

## Effects of Leaf Movement on Radiation Interception in Field Grown Leguminous Crops

### IV. Relation to leaf temperature and transpiration among peanut cultivars\*

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**Abstract :** Leaf movement and its relations to radiation interception, transpiration and leaf temperature in peanut cultivars were examined. Five cultivars (Chibahandachi, Tachimasari, Kanto 56, Valencia and Kintoki) were grown under field conditions. At the pod filling period, leaf movement was restrained by covering with a nylon net. The diurnal changes of leaf temperature, the intercepted radiation of leaflets in the uppermost layer of the canopy, and the infrared thermal images were compared with those of the control. Transpiration rate and stomatal resistance were measured in the control plants. The leaf temperature of the treated plants of Tachimasari, Valencia and Kintoki were higher than those of the control. The control had a similar leaf temperature to the air temperature. Chibahandachi and Kanto 56 had higher leaf temperature in the control during the afternoon. The leaf temperature of the treatment decreased in the afternoon. The control plants intercepted greater radiation than the treatment in Kanto 56, Valencia and Kintoki on cloudy days. On clear days, a greater amount of radiation was intercepted in Tachimasari and Kanto 56. Chibahandachi had the greatest transpiration rate, followed by Valencia, Kanto 56 and Tachimasari. The infrared thermal images of Tachimasari and Kintoki were higher than those of Chibahandachi and Kanto 56. It was therefore assumed that a cultivar with high transpiration ability showed active diaphototropism and a cultivar with low transpiration ability exhibited active paraheliotropism.

**Key words :** Heliotropism, Infrared thermal image, Intercepted radiation, Leaf temperature, Transpiration.

マメ科作物の葉の調位運動が受光量に及ぼす影響 第4報 ラッカセイ品種における葉温及び蒸散との関係 磯田昭弘・ABOAGYE Lawrence Misa・野島 博・高崎康夫(千葉大学園芸学部)

**要 旨 :** ラッカセイの葉の調位運動の品種間差異について、葉面受光量、葉温及び蒸散速度の点から検討した。5品種(千葉半立、タチマサリ、関東56号、バレンシア、金時)を圃場条件下で栽培し、地上部最盛期に防雀網で群落最上層葉を抑え、自由に調位運動を行っている無処理区の小葉面受光量と葉温の日変化を比較した。また、熱赤外線画像測定機で各区の群落熱画像を撮影するとともに、無処理区の個体を対象に蒸散速度、気孔抵抗を測定した。タチマサリ、バレンシア、金時の3品種では、無処理区の葉温は気温とほぼ同様に推移したが、処理区の葉温は気温より高く推移した。千葉半立、関東56号においては、葉温は無処理区で気温と同様かやや高く推移したが、処理区では午後から気温より低くなった。受光量は曇天日には関東56号、バレンシア、金時で、晴天日ではタチマサリ、関東56号で無処理区が有意に大きくなり、両日とも関東56号が最大の受光量を示した。蒸散速度は千葉半立が最大で、次いでバレンシア、関東56号、タチマサリ、金時の順で、気孔抵抗とは負の相関関係があった。熱赤外線画像測定による群落の葉温はタチマサリ、金時で高くなり、千葉半立、関東56号で低い値を示した。以上のことから、蒸散能力の高い品種は太陽光線避ける運動の程度が小さいことから受光量が大きくなり、蒸散能力の低い品種は太陽光線避ける運動により葉温を下げ、水分ストレスを回避している傾向がうかがえた。

**キーワード :** 受光量、蒸散速度、調位運動、熱赤外線画像、葉温。

Previously, we reported the leaf movement of soybean in terms of radiation interception, leaf temperature and transpiration<sup>8)</sup>. In general, paraheliotropic leaf movement in soybean occurs to avoid excessive solar radiation and to

regulate leaf temperature<sup>8,13,14)</sup>. There were varietal differences in the relationships among leaf temperature, transpiration and heliotropism; a cultivar with high transpiration ability regulated leaf temperature mainly by transpiration and the main controlling factor of leaf temperature would be paraheliotropism in a cultivar with low transpiration ability<sup>8)</sup>. In this experiment, we aimed to investigate the relation of leaf movement to radiation inter-

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ception, transpiration and leaf temperature in peanuts using 5 cultivars, including various plant types and sub species.

