Plant Archives Vol. 20, Supplement 2, 2020 pp. 975-980 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF LIGHT INTENSITY AND NITROGEN ADDITION ON SOME GROWTH PARAMETERS OF PEA (*PISUM SATIVUM* L.)

Mustafa Hameed Al-Majdi[1], Mokhtar Ghobadi[2]*and Saeid Jalali Honarmand[3]

[1]Department of Crop Physiology, Campus of Agriculture and Natural Resources, Razi University, Kermanshah, Iran.

[2,3]Department of Plant Production and Genetic Engineering, Campus of Agriculture and Natural Resources, Razi University, Kermanshah, Iran.

*Author for correspondence: E-mail: ghobadi.m@razi.ac.ir ; m.ghobadi@yahoo.com

Abstract

A field experiment was conducted during 2017-18 and 2018-19 cropping seasons to study the responses of some growth characteristics of pea plant to light intensity and nitrogen fertilizer. Direct sunlight intensities (0, 25, 50, 75 and 100%) and nitrogen fertilizer amounts (0, 35 and 70 kg N.ha^{-1}) were arranged in a factorial experiment with three replications. Different direct sunlight intensities were provided by special grids. The results of both years experiment showed that the effects of light, nitrogen and their interaction effect on the studied traits were significant. Plant height, the number of branches per plant, the number of leaves per plant, plant leaf area and plant dry matter were increased by decreasing direct sunlight intensities. But the above mentioned traits were increased by increasing N fertilizer. Therefore, it seems that the pea plant has the ability to tolerate shade and nitrogen addition, to be in mixed cropping systems.

***Keywords*:** Direct sunlight intensity, nitrogen fertilizer, leaf area, growth traits, pea.

Introduction

Legumes are an important food source and play a significant role in traditional diets in many regions of the world (Nikolopoulou *et al*., 2007). Pea (*Pisum sativum* L.) is an economically important vegetable crop. The pea seeds contain carbohydrate, protein, fat and fiber as well as vitamins A and B. (AL-Qaisi, 2012).

In the field, plants are affected by environmental (such as light) and management (such as nitrogen) factors. Understanding the interaction of environmental and management factors on plant growth is more important than their individual effects.

In plants, sunlight is the source of energy for photosynthesis. Sunlight also regulates plant growth and development processes (Kilic *et al*., 2010). The sunlight regulates photosynthetic assimilation and partitioning of plants (Slewinski and Braun, 2010). Plants use several types of photoreceptors, such as phytochromes and cryptochromes, to perceive aspects of radiation in the environment (Mawphlang and Kharshiing, 2017). However, shading reduces the intensity and changes the spectral composition of the light (Yang *et al*., 2014). For example, reductions in the red/far-red (R/Fr) light ratio and the photosynthetically active radiation (PAR) strongly impair the growth and development of plants under shading (Yang and Li, 2017). Plants can adjust their morphology and physiology to acclimatize toward a modified light quality (e.g., reduced R/Fr ratio) and a decreased PAR. This acclimatization results in the allocation of carbon to the elongation of stem and petiole at the expense of leaf and root development (Park and Runkle, 2017).

Nitrogen (N) is the element most absorbed in soil by plants growing under normal conditions. For this reason and due to their high mobility in soil, N is also the nutrient that is more deficient for most crops all over the world (Torres-Olivar *et al*., 2014). N is an essential element of all organisms, as a component of proteins, amino acids, nucleic acids (DNA, RNA), membrane lipids, ATP, NADH, NADPH, co-enzymes, photo-synthetic pigments and secondary metabolites (Ohyama, 2010). Legume plants have the ability to biological nitrogen fixation. However, biological nitrogen fixation greatly diminished in arid regions or in soils with low organic matter content. Therefore, nitrogen supply by chemical or organic fertilizers is essential (Zahran, 1999).

The absorption of sunlight by the leaves depends on the light intensity, leaf age, leaf structure and pigments (Taiz and Zieger, 2002). On the other hand, various factors such as plant density and nutritional conditions (especially N) affect on sunlight absorption and leaf pigments content (Todd *et al*., 2005). The purpose of this study was to evaluate the response of some pea growth traits to direct sunlight intensities and the addition of nitrogen fertilizer.

