Research Article

Evaluation of the Shade Tolerance of Moth Bean (*Vigna aconitifolia*) and Two Tropical Legume Species

Pantipa Na Chiangmai*, Yupa Pootaeng-on and Thanakrit Khewaram

Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Phetchaburi IT Campus, Cha-Am, Phetchaburi, Thailand

**Corresponding author. E-mail address: m_surin@yahoo.com*

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Abstract

This study aimed to evaluate the shading tolerance ability in moth bean (*Vigna aconitifolia*) in two experiments. In experiment 1, moth bean, *Centrosema pascuorum* cv. Cavalcade and *Stylosanthes guianensis* cv. Tha pra (Tha pra stylo) were grown under different sunlight shading levels by covering these plots with a black net. In Experiment 2, moth bean was intercropped with sunflower (*Helianthus annuus*) synthetic variety (Suranaree (S) 471). Both experiments were conducted in a field trial from May to August in 2011 at Agricultural Practice Farm of Faculty of Animal Science and Agricultural Technology, Silpakorn University, Phetchaburi Information Technology Campus, Phetchaburi, Thailand.

In Experiment 1, the results showed that shading reduced almost all plant growth characteristics, except plant height. All of legume species had possessed different tolerant capacity to shading, but these plants were dead at 90% of the shading level.

In Experiment 2, the agronomic traits of sunflower were not affected by intercropping with moth bean. Fresh and dry weight per plant of moth bean intercropping with sunflower was decreased, comparing with those of a moth bean monoculture. However, there was no significant difference in crude protein content of moth bean between monoculture and intercropping with sunflower.

Key Words: *Vigna*; Moth bean; Shading; Intercropping; Forage crop

Introduction

The *Vigna* species, a diverse plant species which can grow under a wide range of climate and environment (Kharb et al., 1987) has been introduced worldwide. Some species such as *V. radiata* (mungbean) and *V. unguiculata* (cowpea) are used for human diet and for improving the soil fertility. *Vigna* species also have the nutritive value which is suitable for livestock production (Chujaroen et al., 2006; Kongcharoen et al., 2006; Na Chiangmai et al., 2009a; Na Chiangmai et al., 2009b).

Moth bean (*V. aconitifolia*) is one of *Vigna* species that possess a higher nutritional value than *V. unguiculata* line KVC7, *V. radiata* var. *sublobata* (TC1995), *Centrosema pascuorum* cv. Cavalcade and *Stylosanthes guianensis* cv. Tha pra stylo), both under normal and under water stress conditions (Na Chiangmai et al., 2009b).

For this reason, moth bean is considered as an important forage crop in tropical region in the near future. This bean is thus a potential plant which may be used for intercropping with other economically important crops, such as coconut, para-rubber and oil palm. These crops are perennial trees which have been planted with a space between rows wide enough for growing other annual economic plants. As a result, the shading effect of the trees may have detrimental effect on the productivity of the intercropped annual plants.

This study thus aimed to evaluate shading tolerance of moth bean in two situations both as monoculture and under intercropping system with sunflower. Shading tolerance of moth bean will be compared with other two legume species (Cavalcade and Tha pra stylo). The results of this study can be used in the breeding program to obtain better varieties of the beans. The output of this research may also be useful to farmers in choosing crops for mixed or intercropping.

Materials and Methods

Genetic materials and seed preparing

In experiment 1, moth bean (*V. aconitifolia*) was grown under different shading levels (0, 30, 70 and 90 percent of shading) by covering with black plastic nets to simulate various level of shading. The moth bean was tested in comparison with *Centrosema pascuorum* cv. Cavalcade and *Stylosanthes guianensis* cv. Tha pra (Tha pra stylo).

