HortScience 18(2):233–235. 1983.

Albedo Characteristics of a Strawberry Planting

J.T.A. Proctor and W.J. Blackburn[1]
Department of Horticultural Science, University of Guelph, Guelph, Ontario, Canada N1G 2W1

Additional index words. solar radiation, *Fragaria* X *Ananassa*

Abstract. **Albedo of plantings of strawberry (*Fragaria* X *Ananassa* Duch.) and bare soil is a major factor determining the amount of radiation absorbed and used by the crop in various energy exchanges. It varied diurnally and had a mean daily value of about 22% for 7 days in a one-month period during the major plant-growth and fruit-bearing periods. Exposing moist soil, or soil wetting, reduced albedo by about 20%; this reduction was greatest in the 700 to 1350 nm region. Spectral distribution of reflected radiation from strawberry leaves had broad peaks in the 700 to 1300 nm range and was greater than that from soil in the same range.**

Measurements of incoming and outgoing solar irradiances over a crop surface can be used to determine reflecting characteristics of the canopy. Albedo or reflection coefficient is defined as the fraction or percentage of solar radiation that is reflected by the surface; it depends on the crop surface and its color, the moisture conditions, the density of the crop cover, leaf arrangement, and the angle of the sun (5). That energy which is not reflected is absorbed and subsequently dissipated by sensible and latent heat exchange, soil heat conduction, and radiation exchange processes. Therefore, daily and seasonal variations in the albedo of a surface influence the energy budget.

The purpose of this study was to examine the solar radiation regime of a strawberry crop, particularly the spectral distribution of reflected radiation and the diurnal variation of albedo from the canopy and adjacent bare soil. The effect of wetting of soil on albedo was also examined.

Work reported here was primarily carried out at the Horticultural Experiment Station of the Horticultural Research Institute of Ontario at Simcoe (42°51'N, 80°16'W). Data for "solid-bed" strawberry plantings were obtained at Vineland Station (43°11'N, 70°23'W). At Simcoe, the strawberry planting (150 × 82 m) of the cultivar, Guardian, consisted of N-S "matted" rows, with row centers 122 cm apart, plant height 25 to 30 cm, and row spread 60 to 70 cm. The "solid" beds used at Vineland were similar to those described by Ricketson (9).

An Eppley Precision Spectral Pyranometer, placed above the planting with an unobstructed view of the atmosphere, was used to measure the incoming solar irradiance, $K\downarrow$.

Values of the outgoing solar (reflected) irradiance, $K\uparrow$, were measured with Eppley Black and White Pyranometers mounted in an inverted position 1 m above the surface. At this height the view factor of the sensor is about 0.99, indicating that 99% of the energy incident on the instrument originated from the planting (6). These measurements were used to calculate albedo values (α) from $K\uparrow/K\downarrow$.

In determining α for "matted" rows, the pyranometer was inverted at a height of 1 m over the middle of the row where the sensor thermopile viewed both soil and plants. Since "solid-bed" plantings completely covered the ground, the contribution to the reflected solar flux from the soil was assumed zero. A bare-soil area adjacent to the strawberry planting was used to determine soil values of α.

The mean albedo was determined by 3 methods denoted as A, B, and C. In method A, half-hourly values of α were computed from the continuous radiation record and averaged for the day; method B involved calculating the ratio of the daily total of $K\uparrow$ to $K\downarrow$ (7, 8); method C involved the calculation of the slope of the linear regression equation relating $K\uparrow$ to $K\downarrow$ (2, 8, 10).