Materials and Methods

A biennial research was conducted at Campus of Agriculture and Natural Resources, Razi University, Kermanshah, Iran, during 2017-18 and 2018-19 cropping seasons. This place is located in latitude 34°21' North and longitude 47°9' East with elevation 1320 m above sea level and belongs to semi-arid zone.

A factorial experiment based on randomized complete block design (RCBD) was used with three replications. The factors were direct sunlight intensities (0, 25, 50, 75 and 100%) and nitrogen fertilizer amounts (0, 35, and 70 kg N.ha^{-1}). The direct sunlight intensities were provided by special grids prepared for this purpose. N treatments were applied using urea fertilizer with 46% N. Light and nitrogen treatments were applied 30 days after seedling emergence.

Before the seed planting, soil sample were taken from 0-30 depth to soil analysis according to Page *et al*. (1982) method. The soil test results were presented in Table 1. Each plot contains six rows with 25 cm between them. Seeds of pea (Dorian cultivar) were planted at 10 cm distance and 4-5

cm depth. Seed planting dates were March 5, 2017 and March 8, 2018, respectively. Sprinkler irrigation was used for field irrigation. Weeds were removed manually.

Table 1 : Physical and chemical characteristics of the soil.

Objective	Value
Sand (%)	41.5
Silt (%)	42.8
Clay (%)	15.7
Texture	Silty clay
EC ($ds.m^{-1}$)	1.82
pH	7.8
$CaCO_3$ (%)	28
Organic matter (%)	0.99
Total N (%)	0.09
Available P ($mg.kg^{-1}$)	18
Available K ($mg.kg^{-1}$)	360
Mn ($mg.kg^{-1}$)	14
Fe ($mg.kg^{-1}$)	4.5
Zn ($mg.kg^{-1}$)	0.48
Cu ($mg.kg^{-1}$)	1.8

The following growth parameters were studied:

- **Plant height:** The height of the main stem from the soil surface to the end of the stem was measured in ten plants per plot.
- **The number of branches per plant:** The number of branches per plant was counted in ten plants per plot.
- **The number of leaves per plant:** In each plot, the number of three-foliate leaves of ten plants was counted.
- **Plant leaf area:** In each plot, the leaves of ten plants were separated and then leaf area was measured by scanner using special software.
- **Plant dry weight:** From each plot, ten plants were harvested from the soil surface, and all aerial parts of the plants were oven-dried at 72 °C for 48 h and then their dry weight was measured.

Analysis of variance of the data was computed using the SAS statistic software. The LSD test ($P \leq 0.05$) was used to test the differences among mean values.

Results

Plant height

The analysis of variances showed that the effects of light intensity, N and its interaction on plant height were significant in both years (Table 7). The treatment 0% direct sunlight intensity was significantly superior and gave the highest plant height with 65 and 64 cm in 2017-18 and 2018-19 experiments, respectively. While 100% light treatment gave the lowest plant height (Table 2). Plant height increased with the addition of N fertilizer and the highest plant height was obtained in 70 kg $N.ha^{-1}$ treatment. Mean comparison of the light × N interaction showed that the highest plant height (71 and 68 cm in the first and second years, respectively) was observed in the treatment of 0% light and 70 kg $N.ha^{-1}$.

Number of branches per plant

In the analysis of variance, the effects of light intensity, N and their interaction on the number of branches per plant were significant (Table 7). Reducing the light intensity by shading increased the number of branches per plant. The maximum number of branches per plant was obtained in 0% direct sunlight (5.4 and 5.0 branches in the first and second years, respectively) (Table 3). Increasing N fertilizer amounts caused to increase in the number of branches per plant. The mean number of branches per plant in 0, 35 and 70 Kg $N.ha^{-1}$ treatments were 3.5, 4.4 and 5.3 for the first year and 3.1, 4.0 and 5.2 for the second year, respectively. In the interaction effect, the results showed that the highest number of branches per plant was obtained in 0% direct sunlight × 70 kg $N.ha^{-1}$ (7.3 and 6.7 branches for the first and second years, respectively).