In experiment 2, moth bean was grown between rows of a synthetic variety sunflower (*Helianthus annuus*), Suranaree (S) 471 in intercropping system. The moth bean and synthetic variety of sunflower were grown in the sandy clay, and low fertile and slightly acidic soil. Seeds were harvested from the field facility at Agricultural Practice Farm of the Faculty of Animal Science and Agricultural Technology, Silpakorn Unversity, IT Campus, Cha-am District, Phetchaburi Province, Thailand.

Both experiments were carried out from May to August, 2011, at Phetchaburi, Thailand. The area has an elevation approximately 0.4 meter above sea level at N12°37.780´E099°51.067´. The test was conducted when it was the rainy season with an average rainfall of 191.5 mm in May and 108.5 mm in August. The averages of temperature were 27.7 °C in May and 27.3 °C in August. The averages of duration of sunshine were 5.5 hours/day in May and 4.5 hours/day in August, with a mean of a daylength at 12.60 hours.

Growing conditions and Experimental design

In experiment 1, two seedlings of each plant species (moth bean, Cavalcade and Tha pra stylo) were planted per hill, using the spacing 50 cm between rows and 25 cm between hills in 3 x 5.75 m^2 plot size. Each block was divided into three plots. Each of three legume species was randomized for planting in each plot. However, the different on growth characteristic in these species made it difficult for comparison among them. Thus, the observation for the behavior and separated analysis in each species when was grown under different shading levels was designed in this experiment. Thus, Randomized Completely Block Design (RCBD) with four replications were conducted in this experiments in these legume species. Detail of plot layout and experiment design was given in Figure 1.

The data were gathered with respect to number of days after planting when the seedlings emerged, plant height, number of branches and number of leaves, lodging score, fresh weight and dry weight per plant. The data was recorded at about 3 weeks after planting; this date was the first stage when the farmer controlled weed and applied fertilizer. And, the second record was replicated at about two months after planting; this date is the end of vegetative phase in various forage legume species.

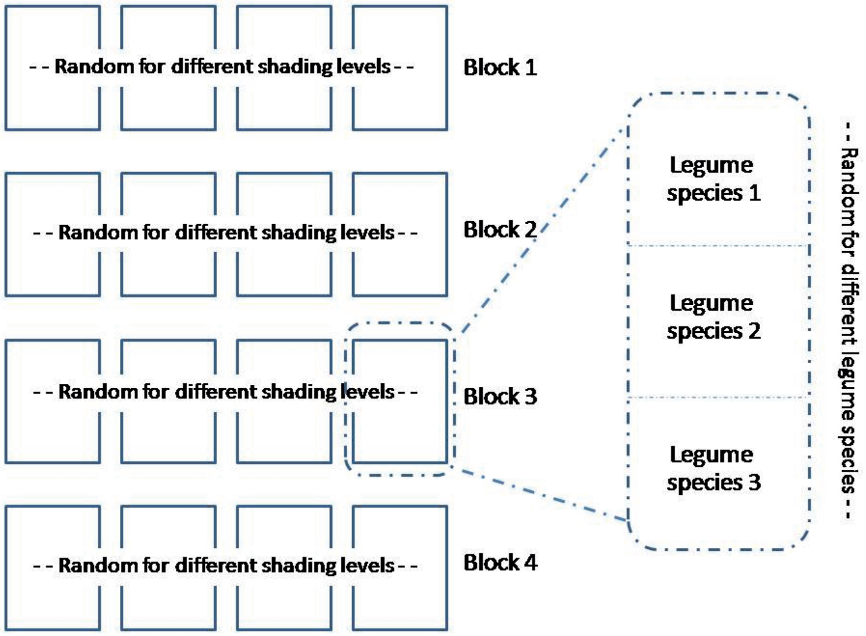

Figure 1 Diagram for experimental set-up for Randomized Completely Block Design (RCBD) with four replications in each legume species.

In experiment 2, moth bean and sunflower were sown at spacing of 0.50 m x 0.25 m, 0.75 x 0.25 m between rows and hills, respectively, and plot sizes were 3 x 5.75 m^2.

