International Journal of Agricultural Technology 2017 Vol. 13(1): 79-89
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Influence of Different Shading Levels on Growth and Yield of Kalmegh, *Andrographis paniculata* Burm. F. (Nees)

Liphan, S.[*] and Detpiratmongkol, S.

Department of Plant Production Technology, Faculty of Agricultural Technology, King Mongkut' s Institute of Technology Ladkrabang, Bangkok, Thailand.

Liphan, S. and Detpiratmongkol, S. (2017). Influence of different shading levels on growth and yield of kalmegh *Andrographis paniculata* Burm. f. (Nees). International Journal of Agricultural Technology 13(1):79-89.

Abstract Kalmegh *Andrographis paniculata* Burm. F. (Nees) is widely used as medicinal plant in Thailand to treat diseases such as sore throat, flu, fever, diarrhea and cough. Kalmegh production in some region is negatively affected by high radiation. However, the information on the effect of shade on growth and yield of Kalmegh is lacking. Thus, the objective of this study was to evaluate the effect of different shading levels on growth and yield of Kalmegh. The study was conducted during December, 2014 to April, 2015, at Faculty of Agricultural Technology, King Mongkut' s Institute of Technology Ladkrabang, Bangkok. A split-plot in randomized complete block design with 3 replications was arranged. Four local Kalmegh varieties (Phisanulok 5-4, Prachinburi, Ratchaburi and Phichit 4-4) and 5 shading levels (0%, 20%, 40%, 50% and 80% of shading) were as main plots and sub plots, respectively. Data were collected on growth and yield of the crop. The results shown that we were not found interaction between Kalmegh varieties and shading levels. Prachinburi variety gave the highest number of branches plant^{-1}, number of leaves plant^{-1}, leaf area, shoot dry weight and leaf dry weight yield and followed by Ratchaburi, Phichit 4-4 and Phisanulok 5-4 varieties, respectively. Shading affected on growth and yield of Kalmegh. In addition, significant different were observed for all growth characters between open light condition (0% shade) and shaded plants. For different shading levels, leaves number plant^{-1}, leaf area, shoot dry weight and leaf dry weight yield were the highest under 20% shading condition. It was concluded that Kalmegh variety Prachinburi performed better in terms of highest growth and yield grown under 20% shading condition.

Keywords: Shading, Yield, Growth, Kalmegh, *Andrographis paniculata*

Introduction

Kalmegh is one of the most important medicinally important plant grown worldwide. Kalmegh *Andrographis paniculata* Burm. f. (Nees) belongs to family Acanthaceae was known as "King of bitters" (Kumar *et al.,* 2012) due to its bitter taste and the weak odor is one of the important herbs classified as an annual and shrub plant in tropical Asian countries. Kalmegh is available

[*] **Corresponding author:** Liphan S.; **Email:** Rabbit.Liphan@hotmail.com

abundantly in India, Pakistan, Sri Lanka, East and West Indies, Mauritius, China, Java, Thailand and Indonesia (Kumar *et al.,* 2012). Kalmegh is known as Fah Talai Jone in Thai Folklore, used in the treatment of various diseases of the liver, colic, fevers, and as anthelminthic. The medicinal herb Kalmegh, grows as a wild plant in the open fields (Biffa, 2003; Jaganath and Teik, 2003; Anonymous, 2008; Niranjan *et al.,* 2010; Akbar, 2011).

Light is the major factor to the life cycle of a plant because it is the energy source that triggers the process of photosynthesis. All plants need sunlight to make their food, and if the available sunlight is reduced the plant have to change and adapt in various ways in order to acclimatize to a new environment. Excessive light intensity resulted in photosynthesis inhibition as it has a destructive effect on photosynthetic pigments (Kumar *et al.,* 2012). The plants grow well in shaded places such as undergrowth in the forest. Under natural conditions, Kalmegh is found in both shaded and wide open areas. This may be a lack of information on growth and physiology related to different light intensities of Kalmegh (Saravanan *et al.,* 2008). Growth and yield of crops are close related to the amount of solar received during the growing period. This study objective was therefore to investigate Kalmegh in growth and yield response to different levels of shading.