### Materials and Methods

The five cultivars in Fig. 1 were grown at the experimental farm of the Faculty of Horticulture, Chiba University in 1994 and 1995. The seeds were sown by hand at an equidistant spacing of 30 cm between and within rows on May 13, 1994 and on May 18, 1995. Fertilizer at a ratio of 30 : 100 : 100 kg ha<sup>-1</sup> of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O was applied just before planting.

The surfaces of the canopy, including the experimental plants were covered twice with a 0.56 mesh nylon net just before the start of the measurements. Consequently, leaves about 5 cm layers from the surface of the canopy, were horizontally restrained. Measurements of radiation interception were made at the pod-filling period, on August 19 and 20 in 1994, and August 16 and 17 in 1995. About 100 integrated solarimeter films<sup>16)</sup> were used in the treated and control plants of every cultivar. They were randomly stuck on every leaflet surface in the uppermost layer of the canopy by double-sided binding tapes for two days as previously described<sup>6)</sup>. At the same time, vertical distribution of leaf area, leaf and stem weight of four plants per cultivar was examined at 5 cm intervals. Leaf and air temperature were also measured in both the control and treated

plants by thermopiles from 4 a.m. to 7 p.m. on August 17, 1994. Leaflets were selected from the uppermost part of the canopy. The details of the measurement were the same as reported in the previous paper<sup>8)</sup>. On September 5, 1994, transpiration rate and stomatal resistance of the leaflets of the uppermost layer of the canopy were measured by a portable CO<sub>2</sub> gas analyzer (CID Corp., CI-301 PS) from 10 a.m. to 1 p.m., when photosynthetically active radiation was greater than 1600  $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>.

On September 5, 1995, under clear weather conditions, infrared thermal images of four cultivars (Chibahandachi, Tachimasari, Kanto 56 and Kintoki) were measured from about 1 m above the canopy by infrared thermometer (AGEMA Crop., Thermovision 470). Data for Valencia was not taken because of its disturbed canopy structure. The measurement was made in both control and treatment plots from 11 a.m. to 1 p.m.

### Results

#### 1. Canopy structure and leaflet area

Chibahandachi and Kanto 56 were the semi-erect type with a short stature (Fig. 1). Their total leaf area index (LAI) attained more than 4, concentrating in the upper layers of the canopy. Tachimasari was an erect type with sparse leaf area as compared to Chibahandachi and Kanto 56. Valencia and Kintoki also had an erect form with sparse leaf area.