The number of leaves per plant

The effects of light intensity, N and their interaction on the number of leaves per plant were significant (Table 7). The number of leaves per plant increased with decreasing the light intensity and increasing the N fertilizer (Table 4). 0% direct sunlight × 70 kg $N.ha^{-1}$ produced the highest the number of leaves per plant (60.3 and 59.6 leaves in first and second years, respectively).

Plant leaf area

According to the analysis of variance, the effects of light intensity, N and their interaction on leaf area were significant at both years (Table 7). The average leaf area at 100 and 0% direct sunlight intensities were obtained 650 and 713 cm^2 per plant in the first year and 668 and 700 cm^2 per plant in the second year, respectively (Table 5). However, an increase in the amount of N fertilizer led to an increase in leaf area. The highest leaf area was observed in 0% direct sunlight × 70 kg $N.ha^{-1}$ interaction effect treatment with 751 and 750 cm^2 per plant for the first and second years, respectively.

Plant dry matter

The effects of light intensity, N and their interaction on the plant dry matter were significant in the two years experiment (Table 7). Plant dry matter increased with decreasing the direct sunlight intensity. But increasing the amount of N fertilizer increased the plant dry matter (Table 6). Maximum plant dry matter was observed in 0% direct sunlight × 70 kg $N.ha^{-1}$ (31.9 and 29.3 $g.plant^{-1}$ in the first and second years of experiment, respectively). Minimum plant dry matter was also obtained in 100% direct sunlight × 0 kg $N.ha^{-1}$ (18.3 and 18.8 $g.plant^{-1}$ in the first and second years of experiment, respectively).

Table 2 : The responses of plant height (cm) to direct sunlight intensities and nitrogen amounts in pea plant during 2017-18 and 2018-19.

Direct sunlight intensity (%)	2017-18 Nitrogen (kg.ha^{-1})				2018-19 Nitrogen (kg.ha^{-1})			
	0	35	70	Average	0	35	70	Average
0	61.24	64.45	71.80	65.83	60.58	63.88	68.04	64.17
25	57.82	61.23	64.80	61.28	57.52	60.32	64.22	60.69
50	55.73	57.48	60.11	57.77	54.77	56.93	59.29	57.00
75	51.68	55.00	56.53	54.41	50.92	54.41	55.89	53.74
100	49.07	52.27	54.09	51.81	48.36	52.23	53.37	51.32
Average	55.11	58.08	61.47		54.43	57.55	60.16	
LSD $_{(0.05)}$	Light intensity=1.02 ; Nitrogen=0.79 light intensity × Nitrogen=1.76				Light intensity=0.71 ; Nitrogen=0.55 Light intensity × Nitrogen=1.23			

ns, ** and * represent non-significant, significant at 1 and 5% probability levels, respectively

Table 3 : The responses number of branches per plant to direct sunlight intensities and nitrogen amounts in pea plant during 2017-18 and 2018-19.

Direct sunlight intensity (%)	2017-18 Nitrogen (kg.ha^{-1})				2018-19 Nitrogen (kg.ha^{-1})			
	0	35	70	Average	0	35	70	Average
0	3.33	5.67	7.33	5.44	3.67	4.67	6.67	5.00
25	4.00	4.67	5.67	4.78	3.67	4.33	5.67	4.56
50	4.00	4.67	5.33	4.67	3.33	4.00	5.33	4.22
75	3.33	3.67	4.67	3.89	3.00	3.67	4.67	3.78
100	3.00	3.67	3.67	3.44	2.00	3.33	3.67	3.00
Average	3.53	4.47	5.33		3.13	4.00	5.20	
LSD $_{(0.05)}$	Light intensity=0.44 ; Nitrogen=0.35 light intensity × Nitrogen=0.77				Light intensity=0.32 ; Nitrogen=0.25 Light intensity × Nitrogen=0.55			

Table 4 : The responses number of leaves per plant to direct sunlight intensities and nitrogen amounts in pea plant during 2017-18 and 2018-19.

