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Effect of Polyolefine Greenhouse Covering Film on Growth of Lettuce and Cucumber in Cool Season Cultivation

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Abstract. This study evaluated the effect of polyolefine greenhouse covering film on growth of lettuce and cucumber. The growth of lettuce and cucumber plants under conventional film (polyethylene plus ethylene-vinyl acetate, PE + EVA) and polyolefine (PO) film were evaluated in a greenhouse. The physical qualities of PO film, such as tensile strength and tear strength, were stronger than conventional PE + EVA film. PO film showed 4% higher transmission performance in photosynthetic active radiation (PAR) than PE + EVA film. The average day and night temperature in greenhouse under PO film were 1.5ºC and 0.8ºC higher but there was no significant difference in relative humidity compared with conventional film. Chlorophyll content of lettuce and cucumber plants grown under PO film were higher than conventional film. Growth characteristics; plant height, leaf area, fresh weight and dry weight of cucumber was shown better for PO film. The yields of cucumber and lettuce was increased 14.0% and 13.6% respectively, when the crops were grown under PO covering film greenhouse.

Key words : cucumber, growth, lettuce, PAR, polyethylene (PE), polyolefine (PO)

Introduction

Greenhouses are used in order to create a more favorable environment that is essential for plant growth and productivity, especially in a semi-arid region like Korea. A greenhouse allows plants to grow during any season of the year by controlling light, air temperature, air humidity and carbon dioxide levels. The greenhouses are usually covered with a material (i.e., glass or plastic) that has the ability to transmit light to provide essential energy for plant growth and production. Conditions of light intensity, duration, and spectral distribution greatly affect plant physiological responses. Light intensity varies greatly according to the climatic zone, season of the year, cloud cover, and anthropogenic factors, e.g. the cleanness and thickness of windows in a greenhouse or the type of film covering the greenhouse. As observed by Pirog (1993), reducing the light intensity by 1% might result in 1% decrease in yield of plants. This is due to the fact that in the process of photosynthesis, compound forming the biomass of plants are produced and the energy necessary for the metabolic process is released.

A wide range of plastic cover materials have been tested as greenhouse covers to save energy subsequently hasten the growth, development and yield of greenhouse crops. Approximately 10% light is lost each time a layer of transparent materials is added, actually amount varying with the material and the angle of incident light (Hurd, 1983). Loss of light has been a major concern in the greenhouse industry as low photosynthesis rate when photosynthetic photon flux density (PPFD) is low, may result in reduction in yield and quality (Challa and Schapendonk, 1984; Cockshull, 1992).

In commercial greenhouse production, more than 90% PE and EVA film are used in Korea (Kwon, 1992; Kwon et al., 2001). PE film is widely used in greenhouse due to the high light transmittance rate, characteristics of less dust particle attachment, and low price, while the disadvantage is low durability (Kwon, 1992; Geoola et al., 1999). In general the quality and quantity of light transmission into the greenhouse depends mainly on greenhouse film. The greenhouse environmental conditions, such as temperature and air humidity, have significant

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impact on the plant growth and development. The range of PAR (400~700 nm) is the most effective for plant growth and development. In this regard, the aim of this study was to evaluate the effect of conventional (PE + EVA) and polyolefine covering film to the growth and quality of lettuce, and cucumber plants.

Materials and Methods

This experiment was carried out in 1.5 m × 1.8 m × 3 m (W × H × L) greenhouses covered with conventional PE + EVA film (0.1 mm, Ihlshin Chemical) and polyolefine (PO, 0.1 mm, Nextchem) greenhouse film, with two replications, in the Protected Horticultural Research Station, RDA, Busan Korea, in 2010. The area of the greenhouse was cropped with a cucumber and lettuce.

Cucumber (Black Pearls, Seminis Korea Co.) and lettuce (Red Tukseom, Syrians seeds Co.) seeds were sown in a nursery greenhouse and transplanted to the growing pot (peat moss : loamy soils : composite manure = 5 : 4 : 1). Cucumber and lettuce were harvested at five and four weeks after transplanting, respectively. The experimental greenhouses were well ventilated to maintain temperature around 25~30°C, using temperature, RH and rain sensors. Auto aero dripper irrigation system was developed following electric soil moisture meter. Commercially available nutrient solution was supplied to the plant every one or two weeks (Fig. 1D, E). Portable spectro radiometer (LI-COR, 300~1100 nm) was used to measure plant photosynthetic rate during 12:00 to 13:00 with three replications. Relative humidity (RH) and temperature were recorded using portable datalogger (Thermo recorder TR-72U, T&D Corp. Japan), installed at 1.5 m height above the ground in the center of the greenhouse. Growth data were taken for number of fruits per plant, weight of each fruit of cucumber, and number of leaves and weight of lettuce plant. For chlorophyll analysis, 20 ml methanol added to the 0.5 g plant sample in an erlenmeyer flask kept for 24 hr at room temperature. The absorbance of extract solution was measured at 665.2, 652.4 and 470 nm wavelength using UV- visible spectrophotometer (Cary-100, Varian, Australia).

