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Effect of Non-Woven Rowcover on Plant Environment and Growth

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Abstract

The effects of a rowcover made of spunbonded polypropylene on environmental factors (solar radiation, air, soil and plant temperature, vapor pressure deficit, and matric potential of soil water) and growth of spinach plants (*Spinacia oleracea* L.) were investigated. The rowcover reduced the amount of solar radiation, increased air, plant and soil temperature especially in the daytime, and maintained a higher soil moisture level than that outside of the rowcover. Vapor pressure deficit was not appreciably affected by the rowcover. Effect of the rowcover on the plant water status was not evident and net photosynthesis per unit leaf area was often lower under the rowcover. However, covered plants grew more rapidly than non-covered ones. This phenomenon was ascribed to the rapid appearance and extension of leaves which are affected by the increase in temperature.

Discipline: Horticulture/ Agricultural environment
Additional key words: cool season, spinach, spunbonded polypropylene

Introduction

Rowcover made of non-woven fabrics has rapidly been developed since the early 1980s, and presently, it is widely used for vegetable production in Europe, USA, and Japan. In the rowcover method, covering with or without cheap supporting frames[11] is practiced. Non-woven rowcovers are used to enhance plant growth[4] and to control insect pests[6].

Non-woven fabrics are light in weight and porous. Many kinds of non-woven fabrics are being marketed in Japan. They are produced by the agglutination of split films as lattice or fine fibers comparable to Japanese paper (Plate 1). Main materials used are polyethylene and polyvinylalcohol for the split film type and polypropylene and polyester for the fine fiber type (spunbonded fabric). Thin non-woven fabrics are suitable for a rowcover because they can cover plants directly and promote ventilation without opening of the skirt of the cover. Physical properties of some of them were reported[1].

In this paper, the effects of a non-woven rowcover on the plant environment and growth in the temperate zone of Japan are reported. The use of a rowcover (non-woven or other fabrics) in the Japanese subtropical zone was described in previous papers[6,11].

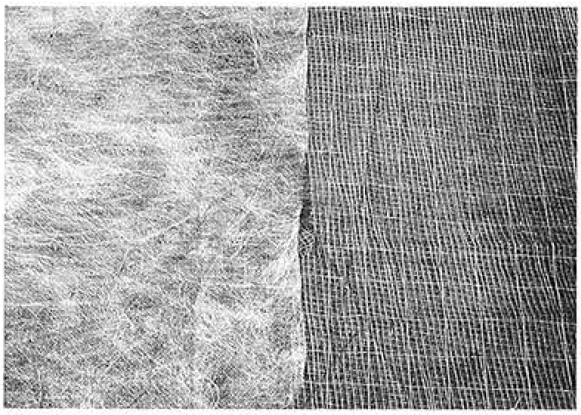

Plate 1. Non-woven fabrics
Left: Fine fiber type (spunbonded) fabric,
Right: Split film type fabric.

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Materials and cultivation methods

Spunbonded polypropylene (Paopao 90; 20 g·m^{-2} weight, Mitsui Petrochemical Industries, Tokyo) and spinach (*Spinacia oleracea* L.) cv. Oracle (Sakata Seed Co., Yokohama) were used as rowcover and plant materials, respectively. The investigations were carried out at the National Research Institute of Vegetables, Ornamental Plants and Tea in Mie Prefecture, Japan (34°N, 136°E).

Both covered and non-covered plots consisted of two soil beds 5 m in length, 60 cm in width with flat tops piled up at a height of 10 cm. There were two rows of plants in each bed at an interval of 20 cm. Plants were thinned out at a spacing of about 7 cm when two leaves unfolded. The rowcover material laid at 15 cm above the surface of a soil bed with supports. Fertilizer application and other practices followed standard methods.

Environmental changes induced by rowcover

1) Methods for measurements

Measurement of environmental factors was carried out inside and outside of the rowcover in the same way. Solar radiation was measured using solarimeters. Dry and wet bulb temperatures for the determination of air temperature and vapor pressure deficit were measured using ventilated psychrometers which were located at 10 cm above the surface of the soil beds. Soil temperature was measured with copper-constantan (type T) thermocouples 0.3 mm in diameter which were buried at a depth of 5 and 10 cm in the soil beds. Plant temperature was measured by inserting type T thermocouples 0.1 mm in diameter in two areas of middle leaves without mutual shading, one area of lower leaves and in the growing point area. Matric potential of soil water was measured at a 10 cm depth in the soil beds using tensiometers (DIK-3130, Daiki Rika Kogyo, Tokyo).

2) Results

The environment inside and outside of the rowcover displayed significant differences (Fig. 1).

Intensity of solar radiation under the rowcover was about 80% of that outside. Air temperature was higher under the rowcover during fine days with weak wind. In windy days with weak solar radiation and in the night, however, the air temperature under the rowcover was often similar to or lower than that outside.