For intercropping, two seeds of moth bean and one seed of sunflower were planted per hill. The intercropping was arranged alternately between rows among these two species (one row of sunflower was planted alternately with one row of moth bean). Thus, it has two treatments (mono- and intercropping) which were arranged in RCBD with three replications.

The data were collected as fresh and dry weight per plant of moth bean at 100 days after planting which was the same date for harvesting of sunflower seeds. At maturity (about 100 days after planting) of sunflower, six traits such as plant height, disk size, head dry weight, seed number per head, shelling percentage and 100 seeds weight were determined. In moth bean, the upper ground part (or shoot part) was taken for dry matter and crude protein content analysis.

In both experiments, the plants were irrigated twice a day and weed control was conducted manually once at 30 days after planting. No fertilizer was applied in the experiment.

Results

For experiment 1, the results were shown in Table 1, 2, 3 and 4. Different shading levels were found to affect all agronomic traits by decreasing the values of characteristics in moth bean, Cavalcade and Tha pra stylo, except branch number and lodging score in Tha pra stylo (Table 1-3).

It was found that different shading levels affected all traits of moth bean, except lodging score and plant height between shading levels at 0% to 70% at 24 and 68 days after planting, respectively (Table 1).

Table 1 Characteristics of moth bean grew under different levels of sunlight shading (mean ± SE) and value percentage from control values (in the parentheses in lower line) at 24 and 68 days after planting.

Sunlight shading levels	Germination day (DAP†)	Plant height (cm)	Leaf number (no./plant)	Lodging score£
at 24 DAP				
0% (control)	4.5±0.5a (100%)	5.03±0.71c (100%)	3.25±0.03a (100%)	3.85±0.15 (100%)
30%	3.0±0.0b (67%)	11.25±0.99b (224%)	2.90±0.06b (89%)	3.40±0.16 (88%)
70%	3.0±0.0b (67%)	14.75±0.75a (293%)	2.25±0.09c (69%)	3.25±0.18 (84%)
90%	3.0±0.0b (67%)	NA§	NA	NA
Mean	3.4	10.34	2.80	3.50
F-test	**	**	**	NS‡
LSD (0.05)	0.80	2.69	0.25	0.54
Sunlight shading levels	**Branch number (no./plant)**	**Plant height (cm)**	**Leaf number (no./plant)**	**Lodging score**
at 68 DAP				
0% (control)	11.75±0.85a (100%)	101.50±14.91 (100%)	85.00±6.77a (100%)	4.25±0.25a (100%)
30%	3.25±1.38b (28%)	94.00±2.68 (93%)	32.00±3.19b (38%)	1.75±0.25b (41%)
70%	0.00±0.00c (0%)	117.75±5.12 (116%)	8.75±0.48c (10%)	1.00±0.00b (24%)
90%	Dead	Dead	Dead	Dead
Mean	5.00	105	41.92	2.33
F-test	**	NS	**	**
LSD (0.05)	2.95	32.41	11.21	0.87

† DAP, days after planting.

‡ NS, not significant at the 0.05 level of probability.

** significant at the 0.01 level of probability.

§ NA, not applicable.

£ Lodging score, 4 = erect; 3 = curve not over 45 degree; 2 = curve over 45 degree; 1 = flat on floor.

At 24 days after planting of moth bean, number of days to emergence, plant height and leaf number per plant were affected, in response to the increased shading level between 0%-70% (Table 1). Leaf number per plant decreased, when compared with the control treatment. Date of germination also decreased as the shading levels had increased. Plant height, however, had responded differently from other traits to shading level in that this trait increased by 224% and 293% from that of the control treatment at 30 and 70% shading levels, respectively.

At 68 days after planting of moth bean, there were significant difference in number of branches, number of leaves and lodging score. At high shading levels, there were the decreased in a number of branches, number of leaves and lodging score, comparing with those of the control treatment (as 28, 38 and 41 percent at 30% shading level, and as 0, 10 and 24 percent at 70% shading level, respectively). There was significant difference in plant height between the different levels of shading. All the plants of three legume species died after exposure to 90% of shading level.