Materials and methods

Experimental site: The research was carried out at the nursery house of Faculty of Agricultural Technology, King's Mongkut Institute of Technology Ladkrabang, Ladkrabang district, Bangkok province, Thailand (13° 43' 36.21" N latitude and 100° 46' 48.45" E longitude) with an elevation of 1.5 m. above mean sea level during December 2014 to April 2015. The used soil in the experiment was Bangkok series and clay in texture. The soil was slightly acidic with pH 6.10. The mean annual rainfall for five years from the year of 2010 to 2015 was 151.98 mm. The mean daily temperature is 30.95 °C.

Experimental design: The experiment was arranged in a split-plot design with three replications. The main plot was the four local commercial Kalmegh varieties (Phisanulok 5-4, Prachinburi, Ratchaburi and Phichit 4-4) and the sub-plot was the kind of five shading levels such as 0% (no shading / control), 20%, 40%, 50% and 80% shading provided by black net. In 0% shading treatment, sunlight was allowed to fall over the Kalmegh plants without any barrier. Kalmegh plants were placed in different lath houses, constructed using wooden post and planks. Each lath house was 4 m long, 4 m wide and 2 m height. Each lath house, except for the control, was covered with different density black shading net according to the objectives of the experiment. Stem cuttings were conducted from mother plant of Kalmegh. Stem cutting was placed in shaded

seedbed for root initiation. Fifteen days old stem cuttings were planted in the experiment. One stem cutting was planted in each pot. The pot was irrigated and intercultural operations like weeding were done as and when necessary. Irrigation was given to the plants after planting till harvest. Other cultural practices were made as and when necessary.

Data collection and analysis: At harvest, 120 days after transplanting (DAT), all of plant from each pot in each supplication and treatment for data collection. Data collected included: number of branches, number of leaves, number of pods and shoot dry weight. The leaf area (cm^2) of harvested leafy Kalmegh was measured using a leaf area meter (LI-3100 area meter, USA). Chlorophyll content was measured using a chlorophyll meter (SPAD-502, Minolta Co, Japan). For all treatments, the leaf of Kalmegh was inserted into the leaf clip and SPAD value measured 5 times from different spots of a single leaf and bract. Chlorophyll a and b in leaf were measured by 80% acetone. Absorbance was taken at 645 and 663 nm using UV-VIS spectrophotometer according to Witham *et al.* (1971). Crop growth rate on plant mass (CGR, g m^{-2} day^{-1}) during the monitoring period was calculated from the formula: $CGR = \frac{1}{p}\ x\ \left(\frac{dw}{dt}\right)$ where CGR = crop growth rate, p = ground area, dw = dry weight production in t days, dt = number of days.

Collected data were analyzed by analysis of variance using ANOVA following the procedure for Split-plot design. Least significant different (LSD) values were calculated at 0.05 probability level wherever the F-test was significant. Data analysis was performed using WINDOWSTAT statistical software.

Results and Discussion

Number of branches

Number of branches $plant^{-1}$ varied significantly among the varieties at harvest (Table 1). The highest number of branches $plant^{-1}$ (25.33) was recorded in the variety Prachinburi and the lowest number of branches $plant^{-1}$ (19.73) was recorded from the variety Phisanulok 5-4. Kalmegh grown at 0% shading had significantly ($P<0.05$) higher number of branches $plant^{-1}$ when compared to those shaded at 40%, 50% and 80% levels, respectively (Table 1). Kalmegh at 80% shading had the highest number of branches $plant^{-1}$ (27.00) while those shaded at 80% had the lowest number of branches $plant^{-1}$ (17.00). Shivashankara *et al.* (2000) reported that 10-60% light curtailment produced higher internodal length, increase in number of branches, leaf number in betel vine (Piper betle).

Table 1. Effects of different shading levels on no. of branches plant^{-1}, no. of leaves plant^{-1}, leaf area (cm^2), no. of pods plant^{-1}, pod dry weight and shoot dry weight (g plant^{-1}) at 120 days after transplanting of 4 local Kalmegh cultivars at harvest.

