J. Agr. Met. 48(5): 675 – 678, 1993

Effects of mulching on the thermal environment of root zone and crop growth

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Abstract

Differences in types of row cover can affect the microclimate under the row cover. The temperature at the soil surface and the air temperature between the row cover and soil depend on the physical characteristics of film mulch. Plant growth was more closely related to the accumulated effective soil temperature at a depth of 2.5 cm than the accumulated effective temperature between the soil surface and row cover. The method of estimating the heat balance at the row cover is presented. Fairly reasonable agreement was obtained between the simulation experimental results and observations, and this helps to explain the characteristics of heat fluxes in the row cover.

Key word: mulch,row cover,heat flux,simulation experiment,thermal environment

1. Introduction

There are many types of row covers, each differing in material and porosity. These differences in covering method or row cover type affect the microclimates under row covers and thermal environmental conditions around the root zone. These effects are significant in preventing damage from temperature or wind. In the present study, field and simulation experiments were carried out to clarify the mechanism of thermal conditions around the root zone and the effects of meteorological conditions on plant growth.

2. Experimental method

In the field experiment, surrounding(uncovered) air temperature, air temperature between the row cover and soil surface, soil temperature at various depths, and fresh and dry plant weights were observed. The observation site was located in a field at Yamaguchi University. Table 1 shows the characteristics of row the covers used for the experiment.

Numerical experiments for obtaining diurnal changes in soil temperature and net radiation between the row cover and soil surface were made by giving boundary conditions; namely wind velocity, air temperature and vapor pressure at a height of 1 meter, as well as the conductivity of soil, soil temperature at a depth 1 meter and the heat balance at the soil surface.

From radiation exchange theory, the radiation exchanges between the atmosphere and row cover (Rn1) and between the row cover and the soil surface (Rn2) are expressed in Fig. 1.

where B: radiation, ε: emissivity, T: temperature, γ: albedo, τ: transmissivity, R: net radiation

3. Results and discussion

3.1 Experimental results

Diurnal variations of air temperature between the row cover and soil are shown in Fig.2. In the day time, the temperature at plot 3800N is highest because of high transmissivity.

Fig. 3 shows the daily changes in accumulated different soil temperature between the row cover field and contrast field at a depth of 2.5 cm. The accumulated temperature at plot 3800N is highest for the use daily mean value, while the accumulated temperatures at plots 3800S and 4800S are higher than other plots for the temperature at 6:00 because of the difference in the heating of material.

The relationship betweeen the dry weight of plants and the accumulated effective air temperature (>5°C) or accumulated effective soil temperature at a depth of 2.5 cm are plotted in Fig.s 4 and 5. Plant growth seems more closely related to the accumulated effective soil temperature than the accumulated effective air temperature between the soil surface and the row cover because of small dispersion.

Figure 6 shows the relationship between the relative growth rate and the porosity of the row cover at 9 days after a typhoon hit. From this figure ,it is clear that the effect of the row cover on wind damage is significant in the case of strong wind, and it was confirmed to be an effective method of prorecting plants, mainly at top, from wind damage.

Changes in biomass-C in both soils of the root zone and outside the root zone indicate the same trend (Fig. 7). Biomass-C increased up to the 26th of March and then decreased. The range of fluctuation in the root zone soil was larger than the outside soil of the root zone . Changes in the moisture contents of soils in this experiment hardly affected changes in soil biomass-C .

3.2 The simulation result

The characteristics of the row cover film used in the simulation experiments are listed in tabel 2. Based on the heat balance at the surface , diurnal variations of surface soil temperature at various types of row cover fields are obtained (Fig. 8). As seen in the figure ,the result of case 4 (transmissivity is 0.5) best fits the plot observed at 3800S (transmissivity is 0.50-0.55).

From these results , it is found that this simulation model is fairly good to express the thermal conditions at row cover fields .

Figure 8 shows the diurnal variation of the net radiation between the row cover and the soil surface for various cases. From figure 9 and table 2 , it can be seen that the net radiation under the row cover strongly depends on transmissivity.