The Cavalcade was affected by low shading level on all traits both at 24 and 68 days after planting (Table 2). At 24 days after planting, high shading level showed clear effect with the reduction in the leaf number per plant. At 68 days after planting, at 70% shading level, branch number and leaf number per plant decreased substantially, comparing with those at normal light level (control treatment) (Table 2) (38 and 27 percents, respectively). However, at 90% shading level, all plants stopped growing and plants had wilt symptom and died.

For Tha pra stylo, at 68 days after planting, different levels of light shading had an effect on plant height and leaf number. The reduced values of these traits from control levels were 46 and 57%, respectively at 70% shading level (Table 3). Branch number and lodging score were not significantly different at different levels of shading in this stage of growing.

Fresh and dry weight of all legume species decreased as the level of shading increased (Table 4). The reduction of both fresh weight and dry weight per plant at 30% shading of Cavalcade was less than moth bean and Tha pra stylo, comparing with the control treatment (Table 4). The values of fresh and dry weight per plant at 30 % shading were 39, 17 and 3 percent of control treatment value, and were 38, 17 and 4 percent of control treatment value in Cavalcade, moth bean and Tha pra stylo, respectively. However, at 70% of shading level, both fresh weight and dry weight per plant values were lower than 10%, comparing with the control treatment in all species.

In experiment 2, the results were shown in Table 5 and 6. Crude protein content was not affected by the different growing practices. The crude protein content of moth bean grown in monoculture was 10.88%, while that of the moth bean grown together with sunflower in a mixed-culture was 13.10% (Table 5). Percent dry matter of moth bean grown under monoculture and mixed-culture were not significant different.

Only dry weight per plant of moth bean was affected by the growing practice (Taber 6). In monoculture, dry weight per plant of moth bean was higher (20.70 g/plant) than growing as intercrop with sunflower (10.53 g/plant).

As for sunflower, all of the six agronomic traits were not affected by the different in growing practices; either in monoculture or in intercrop with moth bean (Table 6).

Discussion

In Experiment 1, the decreasing values of growth characteristics in moth bean, Cavalcade and Tha pra stylo caused by high shading level reflected the importance of light for plant growth (Table 1, 2 and 3). Although some characteristic

Table 2 Characteristics of Cavalcade grew under different levels of sunlight shading (mean ± SE) and value percentage from control values (in the parentheses in lower line) at 24 and 68 days after planting.

Sunlight shading levels	Plant height (cm)	Leaf number (no./plant)	Lodging score	
at 24 DAP†				
0% (control)	NA§	NA	NA	
30%	11.39±0.99b	2.65±0.13a	3.95±0.05a	
70%	14.33±0.50a	2.02±0.06b	3.63±0.04b	
90%	8.64±1.09c	0.62±0.22c	3.89±0.08a	
Mean	11.45	1.76	3.82	
F-test	**	**	*	
LSD (0.05)	2.17	0.44	0.22	
Sunlight shading levels	**Branch number (no./plant)**	**Plant height (cm)**	**Leaf number (no./plant)**	**Lodging score£**
at 68 DAP				
0% (control)	6.50±0.29a (100%)	146.60±6.51a (100%)	51.25±2.69a (100%)	4.00±0.00a (100%)
30%	3.50±0.29b (54%)	172.13±18.69a (117%)	24.75±4.09b (48%)	2.00±0.00b (50%)
70%	2.50±0.65b (38%)	103.00±2.08b (70%)	14.00±1.78b (27%)	2.00±0.00b (50%)
90%	Dead	Dead	Dead	Dead
Mean	4.17	140.58	21.25	2.67
F-test	**	**	**	**
LSD (0.05)	2.95	32.41	11.21	0.87

† DAP = Days after planting.