Treatments	No. of branches plant^{-1}	No. of Leaves plant^{-1}	Leaf area (cm^2)	No. of pods plant^{-1}	Pod DW. (g plant^{-1})	Shoot DW. (g plant^{-1})
Main plot (Cultivars)						
Phisanulok 5-4	19.73	246	200.84	28.73	0.19	5.58
Prachinburi	25.33	338	365.20	86.26	1.05	12.85
Ratchaburi	21.20	267	273.72	72.20	0.85	8.62
Phichit 4-4	21.33	285	224.17	39.26	0.45	7.17
Sub plot (Shading levels (%))						
0 (Control)	23.83	363	319.22	82.33	0.93	11.34
20	27.00	469	476.32	127.00	1.54	16.26
40	22.00	285	235.79	44.25	0.49	9.15
50	19.66	212	203.57	24.83	0.20	5.01
80	17.00	91	95.01	4.67	0.02	1.02
Mean	21.90	284	265.98	56.61	0.64	8.56
LSD (0.05) (Cultivars)	2.49	46.37	41.12	6.27	0.11	1.44
LSD (0.05) (Shading levels)	1.11	35.32	22.58	4.74	0.10	0.72
LSD (0.05) (Cultivars x Shading levels)	ns	ns	ns	ns	ns	ns
C.V. (%) (Cultivars)	12.77	18.26	17.30	12.40	20.60	18.92
C.V. (%) (Shading levels)	6.12	14.94	10.21	10.08	22.34	10.19

ns = No significant at the 0.05 probability level ; DW = Dry weight.

Number of leaves

Number of leaves plant^{-1} varied significantly among the varieties at harvest (Table 1). The maximum number of leaves plant^{-1} (338) was obtained from variety Prachinburi whereas the minimum leaves number plant^{-1} (246) was obtained from variety Phisanulok 5-4. There was significant ($P<0.05$) difference in number of leaves plant^{-1} between Kalmegh plant grown under the different shading level. Plant grown under 20% shading gave the highest number of leaves plant^{-1} (469) while the lowest number of leaves plant^{-1} (91) was obtained from plants provided with 80% shading (Table 1). In *Aster scaber* and *Lingularia fischeri*, plant height, leaf number, length and width were increased in 30-50% shading as against the open condition (Hong *et al.*, 1996).

Leaf area

Leaf area varied significantly among the varieties at harvest (Table 1). The variety Prachinburi gave the highest leaf area (365.20 cm^2) followed by Ratchaburi (273.72 cm^2) Phichit 4-4 (224.17 cm^2) and the lowest leaf area (200.84 cm^2) was recorded by the Phisanulok 5-4. Shading the Kalmegh plant at 0% results in significant ($P<0.05$) higher leaf area (319.22 cm^2) when compared to all the other shading levels (Table 1). The lowest leaf area (95.01 cm^2) was obtained from the plant provided with 80% shading whereas the highest (476.32 cm^2) was obtained from those provided with 20% shading. On the other hand Jeong *et al.* (2007) stated that an increased in leaf area of begonia with increased shade levels. Leaf area in weeping fig (*Ficus benjamina* L.) and Croton (*Codiaeum variegatum* L.) (Scuderi *et al.,* 2008) and sweet pepper (Medany *et al.,* 2009) were found to increase leaf area with increased shading levels (Scuderi *et al.,* 2008). Similarly in this investigation, increase in shading level above 20% results in corresponding decrease in number of leaves $plant^{-1}$ and leaf area of Kalmegh. Naidu and Swamy (1994) observed increase in number and area of leaves in *Pongamia pinnata* plant grown in shade.

Number of pods and pod dry weight

Significant variation was found in respect of number of pods $plant^{-1}$ and pod dry weight among the varieties at harvest (Table 1). The highest (86.26 pods and 1.05 g $plant^{-1}$) and the lowest (28.73 pods and 0.19 g $plant^{-1}$) were obtained from variety Prachinburi and Phisanulok 5-4, respectively. The highest number of pods $plant^{-1}$ (127.00 pods) and pod dry weight (1.54 g $plant^{-1}$) were obtained in plants provided with 20% shading as compared to all the other shading levels (Table 1). However, shading reduced the number of pods per plant for soybean as reported by Kurosaki and Yumoto (2003) and Kakiuchi and Kobata (2004, 2006).

