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Growth and Yield of Broccoli under Different Rain Protectors During the Rainy Season in Songkhla Province, Southern Thailand

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ABSTRACT

The objective of this study was to determine the impact of different rain protectors and varieties of broccoli on their growth and yield during the rainy season in southern Thailand. Split plots in a randomized complete block design were used with four replications. The experiment was undertaken from 28 October 2012 to 7 January 2013. The results showed that broccoli grown under a green shade net or a plastic sheet had higher growth and yield compared with those grown in the open field. The average highest total yields under plastic sheet, green shade net and in the open field were 11.11, 7.54 and 5.61 t.ha^{-1}, respectively. The average highest yields of broccoli were obtained from the Yok Kheo variety (10.22 t.ha^{-1}), followed by the Green Queen (7.56 t.ha^{-1}) and Top Green (6.46 t.ha^{-1}) varieties, respectively. Broccoli grown under the plastic sheet could be harvested 13.25 d after transplanting and 2.50 d earlier than those grown in the open field or under green shade net. The results indicated that broccoli should be grown under a plastic sheet or a green shade net to achieve higher yields than from plants grown in the open field. The Yok Kheo and Green Queen varieties are recommended for Songkhla province and the surrounding area.

Keywords: broccoli, rain protectors, plastic sheet, rainy season, humid tropics, southern Thailand

INTRODUCTION

Broccoli (*Brassica oleracea* L. var. *italica* Plenck) is the most important herbaceous biennial cole crop in the Brassicaceae family and is one of the leading vegetables in the world (Khatun *et al*., 2012). Broccoli is a traditional European vegetable that has become widespread in Asia in recent decades because of its many health benefits; the American Cancer Society indicated that broccoli has several anti-cancerogen effects (Sermenli *et al*., 2011). In Thailand, broccoli is cultivated on a limited area. It is generally grown in highland areas where the weather is cool or in lowland areas during the cool season (Pornsuriya *et al*., 1997) because the optimum growing temperature for broccoli is in the range 16–20 °C (Decoteau, 2000). Broccoli has potential as an alternative crop in southern Thailand. However, the selection of planting times and varieties is crucial for successful cultivation due to the humid tropical weather of southern Thailand, especially between September and December when there is continuous heavy rainfall which can cause problems as broccoli can become infected with head rot from the impact of raindrops (Nooprom *et al*., 2013a), and be destroyed by the bacterium *Erwinia carotovora* ssp. *carotovora* that causes

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soft rot disease (Bhat *et al*., 2010). The objective of the current research was to determine the impact of different rain protectors and varieties of broccoli on their growth and yield during the rainy season in Songkhla province, southern Thailand.

MATERIALS AND METHODS

This study was carried out in a research field at Prince of Songkla University, Hat Yai, Songkhla province, Thailand from 28 October 2012 to 7 January 2013 using split-plots within a randomized complete block design. The main plots were three different types of rain protection: open field (control), under a green shade net and under a plastic sheet (5% UV polyethylene film with thickness of 200 µm) with subplots being the varieties of Top Green, Green Queen and Yok Kheo. These varieties have shown good performance such as early growth and yield when planted in Songkhla province (Nooprom and Santipracha, 2011). Broccoli seed was sown in plastic baskets (32 × 40 × 10 mm). When the first true leaf had emerged, the seedlings were transplanted into 5 cm pots. At the fourth leaf stage, the seedlings were transferred into the field. The plot size was 1 × 5 m. The plant and row spacing were 0.30 × 0.60 m, respectively, and the edge spacing was 0.20 m. Each plot had two rows of 32 plants. The broccoli plants were regularly watered with a sprinkler early in the morning and early in the afternoon except on rainy days. After transplanting, fertilizer (21N-0P-0K) was applied three times at weeks 2, 3 and 4, and a second mix of fertilizer (15N-6.5P-12.5K) was applied twice at weeks 5 and 6. All plots were weeded twice with a hand hoe at weeks 2 and 4 after transplanting. The data were measured: seedling survival rate (%) at 30 d after transplanting (DAT) was determined. The numbers of days from transplanting to the beginning of the time of 50% flowering and to harvest were observed in the plots. At the time to 50% flowering, the plant height was measured for 10 random plants in the plot by taking the distance from the soil surface to the longest top leaf and the plant width was measured for 10 random plants in the plot by taking the distance from the longest leaf on one side to the other longest one on the opposite side. Other data were recorded from harvested plants in the plot: harvested plant, head diameter, head weight and total yield. Light intensity was measured using a light meter (Li-250 LI-COR Biosciences; Lincoln, NE, USA). Daily minimum and maximum temperatures were recorded using a temperature/relative humidity data logger (HOBO U23 Pro v2 U23-001; Onset; Cape Cod, MA, USA), and data of daily rainfall from 28 October 2012 to 7 January 2013 were obtained from the Kho Hong Agrometeorological Station, Hat Yai, Songkhla, Thailand. Growth and yield data were analyzed using analysis of variance and means were separated using Duncan's multiple range test (DMRT) at the 5% level of significance.