The rowcover often enabled to maintain a higher daytime plant temperature while only the temperature

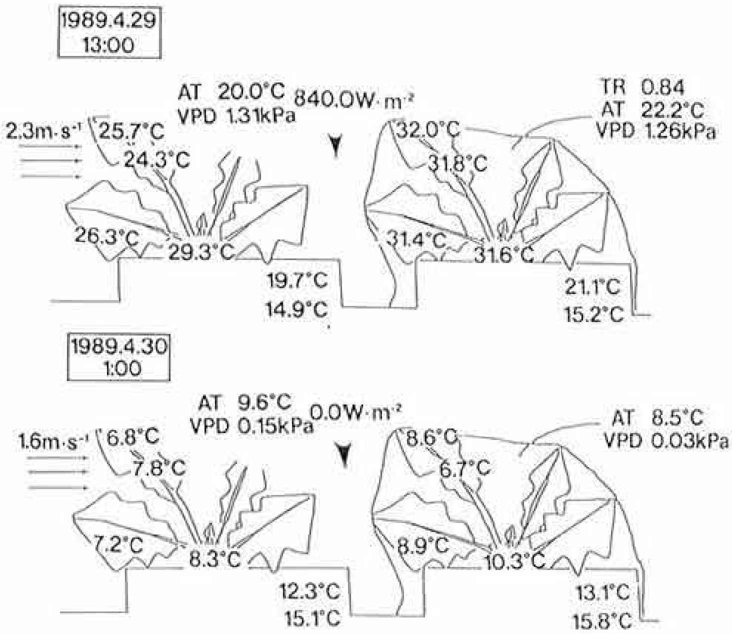

Fig. 1. Plant environment inside and outside of the rowcover
AT: Air temperature,
VPD: Vapor pressure deficit,
TR: Ratio of solar radiation inside and outside of the rowcover.

of the growing points and lower leaves was higher in the night except in frosty (i.e. calm and fine with high radiative cooling) nights. In frosty nights, since the rowcover was covered with dew or frost, radiative cooling decreased. As a result, the plant temperature was higher than outside and plants were protected from frost[3].

The vapor pressure deficit was not appreciably affected by the rowcover. Soil temperature was higher under the rowcover than outside. Matric potential of soil water was higher under the rowcover during continuous fine days (Fig. 2).

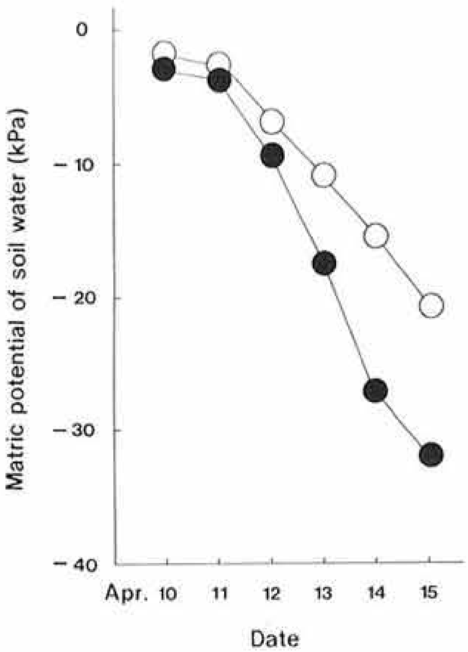

Fig. 2. Changes in matric potential of soil water at 10 cm depth[a)]
a): Weather was fine from 10 to 15 April.

Plant growth under rowcover

1) Methods for measurements

Sampled plants from covered and non-covered plots were weighed and thereafter the plant length, leaf number, leaf area or dry weight were determined. Total leaf area of a plant was measured with an automatic area meter (AAC-400, Hayashi Denkoh, Tokyo). Plant dry weight was determined after 48 h of drying at 80°C.

Net photosynthesis per unit leaf area during the daytime was measured in the middle leaves by an improved half-leaf method[10]. Water potential of a plant was measured by a pressure chamber (DIK-7000, Daiki Rika Kogyo, Tokyo).

2) Results

The rowcover promoted seed emergence of spinach in the cool season (Table 1), especially during continuous fine days after sowing[5]. However, removal of the fabric after emergence resulted in a slight enhancement of plant growth. When covering was applied until emergence, the effect on plant growth was not appreciable compared with covering at the time of sowing. Covering after emergence enhanced plant growth to a similar degree to that of the plants covered since sowing (Table 1).

Net photosynthesis per unit leaf area in the daytime was often lower in spinach plants under the rowcover than outside (Table 2), while the rowcover effect on night respiration was not evident[4]. No visible signs of water stress were observed in plants used in this study. Plant water potential was not appreciably affected by the rowcover (Table 3). Nevertheless, covered plants grew more rapidly than non-covered ones. Weight, leaf appearance and leaf extension were promoted under the rowcover compared with the absence of rowcover during the period from early March to early April (Table 4).