Shoot dry weight

Shoot dry weight varied significantly among the variety at harvest (Table 1). The variety Prachinburi recorded the highest shoot dry weight (12.85 g $plant^{-1}$) followed by Ratchaburi (8.62 g $plant^{-1}$), Phichit 4-4 (7.17 g $plant^{-1}$) and Phisanulok 5-4 (5.58 g $plant^{-1}$), respectively. There was significant ($P<0.05$) difference in shoot dry weight of Kalmegh plant grown under the five different shading levels (Table 1). Kalmegh grown at 20% shading had the highest shoot dry weight (16.26 g $plant^{-1}$) while those shaded at 80% had the lowest shoot dry

weight (1.02 g plant^{-1}). Kakiuchi and Kobata (2004, 2006) reported that total dry weight per plant decreased with an increase in shade.

SPAD values

The results on the determination of chlorophyll values using the SPAD meter (Table 2). Significant variation was found in respect of SPAD values among the varieties. The highest (58.06) and the lowest (50.84) were obtained from variety Prachinburi and Phisanulok 5-4, respectively. Minotta and Pinzauti (1996) reported that the total chlorophyll content is depend on physiological characteristic of species. Kalmegh plant grown under the different shading levels (Table 2). Plant grown under at 80% shading had the highest SPAD values (67.24) followed by 50% shading (59.33), 40% shading (55.66), 20% shading (50.13) and 0% shading (39.97), respectively. According to previous studies, the findings of López-Marín *et al.* (2012) and Zhu *et al.* (2012) where 60% and 30% shading intensity resulted in the highest SPAD values, respectively. However, our finding harmonizes with those reported by Legarrea *et al.* (2010) and Jang *et al.* (2014) noting that higher shading intensity resulted in higher SPAD values and higher chlorophyll concentration. Shade-plants develop acclimation strategies, including larger and thinner leaves which present even a three-fold increase in chlorophylls (Adamson *et al.*, 1991; Taiz and Zeiger 2002). Nonetheless, the excess of light can cause greater degradation and consequently, a reduction in the levels of total chlorophyll (De Carvalho Gonçalves *et al.*, 2005).

Chlorophyll a and b content in leaf

Chlorophyll a and b content in leaf varied significantly among the varieties at harvest (Table 2). The variety Prachinburi was recorded the highest chlorophyll a and b content in leaf (0.14 and 0.38 mg / 100 g of leaf fresh weight) and the lowest chlorophyll a and b content in leaf (0.05 and 0.16 mg / 100 g of leaf fresh weight) was recorded by Phisanulok 5-4. Chlorophyll content in leaf increased progressively with the increase of shading level (Table 2). Plant grown under 80% shading gave the highest chlorophyll a and b content in leaf (0.23 and 0.63 mg / 100 g of leaf fresh weight) followed by 50%, 40% and 20% shading, respectively whist the lowest chlorophyll a and b content in leaf (0.02 and 0.07 mg / 100 g of leaf fresh weight) were obtained from plants grown under 0% shading. It has been postulated that shading increased the quality of chlorophyll and thus increase the photosynthesis efficiency of plant and ultimately the yield increase (E-Aidy *et al.*, 1983). In

Rumhora adiantiformis, around 50 and 70% shading increased the contents of chlorophyll a, b and total chlorophyll (Chen *et al.*, 1999). Thomes *et al.* (2005) reported that high chlorophyll contents might also contribute to higher photosynthetic rate and significant positive correlation between chlorophyll content and photosynthesis rate.

Table 2. Effects of different shading levels on SPAD values, chlorophyll a content and chlorophyll b content in leaf (mg / 100 g of leaf fresh weight) at 120 days after transplanting of 4 local Kalmegh cultivars at harvest.

Treatments	SPAD values	Chlorophyll a content in leaf (mg / 100 g of LFW)	Chlorophyll b content in leaf (mg / 100 g of LFW)
Main plot (Cultivars)			
Phisanulok 5-4	50.84	0.05	0.16
Prachinburi	58.06	0.14	0.38
Ratchaburi	54.42	0.13	0.37
Phichit 4-4	54.40	0.12	0.33
Sub plot (Shading levels (%))			
0 (Control)	39.97	0.02	0.07
20	50.13	0.04	0.15
40	55.66	0.09	0.27
50	59.33	0.15	0.41
80	67.24	0.23	0.63
Mean	54.46	0.11	0.31
LSD (0.05) (Cultivars)	4.62	0.02	0.05
LSD (0.05) (Shading levels)	3.74	0.01	0.03
LSD (0.05) (Cultivars x Shading levels)	ns	ns	ns
C.V. (%) (Cultivars)	9.51	20.37	19.64
C.V. (%) (Shading levels)	8.26	12.30	13.60

ns = No significant at the 0.05 probability level ; LFW = leaf fresh weight.