The spectral distribution of $K\uparrow$ and $K\downarrow$ was determined with an ISCO Model SR spectroradiometer over the range 380–1350 nm. The calibration curve of the spectrora-

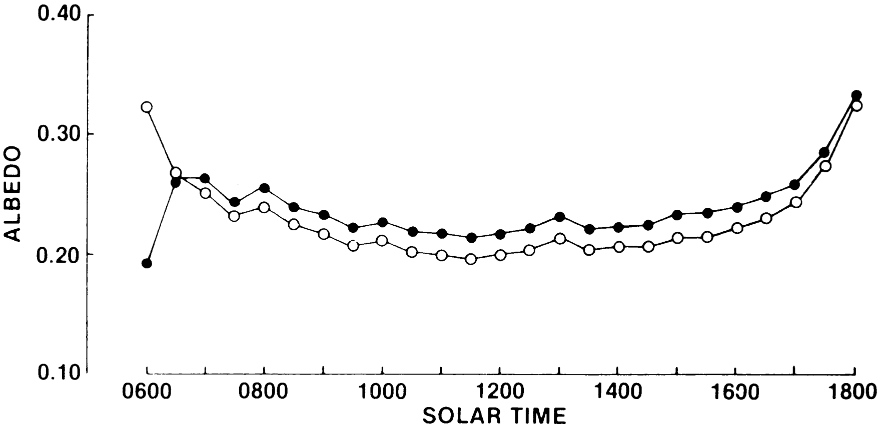

Fig. 1. The diurnal variation of albedo for bare soil (●) and strawberry plants (○) on a clear day (July 7).

Table 1. Mean values of albedo determined by methods A, B, and C for the "matted" row strawberry planting and bare soil.

	Albedo					
	Strawberry planting			Bare soil		
Date[z]	A	B	C	A	B	C
June						
9	0.217	0.212	0.209	0.202	0.205	0.206
15	0.210	0.219	0.227	0.213	0.226	0.235
26	0.213	0.205	0.203	0.189	0.185	0.183
27	0.217	0.208	0.203	0.215	0.208	0.205
28	0.228	0.215	0.209	0.228	0.219	0.215
July						
7	0.231	0.218	0.212	0.239	0.232	0.228
11	0.219	0.214	0.211	0.233	0.230	0.230
Avg	0.219	0.213	0.200	0.217	0.215	0.215

[z] First fruit harvest was on June 19 and last on July 7.

Received for publication Oct. 6, 1982. This research was supported in part by grant No. A6697 of the Natural Sciences and Engineering Research Council of Canada and by the Ontario Ministry of Agriculture and Food. We thank W. Pierce for technical assistance, J.A. Davies and colleagues for assistance at various stages of the work, and R.B. Stewart for reviewing the manuscript. C.L. Ricketson very kindly made his strawberry plantings available for the study. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1] Present address: Crop Production Division, Regional Development and International Affairs Branch, Agriculture Canada, Ottawa, Ontario, Canada K1A OC5

diometer was verified frequently using an ISCO spectral standard lamp. The surface soil moisture was determined gravimetrically using five 100 g samples for each measurement.

The main daily albedo for "solid-bed" plantings, determined on May 24 at Vineland, was found to be 0.224, irrespective of whether method A, B, or C was used to calculate it. Mean albedos for "matted" rows and bare soil were calculated by all 3 methods (Table 1). For individual days, albedo values of the strawberry planting and soil differed by as little as 2%, with little difference observed in albedo values between days. Initially, it was thought that a complete crop cover (solid-bed) would give a higher albedo than plant rows and bare soil. These data, however, do not substantiate this.

In most cases, method A gave the highest values of α and method C the lowest. This is consistent with earlier findings at Simcoe for various horticultural and field crops (2, 8). By using method A, the arithmetic mean is biased toward higher values because equal weight is assigned to all measured intensities. Hence, periods of low radiation intensity cause a marked increase in α. Method C, which weights measured irradiances according to their intensity (10), can underestimate or overestimate the true average value of α if it varies with solar elevation.

Since there is little variation between mean values of α averaged over the 7 days, a value of 0.22 was adopted for the albedo of both bare soil and the strawberry plantings. This value is comparable to those derived in earlier work at the same site (2), where α measurements of 0.23 for 5 "low" annual crops and 0.20 for bare soil were determined.

Values of α for both surfaces on July 7 are plotted in Fig. 1. These data show a characteristic diurnal variation. Except for bare soil at 0600 HR, high values of α were obtained at low solar elevations. The anomalous value at 0600 may be attributed either to instrumental error or to some surface characteristic such as surface roughness as noted elsewhere by Kalma and Badham (4).