Energy balance components for cases 2 and 4 are shown in figure 10. Most incoming radiation is used as latent and soil heat fluxes , and sensible heat fluxes are very small because the temperatures of the row cover are nearly equal to the soil surfaces and the diffusion coefficient is very small between the row cover and soil surface .

4. Conclusion

Differences in row cover types can affect the microclimate under the row cover. Fairly reasonable agreement in thermal conditions are obtained between the simulation experiments and the observations, and the characteristics of heat budget under the row cover were clarified.

References

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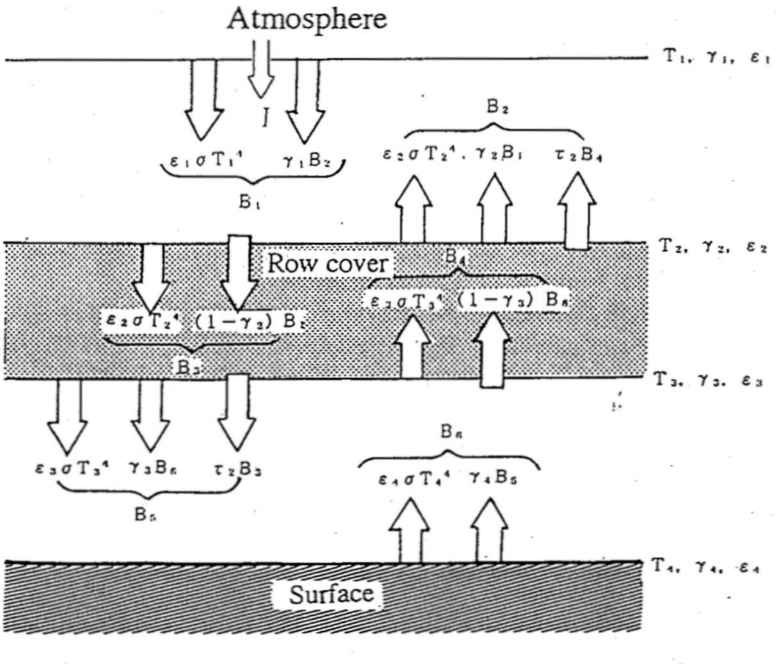

Radiation exchange

$$B_1=\varepsilon_1\sigma T_1^4+\gamma_1 B_2 \quad (1)$$

$$B_2'=\varepsilon_2\sigma T_2^4+\gamma_2 B_1+\tau_2 B_4 \quad (2)$$

$$B_3=\varepsilon_2\sigma T_2^4+(1-\gamma_2)B_1 \quad (3)$$

$$B_4=\varepsilon_3\sigma T_3^4+(1-\gamma_3)B_6 \quad (4)$$

$$B_5=\varepsilon_3\sigma T_3^4+\gamma_3 B_6+\tau_2' B_3 \quad (5)$$

$$B_6=\varepsilon_4\sigma T_4^4+\gamma_4 B_5 \quad (6)$$

Net Radiation

$$R_{n1}=B_1-B_2 \quad (7)$$

$$R_{n2}=B_5-B_6 \quad (8)$$

Heat Balance at Siol Surface

$$S_o+B_o+lE_o+H_o=0 \quad \cdots\cdots (9)$$

Soil Heat Flux at the Surface

$$B=-\lambda_s\frac{\partial T}{\partial z} \quad z\langle 0,\ t\rangle 0 \quad \cdots\cdots (10)$$

Equation of Heat Conduction

$$\frac{\partial T}{\partial t}=\frac{\lambda_s}{c_s\rho_s}\cdot\frac{\partial^2 T}{\partial z^2} \quad \cdots\cdots (11)$$

Fig. 1 Schematic representation of radiation exchanges in an earth-row cover-atmosphere system

