (Maddoni and Otegui, 1996). RUE was calculated by measuring the slope of regression line within dry matter (g/m^2) and cumulative radiation (mj/m^2) according to method introduced by Tsubo and Walker (2002). Meanwhile, by using the information of aerology station, and detraction of 45% of total solar radiation as received visible spectrum (Campaign and Normann, 1998), radiation absorbed in any stage was calculated by PAR received multiplied by radiation interception in any stage of sampling, and finally total radiation interception was calculated cumulatively in any stage. In order to compare the final yield at the end of any growth period, seed yield with 14% humidity was calculated from two middle lines of any terrace without margins and after cutting plants. The entire statistical calculations required were performed by MSTATC software and also comparison of the average treatments was performed by Duncan method.

3. DISCUSSION AND RESULTS

3.1 Leaf Area Index

The results of data variance analysis suggested that (Table 3) the effects of genotype treatments, plant spacing on rows, and their interaction were significant on maximum LAI. The comparison of the average data analysis indicated that the highest and the lowest LAI, 4.20 and 2.30, are related to Parto and KPS genotypes in 10 and 20cm plant spacing on rows, respectively (Table 1). Jamialahmadi et al. (2008) mentioned that any factor that improves growth and development of leaf area at the beginning of the season, and makes the canopy to be closed early, like early harvest and/or probably fertilizer use, may lead to enough leaf area for plant during maximum radiation so the entire interception and utilization of the radiation by the plant increased and plant yield was improved. Asseng et al. (2004) found that the study of growth and accumulation of biomass in various crops showed that biomass production depended on LAI and radiation received during growth period. Zhang et al. (2008) stated that PAR received by the plant mainly depended on LAI and leaves arrangements on canopy that was more important than LAI in the plant.

Review of researchers' findings indicated that the solar radiation interception has direct relationship with leaf area and with increasing the latter radiation receipt also increases, so crop management should be applied in a way that plant photosynthesis maximizes by receiving the entire or major part of the solar radiation, and if that is the case, selection of a genotype and an appropriate spacing on row with respect to canopy allows maximizing solar light interception. Therefore, the optimized LAI is an effective factor on the grain yield and if LAI reaches the optimized value in a short time, the maximum light interception will be received by genotype and as a result, the maximum grain yield is achieved. Selection of the appropriate genotype in a region in terms of structure and leaf distribution on canopy could help grain yield to be achieved. In this research, Parto genotype in plant spacing on row 10cm has the largest LAI.

3.2 Light interception

The results from data variance analysis suggested that (Table 3) genotype treatments, plant spacing on rows, and their interaction on maximum light interception were significant. The comparison of the average data indicated that the highest and the lowest light interception 95.3 and 72.4% were related to genotypes of Parto and KPS in 10 and 20cm plant spacing on row (Table 2). Rajcan & Swanton (2001) reported that LAI is one of the most important structural characteristics and plant abilities in light interception, so any reduction in LAI allows lower radiations to be received and intercepted. Yano et al. (2007) stated that the review of growth and accumulation of dry matter on crops depended on LAI and radiations received during growth period, solar radiation was an energy resource for crops, if a plant wanted to use solar energy effectively, maximum radiation should be received by green tissues of the plant, leaves were considered the main organs for receiving light in crops, so they were seen as the important thing in dry matter production, and plant growth, and crop management was aimed mainly at maximization of the light interception by the crop canopy. Most of agricultural activities like plant spacing on rows and selection of the appropriate genotype are used to receive more light and cover the earth surface. Reduction in radiation penetration into vegetation may reduce crop yield, so any factor that increases radiation absorption may lead to increased crop yield. Then, achieving an optimized yield depends on rapid growth of the canopy and maximization of LAI to intercept maximum light and the growth completion at an appropriate time. A genotype that has high LAI will receives more light and it will have higher grain yield with the optimized efficiency of this input light to plant community. It seems that among the study genotypes, Parto with a suitable geometrical structure that requires an optimized leaf arrangement and optimized LAI has the largest light interception in 10cm plant spacing on the rows.