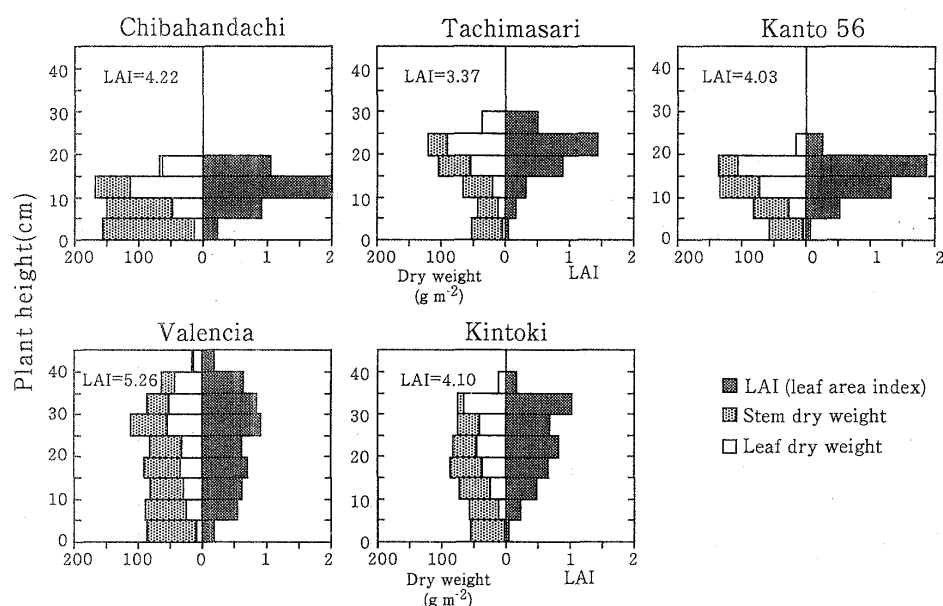


Fig. 1. Vertical distribution of leaf area and dry weight.

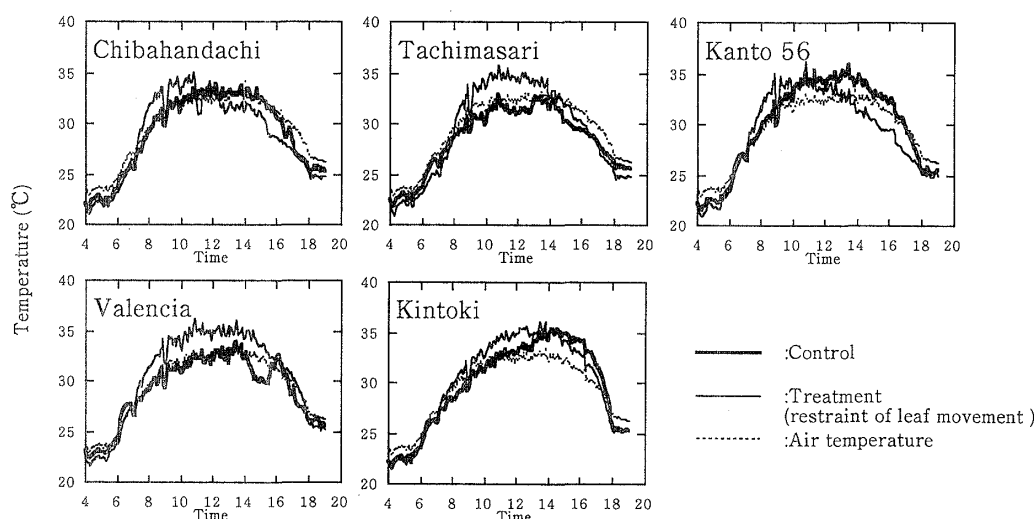


Fig. 2. Diurnal changes of leaf temperature on August 17 in 1994.

## 2. Changes in leaf temperature with time

Greater varietal differences in leaf temperature were observed among the genotypes due to the leaf restraining treatment. In Chibahandachi, the leaf temperature of the control showed a similar trend as the air temperature for most of the daytime and was lower than the air temperature after 4 p.m. The treated plants were higher than the air temperature in the morning, and lower than the air temperature and the control in the afternoon. The control of Tachimasari was lower than the air temperature, and that of the treatment was higher than the air temperature. Kanto 56 and Chibahandachi had similar trends in leaf temperature in both the control and treatment. In both cultivars, the treatment was higher and then lower during the morning and evening. The control was lower in the morning but higher in the afternoon. Valencia showed a similar pattern to Tachimasari, higher in the treatment; and on a par with the air temperature in the control. The leaf temperature in the control and the treatment of Kintoki showed similar changes to the air temperature during the morning and was higher in the afternoon as compared to the air temperature. In the treatment, it was higher than the air temperature during the daytime.

These results suggest that leaf movement in Tachimasari and Valencia reduced their leaf temperature. Kintoki could not regulate its increasing leaf temperature even in the control, due to its inactive leaf movement and lower transpiration rate. In the treatment of Chibahandachi and Kanto 56, although leaf

temperature was higher than the air temperature in the morning, it was lower than the air temperature in the afternoon due to greater transpiration (see Table 2). In Kanto 56, the variation in leaf temperature of the control was greater than the air temperature, indicating its active diaheliotropic (less active paraheliotropic) leaf movement.