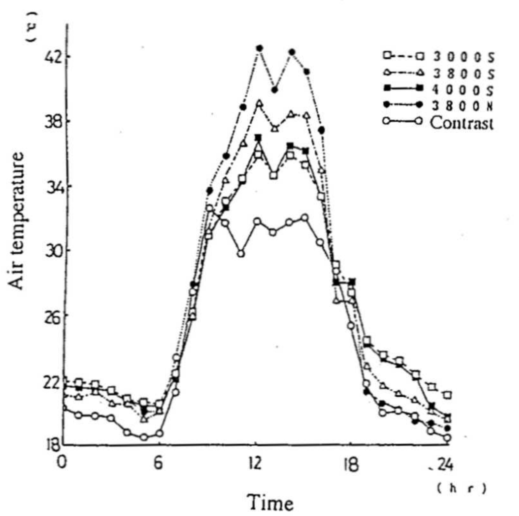

Fig. 2 Diurnal variation of air temperatures between soil and row cover.

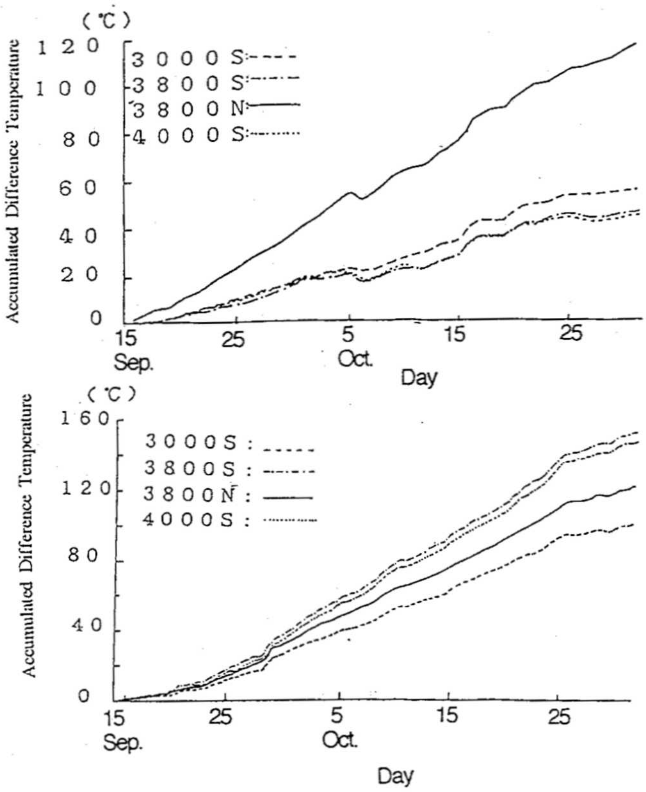

Fig. 3 Daily variation of accumulated difference soil temperature at a depth of 2.5 cm between the row cover field and the contrast field. The upper is for daily mean value and the lower is for the value at 6:00.

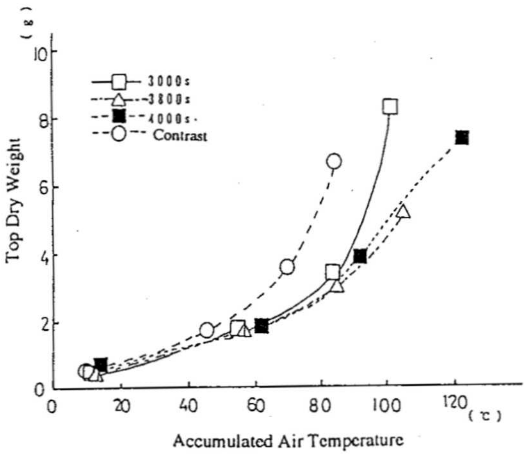

Fig. 4 Relationship between accumulated effective air temperature and dry weight.