Direct sunlight intensity (%)	2017-18 Nitrogen (kg.ha^{-1})				2018-19 Nitrogen (kg.ha^{-1})			
	0	35	70	Average	0	35	70	Average
0	50.67	61.00	69.33	60.33	51.33	60.00	67.67	59.67
25	48.33	54.67	64.00	55.67	47.67	54.67	60.00	54.11
50	43.67	48.33	57.00	49.67	43.33	49.67	54.67	49.22
75	40.33	45.00	50.67	45.33	40.67	45.67	48.67	45.00
100	36.67	41.00	44.00	40.56	36.33	41.00	44.33	40.56
Average	43.93	50.00	57.00		43.87	50.20	55.07	
LSD $_{(0.05)}$	Light intensity=0.71 ; Nitrogen=0.55 light intensity × Nitrogen=1.24				Light intensity=1.56 ; Nitrogen=1.21 Light intensity × Nitrogen=2.70			

Table 5 : The responses of plant leaf area to direct sunlight intensities and nitrogen amounts in pea plant during 2017-18 and 2018-19.

Direct sunlight intensity (%)	2017-18 Nitrogen (kg.ha^{-1})				2018-19 Nitrogen (kg.ha^{-1})			
	0	35	70	Average	0	35	70	Average
0	684.60	703.15	751.57	713.11	666.45	683.66	750.35	700.15
25	655.98	694.95	741.67	697.53	651.96	672.32	731.28	685.19
50	625.53	698.82	761.37	695.24	646.48	663.19	714.92	674.86
75	681.68	684.46	708.07	691.40	642.65	667.45	707.31	672.47
100	602.11	655.94	692.21	650.08	636.45	676.01	692.12	668.19
Average	649.98	687.46	730.98		648.80	672.53	719.20	
LSD $_{(0.05)}$	Light intensity=8.64 ; Nitrogen=6.69 light intensity × Nitrogen=14.96				Light intensity=25.14 ; Nitrogen=19.47 Light intensity × Nitrogen=43.54			

Table 6 : The responses of plant dry matter (g.plant^{-1}) to direct sunlight intensities and nitrogen amounts in pea plant during 2017-18 and 2018-19.

	2017-18				2018-19			
	Nitrogen (kg.ha^{-1})				Nitrogen (kg.ha^{-1})			
Direct sunlight intensity (%)	**0**	**35**	**70**	**Average**	**0**	**35**	**70**	**Average**
0	23.91	24.98	31.90	26.93	23.98	24.85	29.33	26.05
25	22.93	23.23	24.63	23.60	22.97	24.12	24.67	23.92
50	21.83	23.31	26.36	23.84	21.84	23.16	23.53	22.84
75	18.80	22.20	24.27	21.76	20.55	21.90	22.33	21.59
100	18.37	21.37	22.47	20.73	18.85	20.70	20.56	20.04
Average	21.17	23.02	25.93		21.64	22.95	24.08	
LSD $_{(0.05)}$	Light intensity=1.28 ; Nitrogen=0.99 light intensity × Nitrogen=2.21				Light intensity=1.10 ; Nitrogen=0.85 Light intensity × Nitrogen=1.91			

Discussion

In a two-year experiment, the pea plant was exposed to direct sunlight intensities (0, 25, 50, 75 and 100%) and N fertilizer amounts (0, 35 and 70 kg N.ha^{-1}). Some plant growth parameters were studied. The results showed that decreasing of the sunlight intensity increased plant height, the number of branches per plant, the number of leaves per plant, plant leaf area and plant dry weight.

In a plant, there are differences in leaf area, leaf and cuticle thickness, chlorophyll content and stomatal behavior among leaves exposed to sunlight and shade (Taiz and Zieger, 2002). There are many contradictory reports on the influence of light intensities on plant growth and development. Wadud *et al*. (2002) and Ballare (2004) reported that in the plants expose to shading, the leaf area was increased in order to compensate the low photosynthesis rate caused by low light intensity; subsequently increased leaf area increased plant total photosynthesis. On the other hand, some studies show that under light conditions, stem weight was higher than shading conditions (Nayak and Murty, 1980). Under shade conditions, the weight of above-ground parts of the plant was increased due to prolonged vegetative growth (Alvarenga *et al*., 2003). Raven *et al.* (2005) reported that changes in light intensity affect the assimilates distribution in different parts of plant. Alvarenga *et al*. (2003) and Haque *et al*. (2009) reported that seedlings exposed to direct sunlight had different dry matter distribution and produced more leaves than shade-grown seedlings.