## 3. Radiation interception

The global solar radiation was only  $7.55 \text{ MJ m}^{-2} \text{ day}^{-1}$  in 1994 because of cloudy days (Table 1). Chibahandachi and Tachimasari had significantly lower values in the control. Valencia showed the highest value, followed by Kintoki and Kanto 56. The values of the treatment in Chibahandachi and Kanto 56 were significantly lower. The values of the control in Kanto 56, Valencia and Kintoki were significantly higher than those of the treatment. In the treatment, varietal differences were also observed; Tachimasari, Valencia and Kintoki had rather high intercepted radiation, reflecting their sparse leaf density in the upper layers of the canopy. Chibahandachi and Kanto 56 showed low values, indicating mutual shading, even in the upper layers under diffused light conditions.

Global solar radiation in 1995 was rather high, being  $18.64 \text{ MJ m}^{-2} \text{ day}^{-1}$ . Kanto 56 had the highest value, followed by Tachimasari, Valencia and Kintoki. The Chibahandachi value was lowest. There was no varietal difference in the treatment, being around  $10 \text{ MJ m}^{-2} \text{ day}^{-1}$ . Kanto 56 and Tachimasari showed significantly higher values in the control as compared to the treat-

Table 1. Intercepted radiation per unit leaf area ( $\text{MJ m}^{-2} \text{ day}^{-1}$ ) in 1994 and 1995.

Cultivar	1994			1995		
	Control	Treatment	Significance	Control	Treatment	Significance
Chibahandachi	3.58c	2.86b	ns	9.42c	10.04a	ns
Tachimasari	4.25c	4.42a	ns	11.67b	10.22a	*
Kanto 56	5.25b	2.61b	***	13.67a	9.36a	***
Valencia	6.30a	3.95a	***	11.26b	10.37a	ns
Kintoki	6.10ab	4.60a	**	10.42bc	9.97a	ns
Global solar radiation		7.55			18.64	

\*, \*\*, \*\*\*, ns: 5%, 1%, 0.1% level of significance and non-significance, respectively.

Means followed by the different letter are significantly different at 5% level in the same column.

ment. In particular, Kanto 56 intercepted greater radiation due to diaheliotropical movement in both years.

#### 4. Leaf characteristics and transpiration

Valencia and Kintoki, both belonging to subspecies *fastigiata*, had greater leaflet area, followed by Tachimasari and Chibahandachi. Mean leaflet area of Kanto 56 was smallest, although there were no greater differences in specific leaf weight among the cultivars (Table 2). Transpiration rate was greatest in Chibahandachi and Valencia, followed by Kanto 56. Kintoki showed the lowest value. On the contrary, stomatal resistance was lowest in Chibahandachi and highest in Kintoki.

#### 5. Infrared thermal images

Fig. 3 indicates infrared thermal images in the control and the treatment. The brown and white parts indicate the ground surface which was not covered with leaves. The percent of the part greater than  $30^{\circ}\text{C}$  in the infrared thermal images was shown in Tabel 3. Although these figures were not so accurate since soil surface was included in Tachimasari and Kintoki, there were greater differences in leaf temperature among the cultivars. In the control, Tachimasari showed the highest percent of the part greater than  $30^{\circ}\text{C}$  in the

thermal image, followed by Kintoki. Though the greater part of the ground base below its canopy was irradiated because of its active paraheliotropism, its leaf temperature was higher. The images of Chibahandachi and Kanto 56 were almost dark blue, indicating lower temperature. In the treated plots, the greater part of Chibahandachi and Kanto 56 showed still dark blue spots. These results indicate clearly the regulation of leaf temperature by transpiration. Kintoki, and especially Tachimasari, could not reduce their leaf temperature by transpiration.