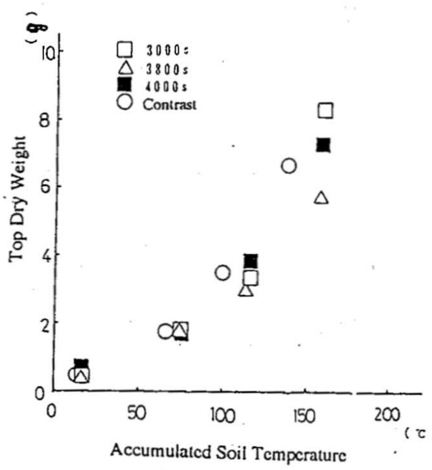

Fig. 5 Relationship between accumulated effective soil temperature and dry weight.

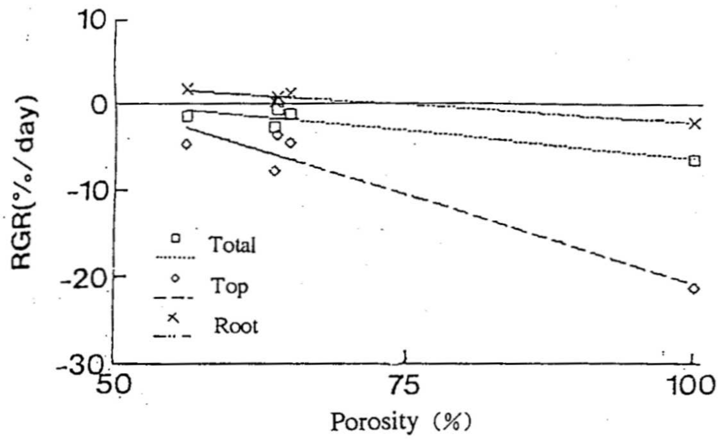

Fig. 6 Relationship between relative growth rate(RGR) and porosity of row cover.

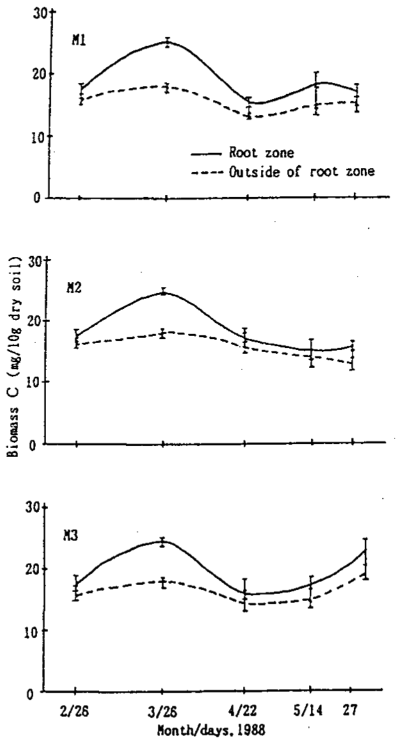

Fig. 9 Changes in microbial biomass-C in the root zone outside root zone soils of the mulch plots.

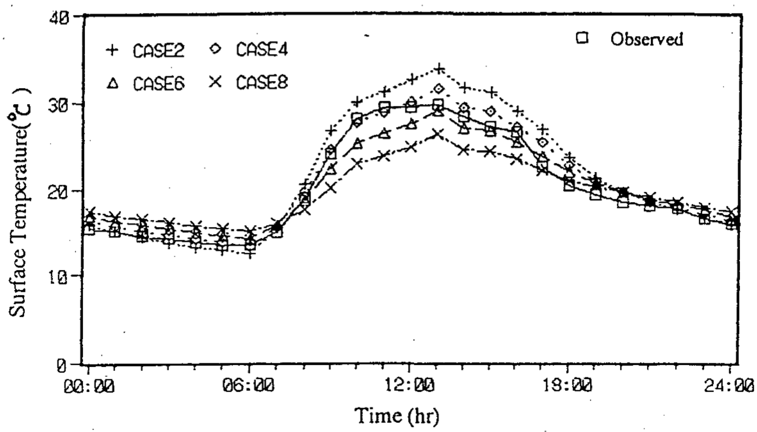

Fig. 8 Diurnal variations of surface soil temperature at row cover field for various cases obtained from simulation experiment.

