Modification of Within-canopy Microclimate in Maize for Intercropping in the Lowland Tropics

I K. D. Jaya[1, 2], C. J. Bell[1] and P. W. Sale[1]

[1] La Trobe University, Victoria.
[2] Fakultas Pertanian Universitas Mataram, Jl. Majapahit 62, Mataram 83125 Indonesia.

ABSTRACT

High temperature and irradiance are major constraints for temperate vegetable production in the lowland tropics. Intercropping, however, may alleviate these constraints. This study examined microclimate changes in a maize canopy grown in different row orientations (north-south and east-west) and population densities (4.8, 7.1, 9.5 and 14.3 plants m^{-2}). Field experiments using cultivar Hawaiian Super-sweet#9 were conducted in Narmada, Lombok, Indonesia in 1998. Irradiance decreased exponentially with increase in LAI. More light tended to be transmitted in the east-west row orientation than in the north-south orientation. The within-canopy temperatures varied slightly with plant density and row orientation. Light and temperature reductions (up to 70% of light and 1.2^{o}C in maximum temperature) in the treatment with 7.1 plants m^{-2} with N – S orientation could create a favourable environment for the production of temperate vegetables such as cauliflower in the lowland tropics.

KEY WORDS

Tropical horticulture, intercropping, canopy, microclimate, maize, cauliflower.

INTRODUCTION

Lowland tropical conditions do not suit temperate vegetables such as cauliflower (*Brassica olearcea* L. var. *botrytis*). However, there is an increasing demand to grow this crop in the lowlands as the consumers are mainly in these areas and transporting cauliflower from the highlands to lowland markets with poor packaging results in bruised curds. The bruised curds are susceptible to bacterial attacks that cause the curd to rot. Other concerns with intensive production in the highland areas involve water and chemical run-off and soil erosion (7, 9).

Cauliflower is known to have a low temperature (vernalising) requirement to induce curd (e.g. 14). Vernalising temperatures are between 2^{o} and 24^{o}C (2). Cauliflower remains in the vegetative stage above these temperatures. However, Jaya and Bell (5) reported that the tropical cauliflower cv. Milky was able to produce curd in the lowland tropics of Lombok, Indonesia at an average daily temperature of 27.7^{o}C and a mean radiant exposure of 15.8 MJ m^{-2} d^{-1}. The quality of the curds was poor (small and yellowish), which was attributed to high irradiance and temperature during curd growth. Manipulating the microclimate during the transitional period from the vegetative to the generative stage up to curd development would therefore be necessary to produce good curd quality. In the tropics, where capital can be one of the major constraints in agricultural production, microclimate modifications that require high inputs such as the use of synthetic shade materials are not feasible. Microclimate modification by cheap and simple means, such as intercropping might be acceptable as well as affordable.

Intercropping has been widely practiced in the tropics to improve land productivity and to avoid yield losses. Intercropping is also used to improve temperate potato production by sheltering the potato plants with a taller species (e.g. 6, 12). Maize is one of the row crops often selected for intercropping to provide shelter to understorey crops because of its wide adaptation over a range of climates. The emphasis of much previous work on intercropping temperate crops in the tropics (e.g. 6, 12) was mainly on soil microclimate characterisation and not on within-canopy microclimate. It has been suggested (11) that light transmission through the canopy is affected by row orientation in addition to plant population density. The experiments reported here were carried out in Lombok, Indonesia (08^{o}31'S and 116^{o}13E, 125 m above sea level) in 1998 to test the hypothesis that both within-canopy temperature and light transmission would be affected by maize plant density and row orientation.

There were 2 experiments with 2 row orientations (north-south (N-S) and east-west (E-W)) and 4 planting densities (4.8, 7.1, 9,5 and 14.3 plants m^{-2}) using the same row spacing of 70 cm. Experiment 1 (January to March) had 3 replications and experiment 2 (May to July) had no replication. The within-canopy temperatures were measured 40 cm above the ground (equivalent to cauliflower's curd height) and ambient temperature was measured at 150 cm height, 5 m outside the experimental plots using platinum resistance thermometers inside a temperature screen. The temperatures were scanned every 2 minutes and the averages were recorded every hour using a portable datalogger (Datataker 500, Data Electronics, Melbourne.). Irradiance was measured using a line PAR Ceptometer (AccuPAR, Decagon Devices, Pullman, WA) by inserting the sensors perpendicular to the rows at 40 cm above the ground.