* significant at the 0.05 level of probability.

** significant at the 0.01 level of probability.

§ NA = Not applicable.

£ Lodging score, 4 = erect; 3 = curve not over 45 degree; 2 = curve over 45 degree; 1 = flat on floor.

Table 3 Characteristics of Tha pra stylo grew under different levels of sunlight shading (mean ± SE) and value percentage from control values (in the parentheses in lower line) at 68 days after planting.

Sunlight shading levels	Branch number (no./plant)	Plant height (cm)	Leaf number (no./plant)	Lodging score[£]
0% (control)	0.75±0.75 (100%)	43.38±0.63a (100%)	12.25±2.39a (100%)	4.00±0.00 (100%)
30%	0.00±0.00 (0%)	10.75±1.11c (25%)	4.75±0.85b (39%)	4.00±0.00 (100%)
70%	0.00±0.00 (0%)	20.00±1.74b (46%)	7.00±0.71b (57%)	3.50±0.29 (88%)
90%	Dead	Dead	Dead	Dead
Mean	0.25	24.71	8.00	3.83
F-test	NS[‡]	**	*	NS
LSD (0.05)	1.50	4.17	4.36	0.58

‡ NS, not significant at the 0.05 level of probability.
* significant at the 0.05 level of probability.
** significant at the 0.01 level of probability.
£ Lodging score, 4 = erect; 3 = curve not over 45 degree; 2 = curve over 45 degree; 1 = flat on floor.

such as branch number and lodging score in Tha pra stylo were not significant different between shading levels at 0%-70%, all plants of the three legume species were wilted and died at 90% of shading level. This evidence showed that high shading level severely affected all three legumes.

For moth bean, all plants wilted and died at 90% shading level at 68 days after planting (Table 1). This means that it can not withstand high level of shading at this age. However, moth bean could survive lower levels of shading at 24 days after planting (Table 1). Plants are exposed to some degree of shade during their growth and development (Valladares and Niinemets, 2008) and this caused a differential tolerance on shading at different growing stages of plant.

Lodging scores from different shading were not different at 24 days after planting in moth bean. This was because plants were still at the early stage of development. At 68 days after planting, plant height was the only one trait which was not affected by the shading level between of 0% to 70% (Table 1). This was because plant height had the negative direction for value changing, comparing with other traits. Three traits (such as date of germination, plant height and leaf number per plant) were highly affected by shading level in moth bean at 24 days after planting (Table 1). This result suggests that difference in shading tolerance could be evaluated by observing the characteristics of these traits.

The reduced values of two traits (such as date of germination and leaf number per plant) were found at higher level of shading when comparing with the control treatment. At higher shading level, moth bean showed decreasing value in date of germination and leaf number per plant

Table 4 Fresh and dry weight per plant of legume species grew under different levels of sunlight shading (mean ± SE) and value percentage from control values (in the parentheses in lower line) at 68 days after planting.

Traits	Sunlight shading levels						
	0% (control)	30%	70%	90%	Mean	F-test	LSD
Moth bean							
Fresh weight	69.81±4.47a	11.55±1.46b	3.14±0.45b	Dead	28.17	**	8.55
	(100%)	(17%)	(4%)				
Dry weight	13.42±0.89a	2.22±0.32b	0.61±0.07b	Dead	5.42	**	1.68
	(100%)	(17%)	(5%)				
Cavalcade							
Fresh weight	22.54±6.93a	8.78±2.46ab	1.64±0.02b	Dead	10.99	*	15.5
	(100%)	(39%)	(7%)				
Dry weight	5.67±1.76a	2.16±0.63ab	0.44±0.02b	Dead	2.76	*	3.94
	(100%)	(38%)	(8%)				
Tha pra stylo							
Fresh weight	3.45±1.00a	0.12±0.04b	0.03±0.00b	Dead	1.20	**	2.01
	(100%)	(3%)	(1%)				
Dry weight	0.85±0.26a	0.03±0.01b	0.01±0.00b	Dead	0.30	*	0.52
	(100%)	(4%)	(1%)				

* significant at the 0.05 level of probability.
** significant at the 0.01 level of probability.