#### Discussion

Peanuts orient leaves diaheliotropically in the morning, paraheliotropically in the afternoon, and diaheliotropically again during the evening. Paraheliotropic and diaheliotropic movement functions to avoid heat stress<sup>1,4,13,15</sup>; and to increase radiation interception and thus increase dry weight<sup>3,11</sup>; respectively. The features of the cultivars used in this experiment are summarized in Table 4. Tachimasari and Valencia had more active paraheliotropism and less active diaheliotropism. On the contrary, Chibahandachi and Kanto 56 showed less active paraheliotropism and

Table 2. Leaflet area, specific leaf weight (SLW), transpiration rate and stomatal resistance.

Cultivar	Mean leaflet area ( $\text{cm}^2$ )	SLW ( $\text{g m}^{-2}$ )	Transpiration rate ( $\text{mmol m}^{-2} \text{ s}^{-1}$ )	Stomatal resistance ( $\text{m}^2 \text{ s mol}^{-1}$ )
Chibahandachi	7.85d	5.66	13.1a	3.83d
Tachimasari	9.90c	6.94	8.4d	6.38b
Knato 56	6.83e	5.26	9.8c	5.14c
Valencia	17.24b	6.11	11.6b	5.17c
Kintoki	19.84a	6.07	6.7e	7.78a

Means followed by the different letter are significantly different at 5% level.

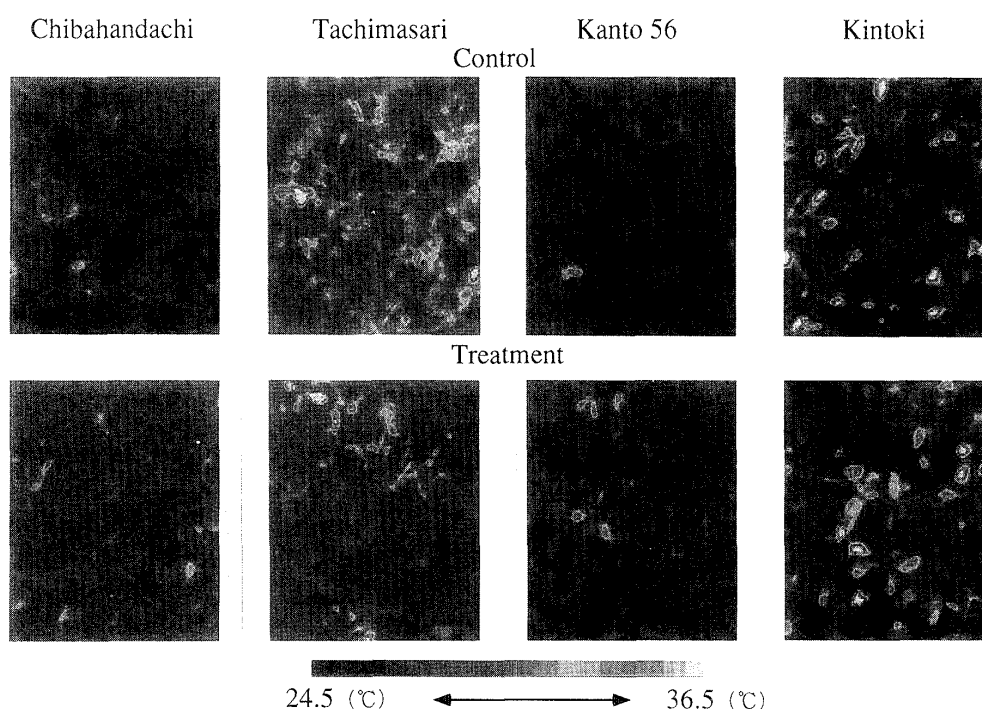


Fig. 3. Infrared thermal images of the control and the treatment (restrained leaves).

Table 3. Percent of the part more than 30°C in infrared thermal images.