3.3 Radiation Use Efficiency (RUE)

The results obtained from data variance analysis demonstrated (Table 3) that genotype treatments, plant spacing on the rows, and their interactions on RUE were significant. The comparison of the average data suggested that the highest and the lowest RUE, 2.55 and 1.64 g/mj are related to genotypes of Parto and KPS in 10 and 20cm plant spacing on rows, respectively (Table 4). John et al. (2005) found that under no stress condition, production of dry matter in plant had a linear relationship with the radiation absorbed by the plant and slope of this relationship indicated RUE. Idinoba et al. (2002) recognized that RUE was one of the first parameters used in most of the plant growth stimulation models that were used to analyze plant production in different regions and to improve management planning and techniques, particularly in heterogeneous environments like arid regions. Awal et al. (2006) stated that light was an important natural resource and if its efficiency increased, level of production could be increased. Alimadadi et al. (1385) reported that because various environmental, plant and crop management factors affected the obtained RUE, it should be noticed that the developed models could apply these factors only under similar conditions, and although a higher RUE indicated better plant capability to convert light into biomass, biomass production with its extreme yield depended mainly on the absorbed radiation by the plant. Dwyer et al. (1992) reported that RUE was largely controlled by genetic factors; however, it was affected by the environmental factors and management operations such as the plant density and spacing, planting date, cultivar and changes in the soil productivity. According to the findings obtained by the researchers and the results of this research, it seems that one of the most important factors in yield is applying light, genotype, and the appropriate plant spacing on rows so that genotype of Parto with the highest LAI and more light interception are more capable of converting light into biomass in 10cm plant spacing on row, and uniform distribution of plant allows the appropriate distribution of solar radiation on the vegetation, and it will lead to reduced intraspecific competition and ultimately it would have a larger RUE and genotype of KPS with the lowest LAI, and the light interception would have the lowest RUE.

3.4 Grain yield

The results of data variance analysis (Table 3) suggested that genotype treatments, plant spacing on the rows and their interaction onthe grain yield were significant. The comparison of the average data indicates that the highest and the lowest grain yield 2573 and 1358 kg/ha are related to genotypes of Parto and KPS in 10 and 20cm plant spacing on rows, respectively (Table 5). In a research, Tesfaye et al. (2006) found that, dry matter accumulationin cereals largely depended on the light absorbed and penetrated into the canopy and the latter itself depended on LAI. Beheshti et al. (2002) mentioned that a change in dry matter produced due to the effect of sources of change (planting arrangement and genotype) on the PAR absorbed and also RUE were considered the basic elements of dry matter accumulation during various growth stages. Board et al. (1992) reported that there was usually a positive correlation between LAI and dry matter ofrespiratory organ and it had a negative correlation with light passed acrossthe canopy. In other words, increased LAI would lead to reduced light passed across the plant canopy. According to the findings of researchers and the results obtained from the present study, it seems that the improved grain yield is the result of increased dry matter accumulation and genotype of Parto that has higher LAI, light interception, and RUE on 10cm plant spacing on the row, would absorb more PAR and higher grain yield would be achieved and it seems that most of the morphological characteristics of genotype of Partoare adjustable with the environmental conditions in which the research had been conducted and have relationship with thegrain yield. It is probably because of the proper balance in the canopy of this genotype and utilization of solar light by the character.