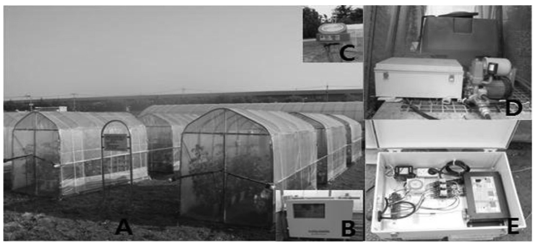

Fig. 1. View of experimental small greenhouse (A), ventilation controller (B), rain sensor (C), irrigated water tank (D), automatic irrigation controller (E).

Results and Discussion

1. Physical characteristics of covering films

Physical characteristics of two different films are shown on Table 1. The PO covering film showed superior physical characteristics in all the parameters, compared to the conventional PE + EVA film.

2. Transmittance of covering films

The characteristics of UV, visible, and near infrared (NIR) light transmittance in PO film and conventional covering film are shown in Fig. 2. UV (300~400 nm), visible (400~700 nm) and NIR (700~1100 nm) light transmittance was 0.8%, 4.1%, and 3.6% higher in PO film compared to conventional film (PE + EVA), respectively. The transmittance for whole light spectrum (300~1100 nm) was 4.3% higher in PO film than conventional film.

The greenhouse inside climate management is very important for the improvement of the resources use efficiency for crop production. Light permission characteristics is greatly affected by the different covering materials. Our findings show that polyolefine film transmits more light compared to conventional film because of its phys-

Table 1. Major physical characteristics of covering films analyzed by Korea testing and research institute.

Covering film	Tensile strength (Widthwise, N/m^2)	Tensile strength (Lengthwise, N/m^2)	Elongation (Widthwise, %)	Elongation (Lengthwise, %)	Tear strength (Widthwise, N/m^2)	Tear strength (Lengthwise, N/m^2)
PE + EVA	2,038	2,528	708	522	1,254	1,087
PO	3,440	3,850	687	644	1,480	1,370

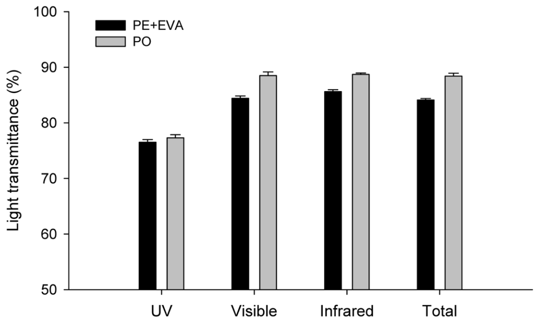

Fig. 2. Light transmittance of UV (300~400 nm), visible (401~700 nm), and near infrared (701~1100 nm) of conventional (PE + EVA) and PO films.

ical properties. Light transmission might be also affected by the color, thickness, and strength of greenhouse film (Roberts 1998; Chun et al., 2006).

3. Temperature and air humidity in greenhouse

Air temperature is significantly higher; 1.5°C at day and 0.8°C at night in PO film covered greenhouse, but no significant difference was found for air humidity (Table 2). In low temperature season, PO film increased the air temperature by 1.5°C during daytime and by 0.9°C during nighttime (Table 3). Average temperature increased 1.6°C in PO film compared to conventional greenhouse film.

4. Growth and yield of cucumber and lettuce

Increasing trend of chlorophyll content in lettuce and cucumber leaf was found in PO film compared to conventional film treatment (Table 4). It is reported that the close relationship between light intensity and chlorophyll content in plant could be generally observed. Spence and Chrystal (1970) found that more light intensity could be more chlorophyll content. However, the ratio of chlorophyll-a and b was found to decrease sequentially from the high light intensity to the low light intensity (Marcus, 1980).

Table 3. Average day and night temperature in greenhouse covered with conventional (PE + EVA) and PO films during the low temperature season. Measured 3rd to march 14th 2010.

Covering film	Air temperature (°C)		
	Mean	Day (08:00~18:00)	Night (18:00~07:00)
PE + EVA	10.1b^z	23.2b	0.9b
PO	11.7a	24.7a	1.8a

^{z}DMRT .05.

Table 4. Chlorophyll content in leaves of cucumber and lettuce grown under the conventional (PE + EVA) and PO films.

Covering film	Cucumber		Lettuce	
	Chl. A	Chl. B	Chl. A	Chl. B
PE + EVA	10.92b^z	4.39a	1.67b	0.51a
PO	11.47a	4.17a	1.87a	0.55a

^{z}DMRT .05.