The effects of light intensities 2000, 4000, 6000 and 8000 foot-candle on four bean (*Phaseolus vulgaris* L.) cultivars showed that the stomata density at the 8000 foot-candle was much more than 2000 foot-candle (Knecht and O'Leary, 1972). Light intensity also changed the stomata behavior (Mansfield *et al.*, 1990; Willmer and Fricker, 1996). Eriksen and Whitney (1981) studied six forage grasses at 27, 45, 70 and 100% direct sunlight intensities. They reported that 45, 70, and 100% light intensities had not significant differences in plant dry matter. But increasing the light intensity decreased leaf nitrogen content. The highest leaf area index was obtained at 45 and 70% light intensities.

Light-dependent changes in plant morphogenesis are regulated by plant hormones (Wu *et al*., 2017). Among the endogenous plant hormones, gibberellins (GA_s) and auxin [indole-3-acetic acid (IAA)] mediate the shading adaptive responses of plants, especially for shade-induced differential growth and elongation (Yang and Li, 2017). Under shade conditions, due to lack of auxin destruction, internodes become weaker, thinner and more susceptible to stem lodging (Ma, 2003). Low values of R/Fr ratio and PAR promoted growth and increased the GA content in the internodes of bean, hypocotyls and leaves of sunflower, and shoots of tomato and arabidopsis (Kurepin *et al.*, 2012). A low R/Fr ratio coupled with a normal PAR increased the endogenous IAA content in the third internode of pea seedlings and the leaves of sunflower (Kurepin *et al*., 2007). Although shading promotes the petiole elongation, the mechanism of how light intensity and quality affect the petiole GA and IAA contents need further study (Morelli and Ruberti, 2000). Therefore, the relationship between the growth of each plant organ and the associated hormones (GA_s and IAA) must be further investigated to reveal the morphological response of plants to the interaction between light quality and intensity. A few studies reported that the specific distributions of GA_s and IAA in radish are strongly correlated with the photo-morphogenetic responses to blue or red light (Kara *et al*., 1997).

The results of our experiment showed that plant height, the number of branches per plant, the number of leaves per plant, plant leaf area and plant dry weight increased with application of 70 kg N.ha^{-1}.

Khan (1986) and Khan *et al*. (1988) found that plant dry weight and grain yield of pea were increased when added 20-50 kg N.ha^{-1} (Carr *et al.*, 1992). Jensen (1987) observed improved flowering parameters when adding 213-244 kg N.ha^{-1} to pea plant. Brkic *et al* (2004) obtained significant increase in pod number, pod weight and number of seeds per pod with adding 40, 80 and 120 kg N.ha^{-1} to pea plant. In a study that 0, 25, 50, 75, 100 and 125 kg N.ha^{-1} were used for four pea cultivars; results showed that maximum fresh pod weight, number of pod plant^{-1}, pod length, 1000 seed dry weight and seed protein content were recorded in 100 kg N.ha^{-1} (Achakzai and Bangulzai, 2006).

Conclusion

Some conditions reduce extremely the direct sunlight intensity in the crop canopy, such as the presence of weeds, high density planting, and specially mixed cropping systems. The results of the present study showed that the pea plant has the ability to tolerate shade; therefore, in such conditions this plant can be used. On the other hand, application of appropriate amount of N fertilizer improves pea growth under such conditions.

Table 7: Analysis of variance (mean squares) for pea growth parameters under direct sunlight intensities and nitrogen amounts during 2017-18 and 2018-19 experiments.

Year	Source of variations	df	Plant height	Number of branches per plant	Number of leaves per plant	Plant leaf area	plant dry weight
2017-18	Replication	2	1.51^{ns}	4.02**	19.35**	131.12^{ns}	3.65^{ns}
	Light (L)	4	277.08**	5.55**	561.35**	4977.03**	50.65**
	Nitrogen (N)	2	151.89**	12.15**	641.35**	24648.0**	86.26**
	L × N	8	6.26**	1.32**	16.43**	1281.62**	6.24**
	Error	28	1.11	0.21	0.54	79.97	1.74
	CV (%)		9.12	22.84	18.06	7.12	9.77
2018-19	Replication	2	1.80*	2.48**	66.42**	70.75^{ns}	3.27^{ns}
	Light (L)	4	240.98**	5.27**	505.64**	3830.49**	47.03**
	Nitrogen (N)	2	123.57**	16.15**	473.08**	31306.10**	22.48**
	L × N	8	1.97**	0.37**	9.06**	2915.17**	3.16*
	Error	28	0.5412	0.107	2.61	677.85	1.29
	CV (%)		9.17	26.56	17.09	7.50	9.54

References

Achakzai, A.K.K. and Bangulzai, M.I. (2006). Effect of various levels of nitrogen fertilizer on the yield and yield attributes of pea (*Pisum sativum* L.) cultivars. Pakistan Journal of Botany. 38(2): 331-340.