Soil wetness had a pronounced effect on α. The soil type at the measurment site was a Fox sandy loam of the grey-brown Podzolic group. When the soil dries, it leaves an extremely dry, thin crust which increases the value of α. If this crust layer is disturbed by raking to expose the moist underlying soil, as shown in Fig. 2a, α is reduced.

The effect of wetting dry soil on soil albedo was also determined. The albedo of dry soil (0.75% moisture) was reduced by about 50% compared to wet soil (19.09% moisture) over the wavelengths measured (Fig. 2b). Percent surface soil moistures were determined gravimetrically. Reduction in albedo was greatest in the 700 to 1350 nm region.

Except for the characteristic (green leaf) minor pack at 550 nm there was little reflection from strawberry leaves in the visible region up to 700 nm (Fig. 2c). Absorption by chlorophyll in the blue-violet (400–450 nm) and red (640–670 nm) parts of the spectrum (11) and attendent reflections and re-

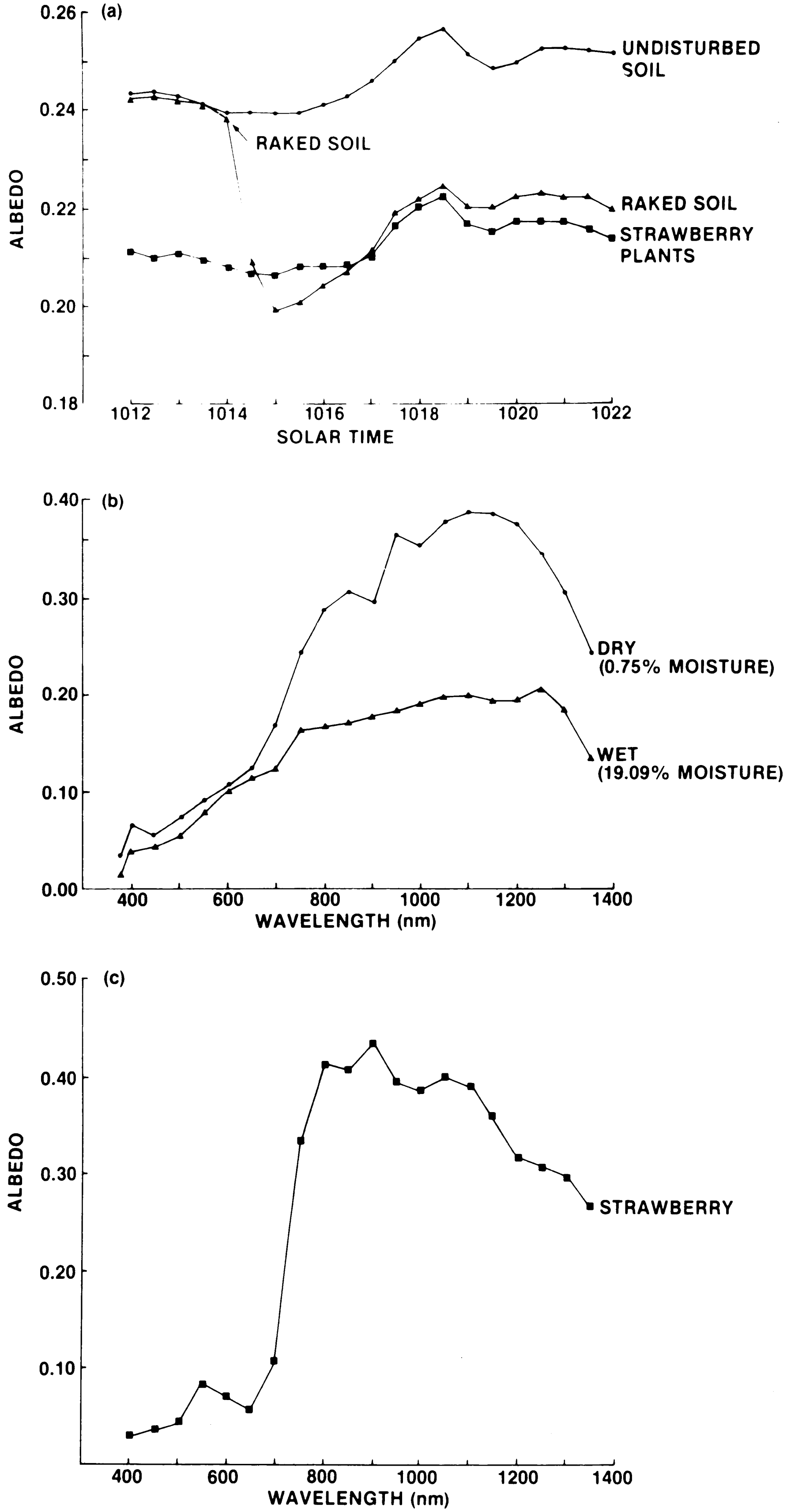

Fig. 2. The effect of (a) raking of dry soil to expose moist underlying soil, (b) wetting of dry soil on soil albedo, and (c) spectral distribution of reflected radiation from strawberry plants.

fractions within the leaf allow for little reflection in this region. Beyond 700 nm the reflectance increased dramatically to a maximum of about 40% in the 800–1100 nm waveband. Transmittance is also known to increase over this range where the majority of the energy in direct sunlight incident on the plants is contained (3).

Reflection from the soil increased almost linearly to about 1000 nm for dry soil and thereafter declined; for wet soil, the initial linear increase was to about 800 nm and then it remained relatively constant to about 1300 nm (Fig. 2b). The spectral distribution of reflected irradiance from the soil not only differed to that from leaves (Fig. 2c), it was less over the wavelengths measured. However, values of α were similar when the soil was dry (Table 1). Therefore, the contribution to reflection from the soil at wavelengths greater than 1350 nm must be greater for soil than for leaves. Data from Bowers and Hanks (1) and Gates, Keegan, Schleter, and Weidner (3) support this contention.