Cultivar	Control	Treatment
Chibahandachi	7.8	16.7
Tachimasari	83.1	31.8
Kanto 56	3.0	10.6
Kintoki	27.3	32.8

more active diaheliotropism. Kintoki was intermediate between the two types. As similarly reported in soybean<sup>8)</sup>, these varietal differences in leaf movement were closely related to transpiration ability and leaf temperature; a cultivar with more active paraheliotropism (less active diaheliotropism) such as Tachimasari could control its leaf temperature mainly by leaf movement; and leaf temperature of a more active diaheliotropic cultivar such as Kanto 56 could be controlled mainly by transpiration. However, only in Valencia there is no similar relationship between heliotropism and transpiration. Valencia seemed to control its leaf temperature mainly by leaf movement.

Oosterhuis et al. reported that paraheliotropism seemed to be an indicator of the onset of water stress<sup>12)</sup>. The relationship between heliotropism and transpiration ability observed in this experiment also reflected the

degree of drought tolerance. The summer seasons in 1994 and 1995 were extraordinarily hot and dry. The peanut cultivars were growing under water-stressed conditions during most of the summer season. A cultivar with more active diaheliotropic movement, such as Chibahandachi and Kanto 56, revealed high drought tolerance. On the other hand, Tachimasari and Valencia were very weak in tolerance, showing closed leaflets during most of the day. The transpiration rate of Chibahandachi was greater. Kanto 56 also seemed to have greater transpiration ability from the viewpoint of leaf temperature, although its transpiration rate was not so high. The control had higher leaf temperature, as compared to the treated plants, which showed lower leaf temperature than the air temperature. In particular, the leaf temperature of Kanto 56 ranged higher, as compared to the air temperature. There are only a few reports about the optimum temperature in peanut; it was higher than 31°C<sup>9)</sup>, around 30°C for leaf expansion<sup>2)</sup> or 36.5°C for emergence<sup>10)</sup>. The maximum and mean air temperature was 34.2°C and about 32°C on the experimental days, respectively. These results suggest that a cultivar with high transpiration ability, such as Kanto 56, might not need to avoid solar radiation to reduce its leaf temperature. Both transpiration

Table 4. Features of the cultivars observed in this experiment.

Cultivar	Leaf movement*		Transpiration	Leaf temperature in thermal images**
	Paraheliotropism	Diaheliotropism		
Chibahandachi	less active	active	high	low
Tachimasari	more active	less active	low	high
Kanto 56	less active	more active	medium or high	low
Valencia	active	less active	high	—
Kintoki	less active	less active	low	medium or high

\* Relative activeness among the cultivars.

\*\* Leaf temperature in thermal images were not measured for Valencia.

and paraheliotropism functions to reduce leaf temperature and to avoid heat stress. In peanut, therefore, the regulation of leaf temperature by transpiration seems to occur prior to paraheliotropic leaf movement.

We have examined leaf movement in soybeans and peanuts<sup>6,7,8)</sup>. Greater differences were found between the crops, in addition to varietal differences within the crops. Both crops orient leaves diaheliotropically to paraheliotropically, and diaheliotropically again during the day. However, peanuts generally had a longer period of diaheliotropic movement as compared to soybeans, indicating higher drought tolerance. Mohamad et al.<sup>10)</sup> assumed that varietal differences in optimum temperature for emergence might depend on differences in the climatic conditions of the breeding sites. In support of this, the differences in leaf movement between peanut and soybean may therefore reflect on the differences in climatic conditions of their origins. Further research will be required to answer this interesting question.

In this experiment, a portable CO<sub>2</sub> gas analyzer was used for measuring transpiration ability. Some results obtained by this instrument differed from the features derived from the leaf temperature using infrared thermal images or the thermopiles. Only several leaflets of each cultivar were measure in this experiment by the CO<sub>2</sub> gas analyzer, which is not the most suitable for the measurement of transpiration. In addition, Hirose et al.<sup>5)</sup> observed greater cyclic changes in the transpiration rate of peanut leaves. Thus water status of the whole canopy could not be accurately determined. These conditions might also cause the difference in the relationship between heliotropism and transpiration in Valencia, as compared to the other cultivars. In addition,

soil water conditions may also affect leaf movement greatly. More accurate measurements of the water status of plants and soil will be needed to make clear the relationship among leaf temperature, water availability and leaf movement.

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