AL-Qaisi, W.A. (2012). Effect of Aspirin spraying (Acetyl Salicylic acid) and extract of *Eucalyptyus incrassta* on growth and yield of Pea (*Pisum sativum* L.). Baghdad scientific journal. 9(3): 87-98.

Alvarenga, A.A.; Castro, E.M.; Castro Lima Junior, E. and Magalhaes, M.M. (2003). Effects of different light levels on the initial growth and photosynthesis of *Croton urucurana* Baill in Southeastern Brazil. Revista Arvore. 27: 53-57.

Ballare, C.L. (2004) Competition: Response to shade by neighbors. In Encyclopedia of Plant and Crop Science. R.M. Goodman (eds.). Marcel Dekker Inc. Wisconsin, U.S.A.

Brkic, S.; Milakovic, Z.; Kristek, A. and Antunovic, M. (2004). Pea yield and its quality depending on inoculation nitrogen and molybdenum fertilization. Plant, Soil and Environment. 1: 39-45.

Carr, P.M.; Martin, G.B.; Caton, J.S. and Poland, W.W. (1992). Forage and nitrogen yield of barley-pea and oat-pea intercrops. Agronomy Journal. 90: 79-84.

Eriksen, F.I. and Whitney, A.S. (1981). Effects of light intensity on growth of some tropical forage species. I. Interaction of light intensity and nitrogen fertilization on six forage grasses. Agronomy Journal. 73: 427-433.

Haque, M.M.; Hasauzzaman, M. and Rahman, M.L. (2009). Effect of light intensity on the morphophysiology and yield of bottle ground (*Lagenaria vulgaris*). Academic Journal of Plant Sciences. 2: 158-161.

Jensen, E.S. (1987). Seasonal patterns of growth and nitrogen fixation in field-grown pea. Pant and Soil. 101: 29-37.

Kara, A.N.; Kotov, A.A. and Bukhov, N.G. (1997). Specific distribution of gibberellins, cytokinins, indole-3-acetic acid, and abscisic acid in radish plants closely correlates with photomorphogenetic responses to blue or red light. Journal of Plant Physiology, 151: 51–59.

Khan, G.S. (1988). Effect of nitrogen and N uptake in pigeon pea *Cajanus cajan.* Tropical Agriculture (Trinidad) 72: 76-79.

Khan, H.; Mashiatullah, A. and Mahmood, N.H. (1986). Response of soybean to artificial inoculation at different levels of added nitrogen. *Annual Report.* NIFA., Tarnab, Peshawar, Pakistan. 177-179.

Kilic, S.; Karatas, A.; Cavusoglu, A.; Unlu, H. and Padem, H. (2010). Effects of different light treatments on the stomata movements of tomato (*Lycopersicon esculentum* Mill. cv. Joker) seedlings. Journal of Animal and Veterinary Advances. 9: 131-135.

Knecht, G.N. and O'Leary, W.J. (1972) The Effect of light intensity on stomata number and density of *Phaseolus vulgaris* L. leaves. International Journal of Plant Science, 133: 132-134.

Kurepin, L.V.; Walton, L.J.; Hayward, A.; Emery, R.J.N.; Pharis, R.P. and Reid, D.M. (2012). Interactions between plant hormones and light quality signaling in regulating the shoot growth of Arabidopsis thaliana seedlings. Botany. 90(3): 237–246.

Kurepin, L.V.; Walton, L.J.; Reid, D.M.; Chinnappa, C.C. and Pharis, R.P. (2007). Uncoupling light quality from light irradiance effects in *Helianthus annuus* shoots: putative roles for plant hormones in leaf and internode growth. Journal of Experimental Botany, 58: 2145–2157.