In calculations involving the receipt, distribution, and use of solar irradiance by the strawberry crop, allowances must be made for the greater than 20% of the incident energy that is lost through reflection by the crop.

Literature Cited

1. Bowers, S.A. and R.D. Hanks. 1965. Reflection of radiant energy from soils. Soil Sci. 100:130–138.
2. Davies, J.A. and P.H. Buttimor. 1969. Reflection coefficients, heating coefficients and net radiation at Simcoe, Southern Ontario. Agr. Meteorol. 6:373–386.
3. Gates, D.M., H.J. Keegan, J.C. Schleter, and V.R. Weidner. 1965. Spectral properties of plants. Appl. Optics 4:11–20.
4. Kalma, J.D. and R. Badham. 1972. The radiation balance of a tropical pasture: 1. The reflection of short-wave radiation. Agr. Meteorol. 10:251–259.
5. Kyle, W.J. 1971. Daytime radiation regimes within a corn canopy. Publications in Climatology 2, Dept. of Geography, McMaster Univ., Hamilton, Ontario, Canada.
6. Latimer, J.R. 1972. Radiation measurement. International Field Year for the Great Lakes/International Hydrological Decade. Technical Manual Series 2, Ottawa, Canada.
7. Monteith, J.L. and G. Szeicz. 1961. The radiation balance of bare soil and vegetation. Quart. Roy. Meteorol. Soc. 87:159–170.
8. Proctor, J.T.A., W.J. Kyle, and J.A. Davies. 1972. The radiation balance of an apple tree. Can. J. Bot. 50:1731–1740.
9. Ricketson, C.L. 1967. "Solid-bed" plantings—a promising method of growing strawberries. Hort. Res. Inst. Ontario Rpt. for 1967. p. 15–22.
10. Stanhill, G., G.J. Hofstede, and J.D. Kalma. 1966. Radiation balance of natural and agricultural vegetation. Quart. J. Roy. Meteorol. Soc. 92:128–140.
11. Zscheile, F.P. and C.L. Comar. 1941. Influence of preparative procedure on the purity of chlorophyll components as shown by absorption spectra. Bot. Gaz. 102:463–481.