Table 5 Characteristics of crude protein and dry matter percentage of moth bean grew under mono- and mixed culture (with sunflower).

Cultures	% crude protein (on dry basis)	% dry matter
Monoculture	10.88±3.13	10.05±0.28
Mix culture	13.10±1.34	10.28±0.30
Mean	11.99	10.16
F-test	NS‡	NS

‡ NS, not significant at the 0.05 level of probability.

Table 6 Characteristics of moth bean and sunflower grew under monoculture and mix culture.

Cultures	Plant height (cm)	Fresh plant weight (g/plant)	Dry plant weight (g/plant)
Moth bean			
Monoculture	161.97±7.43	137.97±28.59	20.70±2.76a
Mix culture	151.50±12.12	55.47±6.80	10.53±0.91b
Mean	156.74	96.72	15.62
F-test	NS[‡]	NS	*
LSD (0.05)	39.89	93.76	8.23

Cultures	Plant height (cm)	Head diameter (cm)	Head dry weight (g)
Sunflower			
Monoculture	169.53±5.10	12.53±0.38	18.90±2.17
Mix culture	171.37±6.03	13.27±0.79	20.80±2.73
Mean	170.45	12.90	19.85
F-test	NS	NS	NS
LSD (0.05)	5.69	4.14	2.62

Cultures	Seed number (no./plant)	% shelling	100 seed weight (g)
Sunflower			
Monoculture	620±102	51.83±3.69	3.57±0.25
Mix culture	595±60	50.77±0.66	3.33±0.13
Mean	608	51.30	3.45
F-test	NS	NS	NS
LSD (0.05)	396.58	13.24	1.50

‡ NS, not significant at the 0.05 level of probability.

* significant at the 0.05 level of probability.

(Table 1). Thus, the date of germination was the first parameter to indicate the stress of shading for the growing of moth bean.

Although leaf number per plant in moth bean did not constantly decrease, this trait had higher shading tolerance when comparing with date of germination which remained at higher percentage at 30% and 70%, comparing with at 0% of shading level (Table 1).

The response of plants in increasing height occurred because they competed for light for plant photosynthesis (Porter, 1937; Bunce et al., 1977; Nagashima et al., 1995; Schmitt et al., 1999). Thus, the stem extension reached to more than 2 times of control treatment.

The significant effect of shading level was found on lodging score only at 68 days after planting. At 30% shading level, plant lodging was also observed and the score was less than 50% when comparing with the control treatment. Plants grown in the shading typically have low root/shoot ratio, possess slender stems, and have low branching (Smith, 1982; Weiner et al., 1990; Sparkes et al., 2008). Thus, they were easily lodged because the stem diameter, stem stiffness, and root anchoring were reduced (Niklas, 1998).

Although light is an important resource for photosynthesis, both insufficient and excess sunlight can limit the performance of plants (Grubb, 1998; Valladares and Niinemets, 2008). The elongation of plant shoot in low light is one of the trait that shows phenotypic plasticity, which tends to be high in non shade-tolerant species. While phenotypic plasticity tends to be low in shade-tolerant species (e.g., scant elongation in low light), plasticity for certain traits, particularly for morphological features such as shoot elongation will optimizes light capturing (Valladares and Niinemets, 2008).

Lodging was found in plant receiving more shading level than normal light condition. There were several reports that lodging had limited yield in many plants such as barley (Day, 1957), grain sorghum (Larson and Maranville, 1977) and rice (Basak et al., 1962; Setter et al., 1997).

The changing in all traits under different shading levels could be observed in Cavalcade (Table 2). Number of leaves per plant was clearly decreased at different levels of shading (Table 2). This indicates that shading stress can be observed at the early stage of plant growth in Cavalcade. Number of branches per plant could also be an indicator of insufficiency of light for Cavalcade at the later growth stage (at 68 days after germination).