RESULTS AND DISCUSSION

Growth response

Broccoli growing under the green shade net and under the plastic sheet had higher seedling survival rates than those grown in the open field with values between 86.97 and 88.80%. These results may have been due to lower light intensity and higher relative humidity (Figure 1a and 3) obtained under both protectors compared with the open field. Under the green shade net, the low light intensity resulted in a lower temperature. Even though there was a higher temperature under the plastic sheet compared with the other methods (Figure 2), there was little increase in the relative humidity compared with the open field. The optimum temperature for broccoli production is in the range 16–20 °C (Decoteau, 2000) except for the heat-tolerant hybrid varieties which are better adapted to temperatures higher than 30 °C (Asian Vegetable Research and Development Center, 1999). These factors supported better broccoli growth under cover compared with the open field.

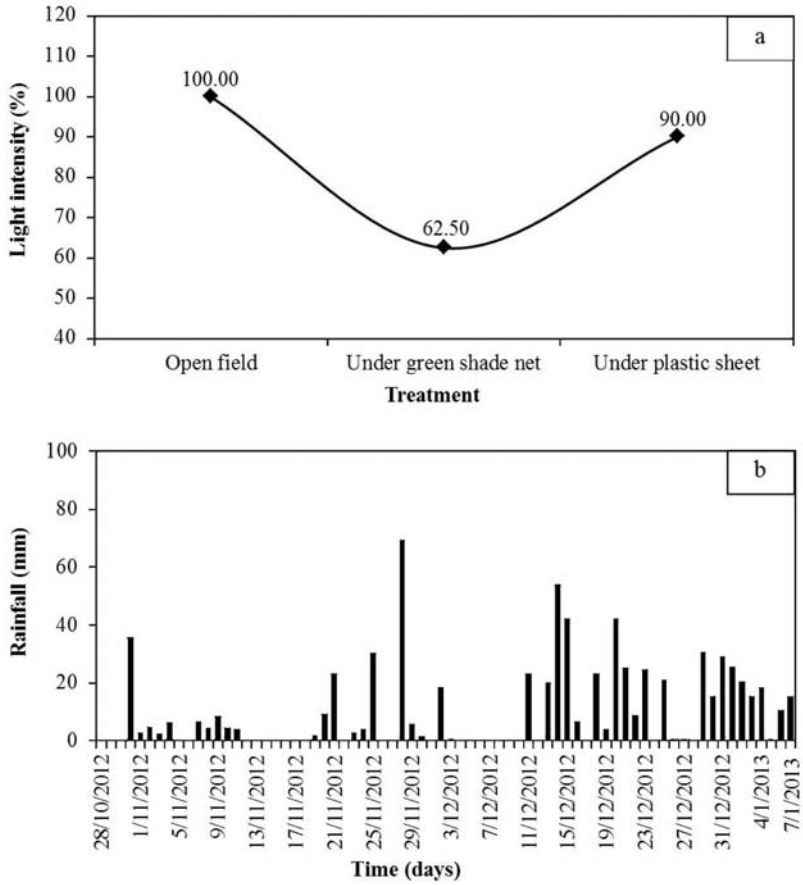

Figure 1 Light intensity (a) and daily rainfall (b) under different rain protectors.