Table 1. Growth of spinach plants in plots under the rowcover until/after emergence[a)]

	Rowcover treatment			
	Since sowing	Until emergence	After emergence	Without cover
Emergence time[b)]	6 March	6 March	10 March	10 March
Plant length (cm)	8.1	6.9	8.8	6.4
Leaf number ($plant^{-1}$)	10.2	8.9	9.5	7.6
Fresh weight ($g \cdot 10\ plants^{-1}$)	30.7	22.2	28.8	17.9
Dry weight ($g \cdot 10\ plants^{-1}$)	2.6	2.2	2.4	1.7

a): Seeds were sown on 19 February. Plants were sampled on 10 April.
b): Date when the germination percentage exceeded 80%.

Table 2. Net photosynthesis of spinach plants in the daytime

Date	Net photosynthesis per unit leaf area ($g\ CO_2 \cdot m^{-2} \cdot day^{-1}$)	
	No rowcover	Rowcover
30 April	12.18	10.94
2 May	21.53	15.25
3 May	18.32	14.88
9 October	13.71	14.23
19 November	10.66	9.84
20 November	11.49	10.66
11 December	9.30	11.77
13 December	13.53	12.30

It was anticipated that plant growth would become more uniform by the use of the rowcover because the growth of the plants which reached the cover may be reduced by the pressure of the cover. However, uniformity of plant growth did not increase by the use of the rowcover, actually (Table 5).

Discussion

In this study, changes in the plant environment associated with the rowcover included a decrease of solar radiation, increase of air and plant temperature

Table 3. Water potential of spinach plants[a)] under or without rowcover

Date	Weather	Time	Plant water potential (− kPa)					
			No rowcover (Replications)			Rowcover (Replications)		
			1	2	3	1	2	3
7 April	Fine	8:00	39.2	78.4	127.4	117.6	88.2	78.4
		11:30	98.0	78.4		98.0	68.6	
		14:00	78.4	98.0		88.2	78.4	
		17:15	274.4	392.0	127.4	441.0	137.2	421.4
13 April	Cloudy	9:00	39.2			58.8		
		11.45	98.0	68.6	117.6	235.2	39.2	78.4
		16:30	176.4	39.2		235.2	58.8	

a): Plants were covered on 2 April when the 7th leaf appeared.

Table 4. Growth of spinach plants in spring[a)]

	No rowcover	Rowcover
Fresh weight ($g \cdot plant^{-1}$)	6.1	9.8
Dry weight ($g \cdot plant^{-1}$)	0.6	0.8
Total leaf area ($cm^2 \cdot plant^{-1}$)	106.8	187.8
Leaf number ($plant^{-1}$)	8.7	13.0
Mean leaf size ($cm^2 \cdot leaf^{-1}$)	9.4	11.9

a): Increases for the period from 5 March to 9 April are indicated.

Table 5. Coefficient of variance (CV) in plant length and fresh weight in spinach plants with or without rowcover

Date of sowing	Date of sampling	Treatment	Plant length (cm)	CV	Fresh weight ($g \cdot plant^{-1}$)	CV
25 Sep. 1990	1 Nov. 1990	No rowcover	16.5	0.107	12.27	0.285
		Rowcover	17.9	0.148	12.63	0.344
25 Oct. 1990	24 Jan. 1991	No rowcover	8.9	0.082	8.63	0.185
		Rowcover	11.8	0.128	13.10	0.235
5 Feb. 1991	12 Apr. 1991	No rowcover	13.4	0.095	9.14	0.292
		Rowcover	18.4	0.131	14.62	0.282

in the daytime, and a higher moisture level in soil (Figs. 1, 2). Moreover it was reported that the air flow decreased by the rowcover[4]. The decrease of air flow resulted in the increase of the daytime temperature and reduction of soil water loss. The lower air and middle leaf temperature under the rowcover in the night may have been ascribed to radiative cooling and the lack of heat supply from the upper air due to the decrease of the air flow.

The rowcover effects throughout the period after emergence contributed significantly to plant growth (Table 1). Tables 2 and 4 indicate that the factor which compensated for the low net photosynthetic rate per unit leaf area was the rapid appearance and extension of leaves, resulting in an enlargement of the total leaf area.

Leaf appearance and extension may have been enhanced by the increase of temperature induced by the rowcover. In many studies[2,8,9], it was suggested that the increase of air and/or soil temperature enhances leaf growth in the cool season. Although soil moisture is also effective in leaf extension[7,12,13], the effect of the preservation of the soil moisture on the plant water status induced by the rowcover or the effect on leaf growth was not evident.

Higher temperature, especially in the daytime, under the rowcover is considered to be the major factor for the enhancement of plant growth in the cool season. Since the rowcover effect on the increase of the temperature is pronounced on fine and calm days, rowcover culture may be suitable in regions with such meteorological conditions.

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