Growth characteristics of cucumber plant were significantly affected by the covering film (Table 5). All the growth parameters were greatly increased under PO film covering treatment compared to conventional PE + EVA film. The number of leaves (28.0 ea/plant) and leaf weight (114.3 g/plant) of lettuce, and number of fruits (5.1 ea/plant) and fruit weight (841 g/plant) in cucumber were significantly higher in PO film covering treatment than conventional greenhouse covering film (Table 6).

The yield of greenhouse-grown lettuce was greatly affected by the type of covering film. Using a film with a higher PAR transmittance resulted in heavier weights. Since solar radiation is the source of energy used in the process of photosynthesis by which assimilates are formed and chemical energy is produced that is respon-

Table 2. Average day and night temperature and air humidity in greenhouses covered with conventional (PE + EVA) and PO films. Measured from October 1st to November 2nd, 2010.

Covering film	Air temperature (°C)			Air humidity (%)		
	Mean	Day (08:00~18:00)	Night (18:00~07:00)	Mean	Day (08:00~18:00)	Night (18:00~07:00)
PE + EVA	15.7b^z	23.7b	9.7b	85.0a	67.0a	98.9a
PO	16.8a	25.2a	10.5a	84.8a	67.2a	99.0a

^{z}DMRT .05.

Table 5. Growth characteristics of cucumber grown under the conventional (PE + EVA) and PO films.

Covering film	Plant height (cm)	Stem diameter (mm)	No. of nodes (ea/plant)	Leaf area (cm^2/plant)	Fresh weight (g/plant)		Dry weight (g/plant)	
					Leaves	Stem	Leaves	Stem
PE + EVA	118.2b[z]	10.8b	17.6a	4,521b	239.8b	84.7b	30.8b	8.0b
PO	129.4a	11.6a	18.2a	5,364a	278.9a	97.2a	33.8a	9.1a

[z]DMRT .05.

Table 6. Yield of lettuce leaf and cucumber fruit grown under the conventional (PE + EVA) and PO films.

Covering film	Lettuce		Cucumber	
	No. of leaves (ea/plant)	Leaf weight (g/plant)	No. of fruits (ea/plant)	Fruit weight (g/plant)
PE + EVA	25.1 b[z]	100.6 b	4.4 b	740 b
PO	28.0 a	114.3 a	5.1 a	841 a

[z]DMRT .05.

sible for the course of all metabolic process taking place in plant cells, the presence of the light constitutes the main factor determining the growth and weight increase of plants while its deficit limits the yielding (Lawlor 2001).

Changes in greenhouse microclimates may have significant effects on growth, development and productivity of crops (Cockshull, 1992; Athanasios. and Xiuming, 1997). Net photosynthetic rates are reduced at low light levels and the loss of tomato yield was proportional to the loss of light (Challa and Schapendonk, 1984; Cockhull et al., 1992). High temperature and PAR stimulated plant growth and increased the yield of various greenhouse fruit vegetables (Van Winden et al., 1984). The result obtained in our research for lettuce and cucumber concurs with Van Winden et al., (1984). In our findings, lettuce and cucumber yield was higher due to the higher light transmittance and temperature level for being physical properties of PO film treatment.

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상추와 오이재배 하우스의 저온기 PO필름 피복효과

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적　요. 본 연구는 비닐하우스 피복재인 폴리오레핀(PO)계 필름의 효과를 구명하고자 관행의 피복필름(PE + EVA)과 비교하여 피복재별 물리적 특성과 상추와 오이의 생육 및 수량을 검토하였다. 인장강도, 인열강도 등 피복재의 물리적 특성은 일반필름보다 PO필름이 우수하였다. 400~700 nm의 광합성유효광의 투과율은 일반필름에 비해 PO필름이 4.1% 높았고, 전체 광선투과율(300~1,100 nm)도 PO필름이 4.3% 높았다. 하우스 내의 주간 평균기온은 일반필름보다 PO필름이 1.5°C 높았고, 야간 평균기온도 PO필름이 0.8°C 높게 유지되었다. 주야간 상대습도는 필름 간에 유의적 차이가 없었다. 엽록소 함량은 오이의 경우 필름 간 유의적 차이는 없었으나 일반필름에 비해 PO필름이 엽록소 a가 약간 높았으며, 상추는 PO필름이 일반필름보다 유의하게 높았다. 수확기 오이 생육에 있어서 초장, 엽면적, 생체중 및 건물중 모두 일반필름보다 PO필름을 피복한 하우스에서 크고 무거웠다. 수확한 오이의 과실 수량은 일반필름에 비해 PO필름이 14.0% 높았고, 상추 수량도 일반필름보다 PO필름이 13.6% 높았다.

주제어 : 광합성유효광(PAR), 상추, 생육, 오이, 폴리에칠렌, 폴리오레핀