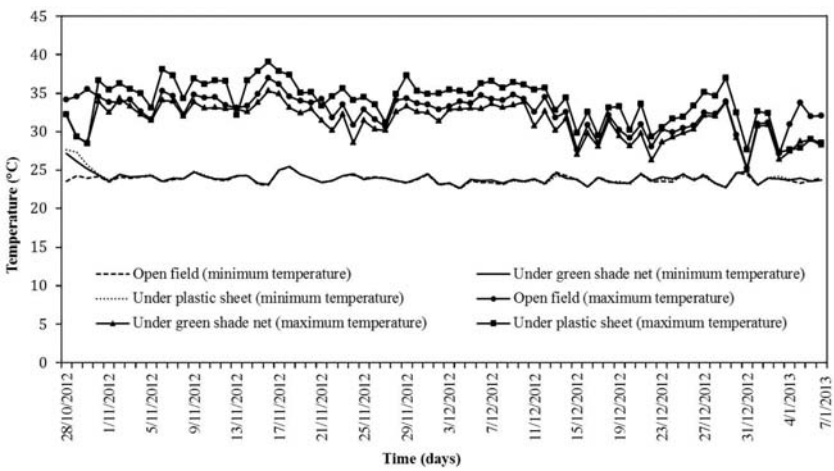

Figure 2 Daily minimum and maximum temperatures under different rain protectors.

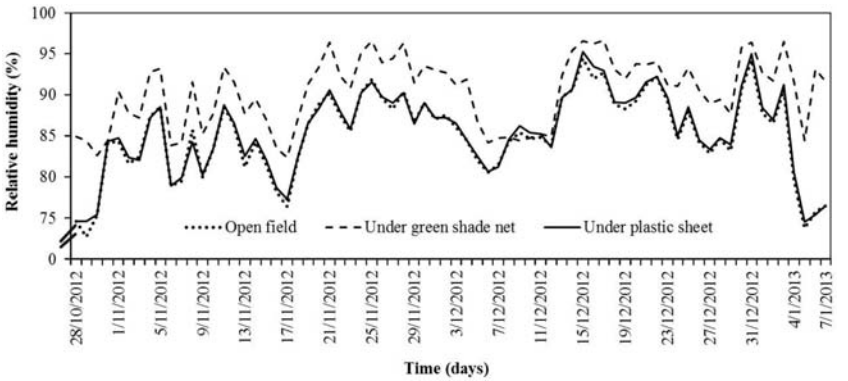

Figure 3 Daily relative humidity under different rain protectors.

The Yok Kheo and Green Queen varieties had high seedling survival rates between 83.59 and 84.11% (Table 1) while the Top Green variety had a moderate seedling survival rate of 73.69%. Growth rate depends on the characteristics of the broccoli varieties (Nooprom and Santipracha, 2011). The interaction between different rain protectors and varieties revealed that Yok Kheo had the highest seedling survival rate (92.18%) when grown under the green shade net. Top Green had the lowest seedling survival rate of 50.77% when grown in the open field. Under both the green shade net and plastic sheet, broccoli plants had greater plant heights and widths compared with those grown in the open field because the former had low light intensity that stimulated the synthesis of gibberellins which accelerated the expansion of nodes and internodes (Puwiwat, 2000). In

Table 1 Effect of different rain protectors and varieties on seedling survival rate, plant height and plant width of broccoli.

Treatment	Variety			Mean
	Top Green	Green Queen	Yok Kheo	
Seedling survival rate (%)				
Open field	50.77^{c}	75.00^{b}	71.09^{b}	65.62^{B}
Under green shade net	85.15^{a}	89.06^{a}	92.18^{a}	88.80^{A}
Under plastic sheet	85.15^{a}	88.28^{a}	87.49^{a}	86.97^{A}
Mean	73.69^{B}	84.11^{A}	83.59^{A}	
Plant height (cm)				
Open field	37.18^{f}	39.88^{ef}	41.81^{de}	39.62^{C}
Under green shade net	46.39^{bc}	48.26^{ab}	51.26^{a}	48.63^{A}
Under plastic sheet	43.45^{cd}	46.62^{bc}	48.39^{ab}	46.15^{B}
Mean	42.34^{C}	44.92^{B}	47.15^{A}	
Plant width (cm)				
Open field	56.90^{ef}	53.78^{f}	61.01^{cd}	57.23^{C}
Under green shade net	72.38^{a}	67.62^{b}	73.45^{a}	71.15^{A}
Under plastic sheet	62.52^{c}	58.25^{de}	67.52^{b}	62.76^{B}
Mean	63.94^{B}	59.88^{C}	67.35^{A}	