RESULTS AND DISCUSSION

Leaf area index (LAI) was affected by population density and crop age in both experiments, but not by row orientation (Table 1). The increase in LAI in weeks 3 to 5 resulted in a large increase in light interception by the canopy, allowing only a small proportion of light to be transmitted (Figure 1). The fraction of light transmitted by the fully developed canopy at 5 weeks after sowing (WAS) was higher than that reported by Watiki et al. (13) in their experiment in Queensland but lower than that reported by Murphy et al. (8) in their experiment in Canada. The difference could be due to the difference in cultivar or to the different latitudes, or light scattering effects, resulting in differences in the angles of incident irradiation.

Table 1. Effect of plant density and age of crop on leaf area index (LAI) of the maize crops in experiment 1. Similar data were recorded in experiment 2.

Plant density (plants/m^2)	Weeks after sowing					
	1	2	3	4	5	6
	(Leaf Area Index ($m^2 m^{-2}$))					
4.8	0.006a	0.1a	0.4a	1.5a	2.4a	2.3a
7.1	0.008b	0.1a	0.7b	2.0b	3.3b	3.2b
9.5	0.01c	0.2b	0.9c	2.8c	4.4c	4.4c
14.3	0.02d	0.7c	1.3d	4.0d	6.4d	6.2d

Means within columns followed by different letters differ significantly ($P < 0.05$)

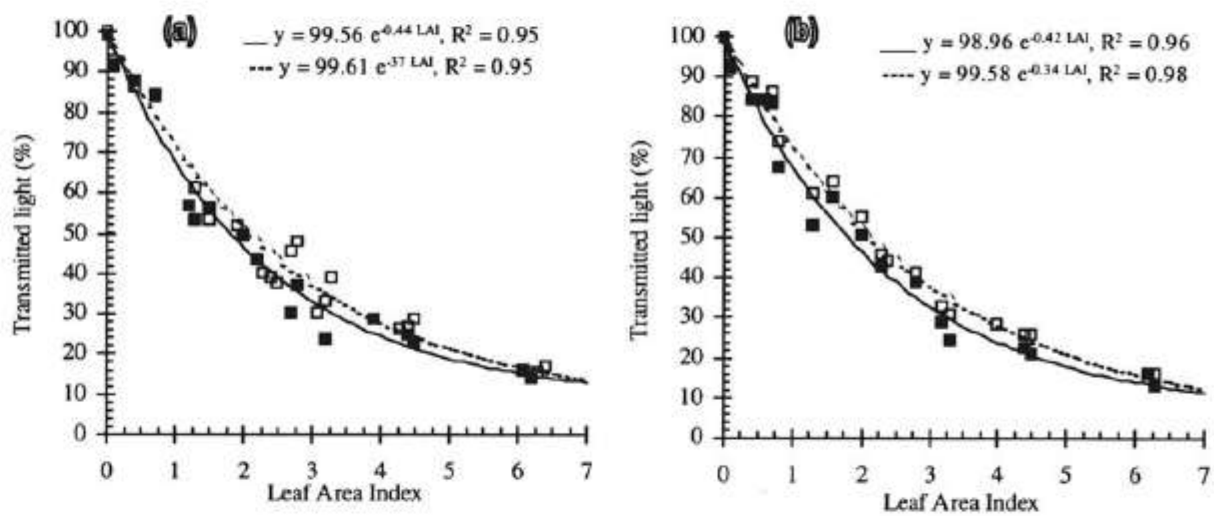

Figure 1. Relationship between transmitted light (%) and LAI in experiment 1 (a) and experiment 2 (b). The closed symbols are N – S and the open symbols are E – W orientations.

The canopy extinction coefficients (*k*) derived from the nonlinear regressions shown in Figure 1 were greater for the N–S orientation (0.44 ? 0.028 and 0.42 ? 0.043 for experiments 1 and 2 respectively) than for E–W rows (0.37 ? 0.030 and 0.34 ? 0.032 for experiments 1 and 2 respectively). However, the results of parallel curve analyses on the transmitted light in the two orientations showed the differences were significant only in experiment 2 ($P>0.05$). The row orientation effect on light attenuation is in accordance with a previous study of soybean crops (4). Differences in *k* in experiments 1 and 2 are attributed to the different solar angles when the light was measured. Light measurements were taken at solar angle of approximately 60^{o} to 70^{o} (experiment 1) and 75^{o} to 90^{o} (experiment 2). A well-spaced maize canopy intercepts less light at a high solar angle than at a smaller solar angle (3).