4. CONCLUSION AND RECOMMENDATIONS

Achievements of modern agronomics and eugenics techniques largely depend on management of light distribution in the plant community. When plants are provided with enough water and nutrients, light is the only thing that has a determinant effect on the plant yield. All the evidence demonstrates that the more light interception is in the plant community, the more grain yield will be achieved. With increasing light interception, the economic yield increases, so the increased light interception to achieve high grain yield requires an appropriate genotype and plant spacing on the row. Purcell et al. (2002) mentioned that the solar light absorption by plants and its application in biomass production indicates the fundamental processes that control the crop growth and yield. Duration of solar light receiving by plants during the season could be managed by selecting cultivars with the optimized growth period, and the increased total PAR received during the season will lead to more biomass production in the mature plant. According to the comparison of mungbean genotypes in this research, it seems that the genotype that could have more LAI, light interception and absorption, and solar RUE, has more grain yield. The genotypes with the structural and engineering characteristics of plant community different from each other have been able to transfer light penetration into the canopy, and the genotype that could better conduct the transfer, it will have more grain yield. The results from the present study suggested that because genotype of Parto with the structural and engineering characteristics of plant community, has better transferred light penetration and distribution as compared to the other genotypes in the study in 10cm plant spacing on the row, and has increased the main reserve of seed that is the result of more PAR received, it had the highest rain yield and the genotype of KPS had the lowest grain yield in 20cm plant spacing on row.

Table-1: Comparison of the average effect of interaction of plant density ×genotype on the maximum LAI

No.	Plant density × genotype	Maximum leaf area index	Statistical level
1	D2G1	4.20	a
2	D4G1	3.73	b
3	D1G1	3.67	b
4	D2G3	3.57	bc
5	D3G1	3.47	bcd
6	D1G3	3.23	cde
7	D4G3	3.13	de
8	D3G3	2.97	fg
9	D4G2	2.67	fg
10	D3G2	2.57	g
11	D1G2	2.43	g
12	D2G2	2.30	g

Table-2: Comparison of the average effect of interaction of plant density ×genotype on the light interception

No.	Plant density × genotype	Light interception (%)	Statistical level
1	D2G1	95.3	a
2	D2G3	90.3	ab
3	D1G1	89.7	abc
4	D4G1	89.0	abc
5	D2G2	85.7	abc
6	D3G1	83.3	bc

7	D1G3	82.0	bc
8	D3G2	82.0	bc
9	D3G3	80.2	cd
10	D4G3	79.7	cd
11	D4G2	72.0	de
12	D1G2	71.1	e

Table-3: Results from variance analysis of maximum LAI, light interception, RUE, grain yield

Mean-square					
Sources of change	**Degrees of freedom**	**LAI**	**Light interception**	**RUE**	**Seed yield**
Replication	2	0.212	47.028	0.78	11032.111
Plant density (D)	2	4.914*	528.028**	0.553**	1007598.361*
Genotype (G)	3	0.200**	246.917**	0.358**	329355.809**
D × G	6	0.179**	87.028**	0.028**	529598.139*
Experimental error	22	0.024	27.755	0.006	42025.566
Coefficientof variation		4.88	6.36	3.82	10.72

Table-4: Comparison of the average effect of interaction of plant density ×genotype on RUE

No.	Plant density × genotype	RUE (g/mj)	Statistical level
1	D2G1	2.55	a
2	D3G1	2.30	b
3	D2G3	2.14	bc
4	D3G3	2.02	cd
5	D2G2	1.96	cde
6	D4G1	1.93	de
7	D1G1	1.93	de
8	D1G3	1.85	def
9	D4G3	1.80	efg
10	D3G2	1.73	fg
11	D1G2	1.66	g
12	D4G2	1.64	g

Table-5: Comparison of the average effect of interaction of plant density ×genotype on grain yield

No.	Plant density × genotype	Seed yield (kg/hectare)	Statistical level
1	D2G1	2576	a
2	D2G1	2470	ab
3	D2G3	2350	ab
4	D3G1	2302	ab
5	D1G3	1985	bc
6	D4G2	1977	bc
7	D4G3	1784	cd
8	D3G3	1711	cd
9	D1G2	1605	cd
10	D2G2	1437	d
11	D3G2	1388	d
12	D4G1	1358	d

REFERENCES

Akmal, M., and Janssens, M.J.J. 2004. Productivity and light use efficiency of perennial ryegrass with contrasting water and nitrogen supplies. *Field crops research*., 88: 143-155.