HortScience 18(2):235–237. 1983.

Effects of Chilling on Respiration and Ethylene Production of 'Hass' Avocado Fruit at 20°C

Irving L. Eaks
Department of Biochemistry, University of California, Riverside, CA 92521

Additional index words. *Persea americana*, ripening

Abstract. **The effects of chilling 'Hass' avocado fruit at 0° or 5°C on the respiratory rates, rates of ethylene production, ripening, and chilling injury symptoms at 20° were compared with the same responses of fruit exposed to a nonchilling temperature (10°) and fruit placed directly at 20°. Fruit held at 10° for 2 weeks were beginning the climacteric and ripened after about 4 days at 20°. Longer exposures at 10° resulted in ripe or overripe fruit. Fruit held for 2 weeks at 0° or 5° displayed normal climacteric patterns and ethylene production at 20°, and developed no significant chilling injury symptoms. Exposures of 4 and 6 weeks at 0° or 5° resulted in the development of chilling injury symptoms, abnormal ripening, atypical respiratory rate patterns, and reduced ethylene production rates which peaked after 2 days at 20° and showed a declining rate thereafter, with no increase in the rate of ethylene production associated with fruit softening.**

Chilling injury of tropical and subtropical fruits results from physiological disturbances when exposed to low, but nonfreezing temperatures below about 10° to 12°C (7). The respiratory rates of nonchilling temperatures following chilling exposures have been observed to evaluate the metabolic dysfunction caused by chilling for various fruits (1, 3, 4, 5, 6, 13). Exposure to chilling temperatures stimulates ethylene production during that time and after transfer to nonchilling temperatures in several fruits (2, 5, 8, 9, 10, 11, 12). However, the ethylene production of cucumbers at 25° after chilling at 2.5° for more than 4 days was reduced below that of fruit held at 2.5° for 4 days (11). Data on the ethylene production of avocado fruit at a nonchilling temperature after a series of chilling exposures are not available.

Reported here are the respiratory rates, ethylene production, and ripening of 'Hass' avocado fruit at 20°C after various chilling and nonchilling exposures compared with fruit placed directly at 20°.

Mature 'Hass' avocado fruit were harvested from Experiment Station trees, randomized, and placed at experimental conditions by noon. Experiments were conducted with mid- and late-season fruit during one season and mid-season fruit the next season. Each treatment consisted of 8 individual fruits. The 8 uniform-sized fruit for each treatment were numbered, weighed, and placed in labeled paper bags for storage. Treatments consisted of a) fruit placed directly in respiratory chambers at 20°C and b) storage for 2, 4, and 6 weeks at 0°, 5°, and 10°. At the end of each storage treatment the fruit were weighed and placed in respiratory chambers at 20°.

The respiratory chambers were aerated with humidified air with the ethylene removed by passing through a glass tube of Purafil (Purafil, Inc.; Chamblee, Ga.) and the CO_2 removed by bubbling through a fritted gas-dispersion tube into 2 N NaOH. The air flow for each chamber was metered through calibrated capillaries at a rate ranging from 8.0 to 8.5 liters/hr. CO_2 production of each fruit was determined by a calibrated Beckman infrared CO_2 analyzer. A switching system sequenced the outlet gas flow from each fruit chamber and an air sample (CO_2-free) through the analyzer. Data were taken from the chart every 12 hr for calculation of respiratory rates. Ethylene production was determined twice daily (0800 and 1600 HR) on 1 ml samples of the outlet gas of each respiratory chamber by a Varian aerograph flame ionization gas chromatograph equipped with a 2 m × 3.2 mm column packed with 60–80 mesh activated alumina. The gas chromatograph was calibrated at each sampling with 1 ml samples of a standard ethylene–nitrogen mixture. Fruit ripening was determined subjectively by applying a slight pressure to each fruit by hand. When ripe the external and internal characteristics were evaluated for chilling injury (4).

The data presented are averages for the mid-season fruit for the 2 years. The 2 daily

---

Received for publication Sept. 24, 1982. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.