Ma, B.L.; Dwyer, L.M. and Costa, C. (2003). Row spacing and fertilizer nitrogen effects on plant growth and grain yield of maize. Canadian Journal of Plant Science. 83(2): 241-247.

Mansfield, T.A.; Hetherington, A.M. and Atkinson, C.J. (1990). Some current aspects of stomatal physiology. Annual Review of Plant Physiology and Plant Molecular Biology, 41: 55-77.

Mawphlang, O.I.L. and Kharshiing, E.V. (2017) Photoreceptor mediated plant growth responses: implications for photoreceptor engineering toward improved performance in crops. Frontiers in Plant Science, 8: 1181.

Morelli, G. and Ruberti, I. (2000) Shade avoidance responses. Driving auxin along lateral routes. Plant Physiology, 122: 621–626.

Nayak, S.K. and Murty, K.S. (1980) Effect of varying light intensities on yield and growth parameters in rice. Indian Journal of Plant Physiology, 23: 309-316.

Nikolopoulou, D.; Grigorakis, K.; Stasini, M.; Alexis, M.N. and Iliadis, K. (2007). Differences in chemical

composition of field pea (*Pisum sativum*) cultivars: Effects of cultivation area and year. Food Chemistry. 103: 847–852.

Ohyama, T. (2010) Nitrogen as a major essential elements of plants. In Nitrogen Assimilation in Plants. Ed Ohyama T. and K. Sueyoshi. Research Signpost, Kerala India, 1-17.

Page, A.L.; Miller, R.H. and Keeney, D.R. (1982). Methods of Soil Analysis. 2ed. American Society of Agronomy, Inc. & Soil Science Society of America. Madison, Wisconsin, USA.

Park, Y. and Runkle, E.S. (2017). Far-red radiation promotes growth of seedling by increasing leaf expansion and whole-plant net assimilation. Environmental and Experimental Botany. 136: 41–49.

Raven, J.A.; Andrews, M. and Quigg, A. (2005). The evolution of oligotrophy: implications for the breeding of crop plants for low input agricultural systems. Annals of Applied Biology. 146: 261-280.

Slewinski, T.L. and Braun, D.M. (2010). Current perspectives on the regulation of whole-plant carbohydrate partitioning. Plant Science, 178: 341–349.

Taiz, L. and Zieger, E. (2002) Plant Physiology, Ed 5. Sinauer Associates, Sunderland, MA.

Todd, A.; Peterson, T.M.; Blackmer, D.D.; Francis, J. and Schepers, S. (2005). Using a chlorophyll meter to improve N management; Soil Scientist G93-1171-A.

Torres-Olivar, V.; Villegas-Torres, O.G.; Domínguez-Patiño, M.L.; Sotelo-Nava, H.; Rodríguez-Martínez, A.; Melgoza-Alemán, M.; Valdez-Aguilar, L.A. and Alia-Tejacal, I. (2014) Role of nitrogen and nutrients in crop nutrition. Journal of Agricultural Science and Technology. 29-37.

Wadud, M.A.; Rahman, G.M.M.; Chowdury, M.J.U. and Mahboob, M.G. (2002). Performance of red amaranth under shade condition for agro-forestry system. International Journal of Biological Sciences, 2: 765-766.

Willmer, C. and Fricker, M. (1996) Stomata, 2nd edn. Vol. 2. Suffolk: St Edmundsbury Press.

Wu, Y.S.; Gong, W.Z. and Yang, W.Y. (2017). Shade inhibits leaf size by controlling cell proliferation and enlargement in soybean. Scientific Reports. 7: 9259.

Yang, C. and Li, L. (2017) Hormonal regulation in shade avoidance. Frontiers in Plant Science, 8: 1527.

Yang, F.; Huang, S.; Gao, R.C.; Liu, W.G.; Yong, T.W. and Wang, X.C. (2014). Growth of soybean seedlings in relay strip intercropping systems in relation to light quantity and red: Far-red ratio. Field Crops Research. 155: 245–253.

Zahran, H.H. (1999). Rhizobium-Legume Symbiosis and Nitrogen Fixation under Severe Conditions and in an Arid Climate. Microbiology and Molecular Biology Reviews, 63(4): 968–989.