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Short communication

Sand mulching and its relationship with soil temperature and light environment in the cultivation of *Lilium longiflorum* cut flower

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ABSTRACT

Lilium longiflorum is one of the most important cut flowers both in the world and in Argentina. To plan a commercial crop, it is necessary to understand tools that relate environmental variables to crop growth and development. One of these tools is leaf expansion, which can be determined from the evolution of the leaf area index (LAI). The technique known as sand mulching substantially modifies the soil temperature but can also alter other environmental variables such as light quality. The objective of this work was to determine whether the application of sand mulching affects the growth rate and leaf expansion of a lilium cut flower crop. The experiment was carried out in a greenhouse at the Faculty of Agronomy, University of Buenos Aires, Argentina, where a lilium crop was planted in the soil, adding a 5-cm layer of fine sand over the entire soil surface to reduce soil temperature. Plant height and number of leaves were measured twice a week and the LAI was estimated by spectral reflectance once a week. The cycle length was also recorded, and the accumulation of dry matter was measured at the end of the experiment. The soil temperature was lower in the first month of cultivation, and there were differences in the light environment and in the water status of the crop. Although there were no significant differences in the cycle length or leaf appearance, sand mulching led to differences in the stem growth rate, LAI and final plant height, resulting in a better quality of the product.

1. Introduction

Lilium (*Lilium longiflorum* Thunb.) constitutes the fourth largest cut flower industry (VBN, 2009) and one of the six most important genera of flower bulbs around the world (CBI, 2016; Hanks, 2015).

Simulation models are efficient tools in crop management and planning. Models can help to understand genetic, physiological and environmental interactions, with interdisciplinary integration. They allow defining production strategies in the planning stage of a future crop or helping to take technical decisions during the crop cycle, including cultural practices, fertilization, irrigation and pesticide use.

Soil temperature affects lilium growth, particularly during cultivation initial stages. Optimum soil temperature during the rooting of the bulb is 12–13 °C, whereas temperatures above 15 °C during the growing cycle decrease the quality of the final product (ibulb.org, 2017). Warmer temperatures also produce shorter stems and fewer flowers per stem (International Flower Bulb Centre (IFBC, 2002) and reduce growth and development of adventitious roots (Kim et al., 2007a). For hybrid L/A (longiflorum x asiatic), the best temperature after rooting is 14–16 °C, with a temperature of up to 20–22 °C being acceptable. Similar optimal temperatures have been reported for other geophytes (Jennings and De Hertogh, 1977; Wilson and Peterson, 1982). Like many other physiological processes, root growth in geophytes is highly regulated by temperature (Kim et al., 2007b). Elevated temperatures in the first 30 days lead to stem length reduction by cycle shortening, abortion, and abscission and/or desiccation of flower buds, whereas low but non-lethal temperatures generally slow down the growth rate and therefore lengthen the crop cycle (Schiappacasse et al., 2006; Mascarini et al., 2007). In addition, light and temperature are the main climatic factors determining the leaf appearance and elongation rates (Repková et al., 2009). While the increase in temperature stimulates the development of leaf primordia, and could therefore accelerate the leaf appearance, light mostly affects the rate of elongation and the duration of leaves. Also, many studies have shown that temperature is the main factor controlling the phyllochron, or rate of leaf appearance, for example in wheat (*Triticum aestivum* L.). Experimental results in wheat suggest that the soil temperature at the crown level, rather than the air temperature at the canopy level, could better predict the rate of leaf emergence (McMaster et al., 2003).

Another way to model the response of a crop to different

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environmental situations is through the evolution of the leaf area index (LAI). Direct measurements of the leaf area by destructive methods are tedious and highly time-consuming, and the number of plants at the end of the experiment is usually lower than at the beginning. In contrast, remote sensors of the plant canopy are a non-destructive, simple and fast method that allows evaluating the temporary changes in the growth and development of the whole plants in situ (Holben et al., 1980; Asrar et al., 1985; Mascarini et al., 2006).

The LAI accuracy obtained from the reflectance measurement depends on the contrast between the soil and the green leaves in a partially closed canopy. The highest contrast occurs in the near infrared region (700–1100 nm), where the transmission and reflectance of the leaves are maximal. Leaves show the highest absorbance in the visible region of the spectrum (400–700 nm). A combination between visible and near infrared reflectance can estimate the fraction of incident radiation that is absorbed by vegetation. Considering that spectral reflectance, radiation absorption and leaf area are interrelated, the LAI could be determined as a function of that fraction (Asrar et al., 1984).

The way to estimate the LAI from reflectance has been successfully applied in several crops such as wheat (Asrar et al., 1985), soybean (Holben et al., 1980), and maize (Gallo et al., 1985). Sims and Gamon (2003) reported a normalized index as a LAI estimator for 23 species of shrubs, trees and grasses, and defined a specific range of wavelengths where accuracy was highest. In a previous study, we used this technique to estimate the LAI in rose cultures (Mascarini et al., 2006). To our knowledge, there are no studies of LAI modeling by means of spectral reflectance in lilium.