Values sharing the same superscript letters are not significantly different ($P \leq 0.05$) by Duncan's multiple range test.

addition, cells expand more for photosynthesis under low light intensity (Nooprom *et al*., 2013b). The appropriate environment under both types of protector resulted in better broccoli growth than in the open field. The Yok Kheo variety had the highest plant height (47.15 cm) and width (67.35 cm) as shown in Table 1, while the Top Green and Green Queen varieties had moderate plant heights and widths. The interaction between the different rain protectors and broccoli varieties showed that the Yok Kheo had the highest plant height (51.26 cm) and width (73.45 cm) when grown under the green shade net. The Top Green and Green Queen varieties had the lowest plant heights and widths when grown in the open field. The mean times to 50% flowering and 50% harvest of broccoli plants grown under the plastic sheet and the green shade net were 37.66 to 38.66 DAT and 47.33 to 49.83 DAT, respectively, compared with 50.75 and 60.58 DAT, respectively, in the open field (Table 2). The mean times to 50% flowering and harvest of the Green Queen variety were earliest at 35.58 DAT and 45.66 DAT, respectively, followed by the Yok Kheo and Top Green varieties. The interaction between the different rain protectors and broccoli varieties showed that Green Queen had an earlier time to 50% flowering and harvest than when it was grown under the plastic sheet and under the green shade net with values of 33.00 and 33.50 DAT and 43.00 and 44.50 DAT, respectively. The longest times to 50% flowering and harvest were observed with Top Green when grown in the open field (61.00 DAT and 70.50 DAT, respectively) as shown in Table 2. Both the green shade net and the plastic sheet created environments that were suitable for broccoli growth by affecting early flowering and harvest compared with the open field. These results were similar to those from a study by Warawut *et al*. (2000), where broccoli growing under a nylon net was observed to have earlier flowering and harvest times compared with plants grown outside the nylon net.

Table 2 Effect of different rain protectors and varieties on time to 50% flowering, time to 50% harvest and harvested plant of broccoli.

Treatment	Variety			Mean
	Top Green	Green Queen	Yok Kheo	
Time to 50% flowering (DAT)				
Open field	61.00^{a}	40.25^{d}	51.00^{b}	50.75^{A}
Under green shade net	43.00^{c}	33.50^{f}	39.50^{de}	38.66^{B}
Under plastic sheet	42.00^{a}	33.00^{f}	38.00^{e}	37.66^{C}
Mean	48.66^{A}	35.58^{C}	42.83^{B}	
Time to 50% harvest (DAT)				
Open field	70.50^{a}	49.50^{de}	61.75^{b}	60.58^{A}
Under green shade net	53.50^{c}	44.50^{f}	51.50^{cd}	49.83^{B}
Under plastic sheet	51.00^{d}	43.00^{f}	48.00^{e}	47.33^{C}
Mean	58.33^{A}	45.66^{C}	53.75^{B}	
Harvested plant (%)				
On the open field	82.75^{ab}	85.37^{ab}	92.15^{ab}	86.75^{A}
Under the green shade net	49.36^{c}	73.88^{b}	75.42^{b}	66.22^{B}
Under the plastic sheet	96.48^{ab}	98.24^{ab}	100.00^{a}	98.24^{A}
Mean	76.20^{A}	85.83^{A}	89.19^{A}	

DAT = Days after transplanting.

Harvest plants are calculated based on 100% value for Yok Kheo grown under the plastic sheet.

Values sharing the same superscript letters are not significantly different ($P \leq 0.05$) by Duncan's multiple range test.