Amimadadi, A., Jahansooz, M., Ahmadi, A., Tavakkol afshari, R., and Rostamza, M. 2006. Evaluation of radiation use efficiency, light extinction coefficient and radiation received at different varieties of cowpea, mung bean and red bean in the second planting. *Pazhouhesh & Sazandegi*., 71: 67-75.

Asseng, S., Jamieson, P.D., Kimball, B., Printer, P., Sayre, K., Bowden, J.W., and Howden, S.M. 2004. Simulated wheat growth affected by rising temperature, increased water deficit and elevated atmospheric CO_2. *Field crops research*., 85: 85-102.

Awal, M.A., Koshi, H., and Ikeda, T. 2006. Radiation interception and use by maize/peanut intercrop canopy. *Agricultural and forest meteorology*., 139: 74-83.

Beheshti, A. Kouchaki A., Nasiri Mahalati M. 2002. Effect of planting pattern onlight andradiation use efficiency inthe canopies of three maize cultivars.,Nahal o Bazr, 18 (4):417-431.

Board, J.E., Kamal, M., and Haryille, B.G. 1992. Temporal importance of greater light interception to increase yield in narrow-row soybean. *Agronomy journal*., 84: 575-579.

Dwyer, L.M., Stewart, D.W., Hamilton, R.I., and Honwing, L. 1992. Ear position and vertical distribution of leaf area in corn. *Agronomy journal.*, 84: 430-438.

Idinoba, M.E., Idinoba, P.A., and Gbadegesin, A.S. 2002. Radiation interception and its efficiency for dry matter production in three crop species in the transitional humid zone of Nigeria. *Agronomy journal.*, 22: 273-281.

Jamialahmadi, M., Kafi, M., and Nasiri Mahallati, M. 2008.Salinity effects on radiation utilization characteristics of Kochia (Kochia scoparia L).*Pazhouhesh & Sazandegi*.,No. 78: 177-185.

John, L.L., Timothy, J.A., Daniel, T.W., Nenneth, G.C., and Achim, A. 2005. Maize radiation use efficiency under optimal growth conditions. *Agronomy journal*., 97: 72-78.

Maddoni, G.A. and Otegue, M.E. 1996. Leaf area, light interception and crop development in maize. *Field crops research*., 18: 81-87.

Purcell, C., Ball, J., Reaper, D., and Voreis, E. 2002. Radiation use efficiency and biomass production in soybean at different plant population densities. *Crop science*., 42: 172-177.

Rajcan, I. and Swanton, C.J. 2001. Understanding maize-weed competition: resource competition, light quality and the whole plant. *Field crops research*., 71: 139-150.

Soltani, A., Roberson, M.J., Rahemi-Karizaki, A., Pooreze, J., and Zarei, H. 2006. Modeling biomass accumulation and partitioning in chickpea (*cicer arietinum L.). Journal of agronomy crop science*., 192: 379-389.

Tesfaye, K., Walker, S., and Tsubo, M. 2006. Radiation interception and radiation use efficiency of three grain legumes under water deficit in a semi-arid environment. *Agronomy journal*., 25: 60-70.

Tsubo, M. and Walker, S. 2002. A model of radiation interception and use by a maize/bean intercrop canopy. *Agricultural and forest meteorology*., 110: 203-215.

Yano, T., Aydin, M., and Haraguchi, T. 2007. Impact of climate change on irrigation demand and crop growth in a Miditerranean environment of Turkey. *Sensors.*, 7: 2287-2315.

Zhang, L., Vander Werf, W., Bastiaans, L., Zhang, S., Li, B., and Spiertz, J.H. 2008. Light interception and utilization in relay intercepts of wheat and cotton. *Field crops research*., 107: 29-42.