Crop growth rate

Crop growth rate determines the dry matter accumulation in a time and land units in a plant community. The crop growth rate value varied significantly among the varieties and shading lavels at 0-30, 30-60, 60-90 and 90-120 days after transplanting (Table 3). Crop growth rate value in this study had an ascending growth. The variety Prachinburi recorded the highest crop growth rate values (0.06, 0.62, 1.48 and 3.89 g m^{-2} day^{-1}) followed by Ratchaburi (0.05, 0.36, 1.15 and 2.49 g m^{-2} day^{-1}), Phichit 4-4 (0.04, 0.29, 1.29 and 1.74 g m^{-2} day^{-1}) and Phisanulok 5-4 (0.03, 0.12, 0.72 and 1.73 g m^{-2} day^{-1}), respectively. There was significant ($P<0.05$) difference in crop growth rate values of

Kalmegh plant grown under the five different shading levels (Table 3). Plant grown under at 20% shading had the highest crop growth rate values (0.07, 0.81, 2.23 and 4.53 g m^{-2} day^{-1}) followed by 0%, 40% and 50% shading while those shaded at 80% had the lowest crop growth rate values (0.03, 0.05, 0.14 and 0.24 g m^{-2} day^{-1}).

Table 3. Effects of different shading levels on crop growth rate values (g m^{-2} day^{-1}) of 4 local Kalmegh cultivars at harvest.

Treatments	Crop growth rate values (g m^{-2} day^{-1})			
	Ages (DAT) (days)			
	0-30	30-60	60-90	90-120
Main plot (Cultivars)				
Phisanulok 5-4	0.03	0.12	0.72	1.73
Prachinburi	0.06	0.62	1.48	3.89
Ratchaburi	0.05	0.36	1.15	2.49
Phichit 4-4	0.04	0.29	1.29	1.74
Sub plot (Shading levels (%))				
0 (Control)	0.06	0.45	1.63	3.20
20	0.07	0.81	2.23	4.53
40	0.05	0.25	1.17	2.83
50	0.04	0.17	0.63	1.51
80	0.03	0.05	0.14	0.24
Mean	0.05	0.35	1.16	2.46
LSD (0.05) (Cultivars)	0.06	0.07	0.21	0.54
LSD (0.05) (Shading levels)	0.02	0.03	0.17	0.31
LSD (0.05) (Cultivars x Shading levels)	ns	ns	ns	ns
C.V. (%) (Cultivars)	15.12	23.30	20.70	24.84
C.V. (%) (Shading levels)	8.81	11.10	18.48	15.37

ns = No significant at the 0.05 probability level ; DAT = Day after transplanting.

Leaf fresh and dry weight yield

Significant variation was found in respect of leaf fresh and dry weight yield among the varieties (Table 4). The highest (6.20 and 3.37 g $plant^{-1}$) and the lowest (4.44 and 1.61 g $plant^{-1}$) were obtained from variety Prachinburi and Phisanulok 5-4, respectively. There was significant ($P<0.05$) difference in leaf fresh and dry weight yield between Kalmegh plant grown under the different shading levels. Plants grown under 20% shading gave the highest leaf fresh weight yield per plant (6.60 g $plant^{-1}$) while the lowest leaf fresh weight yield per plant (3.16 g $plant^{-1}$) was obtained from plants provided with 80% shading (Table 4). For dry leaf dry weight yield, the highest leaf dry weight yield (3.75 g $plant^{-1}$) was obtained from Kalmegh grown 20% shading, while the lowest (0.33 g $plant^{-1}$) was obtained from plant shaded at 80% (Table 4). Increasing

the shading intensity results in a significant (P<0.05) decrease in yield of Kalmegh. These results are in good agreement with the finding of Devkota and Jha (2010) also showed that increasing level of shading could reduce growth and yield of plant. On the other hand, Santiago-Santos and Cedeno-Maldonado (1991) reported that the leaf mass of ngo gai produced under 63 or 73 % shade was greater than that produced under full sun.

Table 4. Effects of different shading levels on leaf fresh and dry weight yield (g plant^{-1}) of 4 local Kalmegh cultivars at harvest.