Tha pra stylo is a perennial forage legume species, and its initial growth is slower than other two legume species in this study (Table 3). Number of leaves per plant and plant height could clearly be an indicator of the unavailable of light for Tha pra stylo at this growth stage.

Plant height of moth bean and cavalcade, however, increased at high shading level, except in Tha pra stylo (Table 3). This was because legume species were short-lived perennial legume (2 to 3 years) (Phengsavanh and Inger, 2003), making it to grow slowly at the early planting stage, compared with moth bean and Cavalcade which were annual plant species.

Fresh weight and dry weight per plant were decreased with the increased shading level (Table 4) and this resulted to the reduction in yield, biomass production and accumulation (Ephrath et al., 1993; Henry and Thomas, 2002; Liu et al., 2010). Thus yield of three legumes species was affected by higher shading level.

At 30% shading level, the percentage of fresh and dry weight per plant of Cavalcade was higher than those of moth bean and Tha pra stylo (Table 4). Moth bean has higher vegetative yield than Cavalcade in normal sunlight level, under both normal water application and water deficiency (Na Chiangmai et al., 2009a). Thus, moth bean was sensitive to shading, and this showed that it had less shading tolerance than Cavalcade. For Tha pra stylo, due to it is slow growth at initial stage, the degree of shading tolerance cannot be compared with that of the other species.

In Experiment 2, there was no significant different on crude protein content from vegetative part between mono- and mixed-culture of moth bean with sunflower (Table 5). This evidence showed that crude protein content of moth bean was not affected under intercropping with sunflower. The crude protein content under intercropping of moth bean with sunflower was lower than that reported by Na Chiangmai et al. (2009b), a result from the pot condition study.

Although moth bean grown under intercropping condition had lower value of dry plant weight than that of monoculture (Table 6), the benefit of intercropping was that this practice could control weed proliferation when comparing with that of the sunflower monoculture.

In competition for light, growth of smaller plants has been affected by shading more than larger plants (Casper and Jackson, 1997). The competition begins when a single necessary factor (as light in this case) is the common demands of the plants (Went, 1973). Moreover, growth reduction also occurred as a result of growing plants at closer proximity (Clements et al., 1929). Both belowground and aboveground competition occurred when the available soil resources were limit (Casper and Jackson, 1997). For aboveground, light is an influencing factor for plant growth and survival and results to competitive interactions in the community (Canham et al., 1990; Valladares, 2003). Thus, the minimum light required for survival and shade tolerance plays a major role in plant community dynamics (Valladares and Niinemets, 2008).

Under mixed-culture, dry plant weight of moth bean was lower than that of monoculture at about twofold. However, there was no significant difference on yield between mono- and mixed-culture in traits of sunflower (Table 6). Thus, moth bean can be grown as intercrop with sunflowers.

Conclusion

This study emphasized the importance of shading level for legumes production, particularly at the early growth stage in three legumes species (moth bean, Cavalcade and Tha pra stylo).

Shading effect reduced the value of all characteristics, except plant height which increased due to shoot elongation. All of three legume species had different shading tolerance ability, except at 90% shading level that they did not survive.

Although many traits were affected by shading in all of three legume species, leaf number per plant and dry shoot weight per plant were mostly affected. Thus, both of these traits are suitable to use as an indicator for shading tolerance. By comparing dry weight per plant, moth bean showed lower shading tolerance than Cavalcade but higher than Tha pra stylo.

In mixed-culture, performance of sunflower was not affected by intercropping. But, intercropped moth bean had lower fresh and dry weight per plant about twofold, comparing with the monoculture. However, crude protein content (based on dry basis) was not different between mono- and mixed-culture.

This suggest that moth bean can be used for planting between rows of sunflower for weed control and forage crop production.

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