In geophytic species, the effect of soil temperature on plant growth and development during the first 30 days is well-documented (Francescangeli et al., 2008; Khodorova and Boitel-Conti, 2013). The use of sand mulching or soil cover can contribute to the reduction of the temperature at the bulb level, positively affecting the growth and development of the plant, especially when the temperature is high for the crop, for example when grown in greenhouses (Lü et al., 2013; Wang et al., 2014).

The soil temperature has a fundamental influence on the success of a commercial lilium crop. Such is the case of spring plantings, which, with increasing temperatures, often result in less development of adventitious roots, fewer leaves and shorter stems (Roberts et al., 1985). Cool temperatures affect hormonal balance, stimulating the synthesis of auxins and gibberellins (Khodorova and Boitel-Conti, 2013), which are related to the growth of stem roots (Inamoto et al., 2013). On the other hand, in *Eucharis grandiflora*, soil chilling increases the production of flowering stems, compared to the soil under uncontrolled temperature (Doi et al., 2000). Since the use of mulching modifies the soil temperature, this could trigger a positive response in the growth and development of lilium plants. The differential response in terms of soil temperature can be detected by the construction of simulation models considering environmental and crop variables.

The objectives of this work were: 1) to compare soil temperature in a lilium crop with and without sand mulching, and 2) to model the effect of environmental factors on some variables of growth and development of lilium.

2. Material and methods

2.1. Experimental design and plot set

The research was carried out in the School of Agronomy of the University of Buenos Aires (34°35′S, 58°29′ W; 25 m above sea level), located within the Buenos Aires Metropolitan Area, the main commercial flower production area in Argentina. The experiment was performed in a greenhouse on soil, in 5 m × 1 m plots, and the crop was started with an L/A hybrid of *Lilium longiflorum* cv 'Brindisi', 14–16 cm in circumference (4.5–5 cm in diameter), with a planting density of 60 bulbs m^{-2} of cultivation bench. The soils of this region are classified as typic Argiudolls, silt loam textural class, with 65% silt and 25% clay. In general, they are deep soils, with good drainage and high content of organic matter (> 4%). Plants were planted on May 6 and harvested on September 10. The treatments were: 1) bare soil control (S); an 2) sand mulching with a soil covered by a 5 cm fine sand addition, < 0.1 cm diameter, after planting the bulbs (M). Sand is widely used by growers due to its relatively low cost and availability, and is suitable to reduce the soil temperature. Xiaoyan et al. (2002) reported lower temperature in soils covered with fine sand than in those covered with a gravel-sand mix (0.5–2 cm in diameter), no differences with gravel (2–3 cm), and a higher evaporation rate. In addition, growers recover this material at the end of the crop cycle and reuse it several times.

Irrigation water was applied daily with head drippers at a flow rate of 2 L h^{-1}, and automatically controlled. The water volume applied depended on the evapotranspiration calculated by the Penman-Monteith method modified by FAO (Allen et al., 1998).

2.2. Measurements and data analysis

During the experiment, air and soil temperature, relative humidity and incident solar radiation were recorded using a datalogger (Licor 1400, Lincoln, NE, USA). Plant height and number of leaf appeared leaves were recorded twice a week. Spectral reflectance was measured once a week and these data were used to estimate the LAI, light quality and water status, as previously mentioned (Mascarini et al., 2006). Crop spectral reflectance was measured with a handheld multispectral radiometer (MRS16C9, CROPSCAN® Inc.; Rochester, USA, 2000) at 450, 500, 550, 610, 660, 680, 710, 730, 760, 780, 810, 870, 950, 1080, 1220 and 1600 nm. Each band had a half peak band width between 5 and 15 nm. The sensor was mounted on an adjustable pole that was parallel to the ground surface with a field of view of 1.0 m diameter over the crop canopy. Measurements were taken in full-sun days, between 11:00 and 13:00 h. During each measurement, the substrate was covered with a black cloth to prevent undesirable reflection from the bare soil or mulching, and was removed after the measurement. Reference reflectance was measured over a white panel placed over the crop, which represented a value of 100%. These data were used to calculate several plant indices and assess the quality of the radiation reflected as described below:

1) Normalized difference vegetation index (NDVI, Sims and Gamon, 2003), calculated as

$$NDVI = (R810 - R680) / (R810 + R680)$$

This is the ratio between reflectance percent in the infrared region (800–1100 nm) and reflectance percent in the red region (600–700 nm). The wave lengths used in this study were 680 nm (reflection in R_{680}) and 810 nm (reflection in near infrared, R_{810}).

1) Water index (WI), which is a ratio between reflectance at a reference wavelength where water does not absorb, and a wavelength where water does absorb. The simple WI is a ratio between the reflectance at a reference wavelength not absorbed by water, and a wavelength absorbed by water. Sims and Gamon (2003) identified three wavelength bands (950–970, 1150–1260 and 1520–1540 nm) which produce the best correlation with the water content since water reaches maximum absorption in the infrared part of the spectrum. These authors suggested that the 1150–1260 nm and 1520–1540 nm bands could be the best to detect the water content with remote sensors. In this work, we used the 1220 nm band because it is strongly absorbed by the lilium plant, penetrates short distances in the canopy, and is sensitive to water in the upper layers or in a thin canopy.

$$WI = R870 / R1220.$$

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