Treatments	Leaf FWY. (g plant^{-1})	Leaf DWY. (g plant^{-1})
Main plot (Cultivars)		
Phisanulok 5-4	4.44	1.61
Prachinburi	6.20	3.37
Ratchaburi	5.11	2.28
Phichit 4-4	4.71	1.88
Sub plot (Shading levels (%))		
0 (Control)	6.11	3.13
20	6.60	3.75
40	5.49	2.83
50	4.20	1.37
80	3.16	0.33
Mean	5.11	2.28
LSD (0.05) (Cultivars)	0.92	0.43
LSD (0.05) (Shading levels)	0.76	0.31
LSD (0.05) (Cultivars x Shading levels)	ns	ns
C.V. (%) (Cultivars)	20.29	21.29
C.V. (%) (Shading levels)	18.03	16.49

ns = No significant at the 0.05 probability level ; FWY = fresh weight yield ; DWY = dry weight yield.

Conclusion

It is concluded that among the studied 4 Kalmegh varieties, Prachinburi was the best growth and yield. The highest growth and leaf dry weight yield were obtained from Kalmegh provided with 20% shading. Increased shading level above 20% significant reduced in stem growth and dry weight yield. However, production of Kalmegh should, therefore be undertaken for Prachinburi variety at 20% shading to obtain the best growth and leaf fresh and dry weight yield.

Acknowledgement

The authors thank the Faculty of Agricultural Technology, King Mongkut' s Institute of Technology Ladkrabang for providing the financial support.

References

Adamson, H. Y., Chow, W. S., Anderson, J. M., Vesk, M. and Sutherland, M. W. (1991). Photosynthetic acclimation of Tradescantia albiflora to growth irradiance: morphological, ultrastructural and growth responses. Physiological Plant 82:353-359.

Akbar, S. (2011). *Andrographis paniculata*: A review of pharmacological activities and clinical effects. Alternative Medicine Review 16:66-77.

Anonymous. (2008). Intellectual property and traditional medical knowledge. World Intellectual Property Organization 933:1-4.

Biffa, M. A. (2003). Conservation and diversity of Hempedu Bumi (*Andrographis paniculata* nees) germplasm in Malaysia. Dissertation of Master of Agricultural Science, Faculty of Agriculture, Universiti Putra Malaysia 1-25.

Chen, R. Y., Zeng, Q. L., Su, W. X., Wu, H. and Li, Z. F. (1999). Effect of shading treatments on growth and some physiological effects in *Rumhora adiantiformis*. Journal of South China Agricultural University 20:77-79.

De Carvalho Gonçalves, J. F., De Sousa Barreto, D. C., Dos Santos Jr, U. M., Fernandes, A. V., Barbosa Sampaio, P. D. T. and Buckeridge, M. S. (2005). Growth, photosynthesis and stress indicators in young rosewood plants (*Aniba rosaeodora* Ducke) under different light intensities. Brazil Journal of Plant Physiology 17:325-334.

Devkota, A. and Jha, P. K. (2010). Effect of different light levels on the growth traits and yield of *Centella asiatica*. Middle-East Journal of Scientific Research. 5:226-230.

E-Aidy, F., Moustafa, S. and El-Afry, M. (1983). Influence of shade on growth and yield of tomatoes cultivated in summer season in Egypt. Plasticulture 59:33-36.

Hong, C. H., Bang, S. B. and Han, J. S. (1996). Effects of shading net on growth and yield of *Aster scaber* Thunb and *Lingularia fischeri* Turcz. RDA. Journal of Agricultural Science and Hort]iculture. 38:462-467.

Jaganath, I. B. and Teik, N. L. (2003). Malaysian herbs series 1. Smile, May/Jun 2003, 4p.

Jang, Y., Mun, B., Do, K., Um, Y. and Chun, C. (2014). Effects of photosynthetic photon flux and carbon dioxide concentration on the photosynthesis and growth of grafted pepper transplants during healing and acclimatization. Horticulture Environment and Biotechnology 55:387-396.

Jeong, K. Y., Pasian, C. C. and Tay, D. (2007). Response of sux Begonia species to different shading levels. Acta Horticulture 761:215-220.