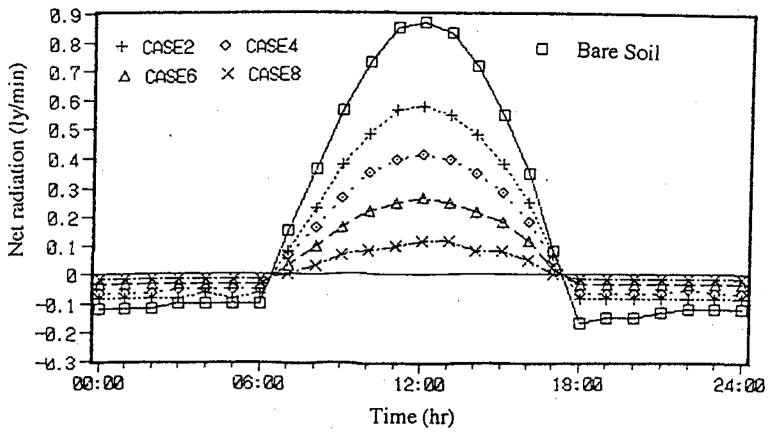

Fig. 9 Diurnal variations of net radiation in the row cover for various cases obtained from simulation experiment.

Table 1 The characteristics of row covers used for field experiments.

Sort	Material	Color	Transmissivity%
3000S	Polyvinyl	Silver	70～75
3800S			50～55
4000S			35～40
3800N		Clear	92～94
Contrast	No cover (Bare soil)		

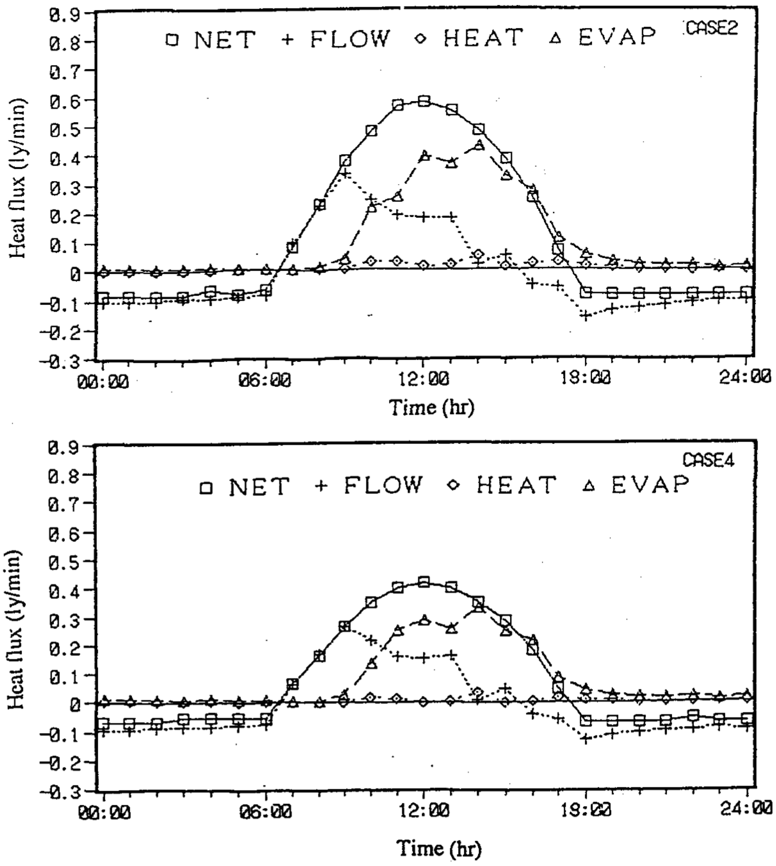

Fig. 10 Diurnal variations of the energy balance component in the row cover for case 4 and case 6 obtained from simulation experiment.

Table 2 Transmissivity and albedo of row cover film used in simulation experiment.

	CASE 2	CASE 4	CASE 6	CASE 8
Transmissivity	0. 7	0. 5	0. 3	0. 1
Albedo	0. 1	0. 3	0. 5	0. 7