Light reductions under the canopy were not always associated with temperature reductions. In fact, only plants with N–S orientation with 7.1 plants m^{-2} produced a significantly ($P<0.05$) lower within-canopy maximum temperature, compared with the corresponding ambient temperature between the 4^{th} and 6^{th} week of growth (Table 2). Unfortunately, neither wind speed nor wind direction was measured in the two experiments but was likely to be significant factors, particularly in the lower densities. Other treatments such as 4.8 and 7.1 plants m^{-2} at E–W orientation and 9.5 plants m^{-2} at N – S orientation had greater within-canopy temperatures than ambient temperature during the daytime. At night, the within-canopy temperatures in all treatments were higher than ambient temperature.

Table 2. Effect of row orientation and plant density on maximum and minimum within-canopy temperatures as well as temperature dynamics at various times between the 4^{th} and 6^{th} WAS in experiment 2.

Treatments		Within-canopy temperature (°C)					
Row orientations	Plant density (plants m^{-2})	Max.	Min.	At 10:00	At 12:00	At 14:00	At 16:00
N - S	4.8	32.5b	20.9bc	29.9ab	31.7b	31.2bc	29.6cd
N - S	7.1	31.3a	20.8b	29.3a	30.5a	30.2a	28.8a
N - S	9.5	33.3c	21.0c	31.4c	32.4c	31.4bcd	29.2abc
N - S	14.3	33.0bc	21.1cd	30.0ab	32.1bc	31.7cd	29.1ab
E - W	4.8	35.2e	20.9bc	31.7c	34.3e	33.2f	30.4e
E - W	7.1	34.2d	21.0c	30.5b	32.9dc	32.7e	29.9d
E - W	9.5	33.1bc	20.9bc	30.0ab	31.9bc	32.0d	29.5bcd
E - W	14.3	32.5b	21.2d	30.0ab	31.6b	31.4bcd	29.5bcd
Above-canopy temperature		32.5b	20.6a	30.2b	31.6b	31.0b	29.0a

Means within columns followed by different letters differ significantly ($P< 0.05$)

At low plant density (4.8 plants m^{-2}) and N-S rows, the canopy provided insufficient shading to reduce temperatures, resulting in similar temperatures within and above the canopy. In E-W oriented rows, there was more direct penetration of radiation which created higher temperatures within the canopy (10), particularly near midday (Table 2). At medium density (7.1 plants m^{-2}), the canopy provided sufficient shading but plants oriented N-S absorbed radiation higher in the canopy than E-W oriented plants. This heat, however, was easily lost to the atmosphere by turbulent transfer since the canopy was still sufficiently open. As a result, the within-canopy temperatures were lower in N-S rows than in E-W rows (Table 2). At high canopy density (LAI) such as at 9.5 and 14.3 plants m^{-2}, more radiation was absorbed in the upper part of the canopy and this became a strong heat source during the day (1). Under these conditions, heat transfer from the top to the bottom of the canopy would be dominated by long wave radiation as the dense canopy reduced the turbulent transfer of heat to the atmosphere. The result was very similar temperatures in N-S and E-W rows (Table 2).

CONCLUSIONS

Maize planted at medium density (7.1 plant m^{-2}) with N-S orientation reduced within-canopy maximum temperatures at 40 cm above the ground by 1.2°C. The temperature reduction was associated with a reduction of irradiance up to 70%. The reduction, especially in temperature, was highly sensitive to row orientation and plant density and at some combinations resulted in increased in temperature. For the purpose of cauliflower-maize intercropping in the lowland tropics, a plant density of 7 plants m^{-2} at N-S orientation appears promising and gives an irradiance of above 300 Wm^{-2} at midday about 5 weeks after sowing. This must be coordinated with the development of the cauliflower so that curd initiation takes place at this time. Early growth of the cauliflowers will take place in higher irradiances to ensure sufficient carbohydrate supply.

More work is needed to study wind speed and direction effects in regulating the within-canopy temperature, particularly in relation to local topography and orographic influences. Finally, the timing of sowing the maize between cauliflower rows in order to match the light and temperature requirements of cauliflower during its ontogeny is vitally important.

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