Kakiuchi, J. and Kobata, T. (2004) Shading and thinning effects on seed and shoot dry matter increase in determi-nate soybean during the seed-filling period. Agronomy Journal 96 : 398-405. doi:10.2134/agronj2004.0398.

Kakiuchi, J. and Kobata, T. (2006) The relationship be-tween dry matter increase of seed and shoot during the seed-filling period in three kinds of soybeans with dif-ferent growth habits subjected to shading and thinning. Plant Production Science 9:20-27.

Kumar, R. N., Chakraborty, S. and Kumar, J. I. N. (2012). Influence of light and developmental stages on active principles of *Andrographis paniculata* (Burm. f.) Wall. ex Nees. Indian Journal of Sciences Research 3:91-95.

Kurosaki, H. and Yumoto, S. (2003). Effects of low tem-perature and shading during flowering on the yield com-ponents in soybeans. Plant Production Science. 6 : 17-23. doi:10.1626 /pps.6.17.

Legarrea, S., Karnieli, A., Fereres, A. and Weintraub, P. G. (2010). Comparison of UV-absorbing nets in pepper crops: spectral properties, effects on plants and pest control. Photochemistry and Photobiology 86:324-330.

López-Marín, J., Gálvez, A., González, A., Egea-Gilabert, C. and Fernández, J. (2012). Effect of shade on yield, quality and photosynthesis-related parameters of sweet pepper plants. Acta Horticulturae 956:545-552.

Medany, M. A., Hassanein, M. K. and Farag, A. A. (2009). Effect of black and white nets as alternative covers to sweet pepper production under greenhouses in Egypt. Acta Hort 807:121-126.

Minotta, G. and Pinzauti, S. (1996). Effects of light and soil fertility on growth, leaf chlorophyll content and nutrient use efficiency of beech (*Fagus sylvatica* L.) seedlings. Forest Ecology and Management 86:61-71.

Naidu, C. V. and Swamy, P. M. (1993). Effect of shade on growth, biomass production and associated physiological parameters in *Pongamia pinneta* (Linn.) Pierre. Indian J. Plant Physiol 34:212-214.

Niranjan, A., Tewari, S. K. and Lehri, A. (2010). Biological activities of Kalmegh (*Andrographis paniculata* Nees) and its active principles - A review. Indian Journal of Natural Products and Resources 1:125-135.

Santiago-Santos, L.R. and Cedeno-Maldonado, A. (1991). Effect of light intensities on the flowering and growth of spiny coriander (*Eryngium foetidum* L.). Journal of Agriculture of the University of Puerto Rico 75:383-389.

Saravanan, R., Krishti, S., Gajbhiye, N. A. and Maiti, S. (2008). Influence of light intensity on gas exchange, herbage yield and andographolide content in *Andrographis paniculata* (Nees.). Indian Journal of Horticulture. 65:220-225.

Sarma, A. S. (1977). Studies on growth and yield under different plant densities and photosynthetic efficiency of wheat genotypes. M.Sc. (Ag.) Thesis, G.B. Pant Univ. of Ag. And Tech. Pantnagar (Nainital).

Scuderi, D., Li Rosi, A., Cassaniti, C., Paratore, A. and Romano, D. (2008). The influence of shading levels on foliage plant growth and quality. Acta Hort 801:1191-1196.

Shivasankara, K. S., Mithila, T. and Maiti, S. (2000). Effect of different light intensities on growth and yield of betel vine (*Piper betel* L.). Plantn. Crops 28:196-200.

Taiz, L. and Zeiger, E. (2002). Plant Physiology. 3rd ed. Sunderland: Sinauer Associates, Inc.

Thomas, J. A., Jaffrey, A., Atsuko, C. K. and David, M. K. (2005). Regulating the proton budget of higher plant photosynthesis. Proc. Natl. Acad. Sci. USA 102:9709-9713.

Witham, F. H ., Blaydes, D. F. and Devlin, R. M. (1971). Experiments in plant physiology. Van Nostrend Reinhold Company, New York.

Zhu, J. J., Peng, Q., Liang, Y. L., Wu, X. and Hao, W. L. (2012). Leaf gas exchange, chlorophyll fluorescence, and fruit yield in hot pepper (*Capsicum anmuum* L.) grown under different shade and soil moisture during the fruit growth stage. Journal of Integrative Agriculture 11:927-937.

(Received: 6 December 2016, accepted: 8 January 2017)