Yield responses

Broccoli grown under the plastic sheet and in the open field had significantly increased harvests between 86.75 and 98.24% compared with those grown under the green shade net (66.22%), perhaps because there was continuous heavy rainfall during the harvesting stage (Figure 1b). The green shade net created a low light intensity of 62.50% and a very high relative humidity of 90.35% (Figures 1a and 3). These factors are suitable for the growth of the bacterium *Erwinia carotovora* spp. *carotovora* which causes soft rot disease in broccoli plants (Bhat *et al*., 2010). In addition, broccoli grown in the open field was infected by high head rot due to the impact of raindrops (Nooprom *et al*., 2013a). The three broccoli varieties had the greatest mean harvested plants between 76.20 and 89.19%. The interactions between the different types of rain protector and the broccoli varieties showed that all three varieties had harvested plants of 82.75% and higher compared with the maximum yield obtained from Yok Kheo grown under the plastic sheet (Table 2). There was significant variation in the head diameter and weight. Broccoli growing under the plastic sheet and green shade net had higher mean head diameters from 11.27 to 12.33 cm and mean plant weights from 341.39 to 362.04 g than those grown in the open field with values of 9.36 cm and 274.21 g, respectively. The Yok Kheo variety had the highest head diameter of 11.93 cm and plant weight of 382.90 g (Table 3), followed by Top Green with a head diameter of 10.74 cm and a plant weight of 315.58 g. Green Queen produced the lowest diameter of 10.29 cm and plant weight of 278.96 g. Different rain protectors and broccoli varieties affected head diameter and weight. The Yok Kheo variety had the highest head diameter (13.04 cm) and plant weight (434.13 g) when grown under the plastic sheet, while the lowest head diameter and plant weight were obtained from Green Queen (8.73 cm and 234.81 g, respectively) when grown in the open field. The total yield varied significantly due to the different rain protectors. Broccoli grown under the plastic sheet or under the green shade

Table 3 Effect of different rain protectors and varieties on head diameter, head weight and total yield of broccoli.

Treatment	Variety			Mean
	Top Green	Green Queen	Yok Kheo	
Head diameter (cm)				
Open field	9.30^{g}	8.70^{h}	10.05^{f}	9.36^{C}
Under green shade net	10.69^{e}	10.42^{e}	12.71^{b}	11.27^{B}
Under plastic sheet	12.24^{c}	11.72^{d}	13.04^{a}	12.33^{A}
Mean	10.74^{B}	10.29^{C}	11.93^{A}	
Head weight per plant (g)				
Open field	264.38^{e}	234.81^{f}	322.86^{cd}	274.21^{C}
Under green shade net	336.90^{c}	295.56^{d}	391.70^{b}	341.39^{B}
Under plastic sheet	345.46^{c}	306.52^{d}	434.13^{a}	362.04^{A}
Mean	315.58^{B}	278.96^{C}	382.90^{A}	
Total yield ($t.ha^{-1}$)				
Open field	3.94^{e}	5.35^{d}	7.52^{c}	5.60^{C}
Under green shade net	5.05^{d}	7.88^{c}	9.67^{b}	7.53^{B}
Under plastic sheet	10.30^{b}	9.44^{b}	13.48^{a}	11.10^{A}
Mean	6.46^{C}	7.56^{B}	10.22^{A}	

Values sharing the same superscript letters are not significantly different ($P \leq 0.05$) by Duncan's multiple range test.

net produced higher mean total yields of 7.53 to 11.10 t.ha^{-1} compared with the open field (5.60 t.ha^{-1}) because the plants in the open field were exposed to direct light and raindrops. High light intensity can reduce the broccoli growth rate and yield during the rainy season (Nooprom *et al*., 2013b), and the raindrops increased the level of broccoli head rot (Nooprom *et al*., 2013a). The plastic sheet provided better protection from the impact of raindrops than the other methods. Under the green shade net, harvested broccoli yields were higher than in the open field. Broccoli plants under the green shade net had a higher mean head diameter compared with the open field. The Yok Kheo variety produced the highest mean total yield of 10.22 t.ha^{-1} (Table 3), followed by Green Queen (7.56 t.ha^{-1}), and Top Green (6.46 t.ha^{-1}). Yok Kheo planted under the plastic sheet produced the highest total yield of 13.48 t.ha^{-1} while Top Green had the lowest total yield of 3.94 t.ha^{-1} when grown in the open field. This finding was similar to Warawut *et al*. (2001) who reported that Top Green and K-Y broccoli grown inside nylon netting had higher total yields than when grown in the open field. Furthermore, Fuji cauliflower grown under shade net had a higher total yield compared with the open field (Puwiwat and Masari, 2001).

CONCLUSION

Broccoli grown under the plastic sheet and under the green shade net had significantly better growth and yield compared with plants grown in the open field. The Yok Kheo and Green Queen varieties produced better yields than Top Green. Based on the results from the study, it could be recommended to grow broccoli under a plastic sheet or under green shade net during the rainy season to produce higher yields than on plants grown in the open field. The Yok Kheo and Green Queen varieties should be grown in Songkhla province and the surrounding area.

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