EVAPOTRANSPIRATION IN MAIZE CROPS AS FUNCTION OF SOIL TILLAGE SYSTEMS

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Abstract
The objective of this study was to compare evapotranspiration of maize crops (ETc) in no-tillage and conventional tillage systems, using measurements of evaporation on the soil surface and transpiration of plants. Two field experiments were carried out in Eldorado do Sul, Brazil, during the cropping seasons of 2001/02 and 2002/03. ETc was calculated by summing the evaporation on the soil surface (microlysimeters) and plant transpiration (heat pulse method). Conventional tillage was the reference treatment in order to establish relative comparisons. Transpiration represented 80 to 90% of the total ETc. During the vegetative period, just before tasseling, ETc in the no-tillage system was 13% lower than in the conventional system. During the flowering period, ETc was higher in the no-tillage by about 10%, which can be attributed to increased soil water availability. Evapotranspiration in no-tillage treatments was highest system during grain filling. Overall, the no till system had 15-20%, higher evapotranspiration.

Additional Keywords: transpiration, water

Introduction
The evapotranspiration of any crop comprises the water losses by evaporation at the soil surface and transpiration by plants. As the crop develops throughout its cycle, the ratio evaporation/transpiration is modified. At the beginning of the plant growth the evaporation is the most important component of the evapotranspiration. But, as the plants growth up the evaporation decreases more and more its participation on the evapotranspiration, and the transpiration increases its importance on the water losses by the plant-soil system. Any modification in the factors affecting the plant-soil system may modify the pattern of variation of the crop evapotranspiration.

The adoption of the no-tillage system may cause several modifications on the physical and hydrological properties of the no-revolved soil, as well as some physical conditions of the soil surface, due to the presence of straw. These changes allow to alterations on fluxes into the soil-plant-atmosphere system, like the processes of evaporation and transpiration, in comparison to the conventional tillage system.

The straw on the soil surface may reduce the evaporation up to 30% in no-tillage, in comparison to conventional tillage, as estimated by Morote *et al.* (1990), Bragagnolo *et al.* (1990), and Salton et al. (1995). According to these authors, reductions on the evaporation would be the main cause of higher water availability to plants in no-tillage system. Otherwise, comparing the two tillage systems through field measurements, Dalmago *et al.* (2003a) observed no differences in evaporation on soil surface. Moreover, sometimes the losses were higher in no-tillage than in conventional tillage systems. Therefore, adopting the no-tillage system must attribute increases on the soil available moisture by adopting the no-tillage system to alterations on its physical properties that affect the water storage capacity, as observed Salton *et al.* (1995).

Increases on the water availability in no-till soils may allow to several plant responses. Measuring the leaf potential on maize crops in the field, Bianchi *et al.* (2003) observed higher values in no-tillage than in conventional tillage, irrespective of the irrigation levels. It was attributed to increments in available water into the no-till soil, that was detected by Dalmago *et al.* (2003b). However, differences on the transpiration of maize plants had no clear tendency, when comparing no-tillage and conventional tillage systems (Dalmago *et al.*, 2003c). Consequently, alterations on the maize crop evapotransporation depend on the participation of the plant transpiration.

Water relations on the soil-plant-atmosphere system into maize cropped on conventional tillage used to be studied in details. By contrast, this approach was not significant when cropping in no-tillage systems. Hence, it is necessary to describe in a deeper way the plant responses to alterations on the water dynamic into crops submitted to the new system. Considering the recent and widely adoption of the no-tillage system by farmers, as well as the importance of water relations in maize, this work aimed to compare the ETc of maize cropped in no-tillage and conventional systems, using field measurements of evaporation on the soil surface and plant transpiration.

Materials and Methods

Field experiments were conducted in the Agronomic Experimental Station of the Universidade Federal Rio Grande do Sul, in Eldorado do Sul, Brazil (30°05'S e 51°39'W, altitude 40 m), in the summer seasons of 2001/02 and 2002/03. The regional climate is a humid subtropical Cfa type (Köppen classification), that prevails in the South Region of Brazil. The annual mean precipitation is 1440 mm and 425 mm occur from November to February, in the experimental period. Maximum global solar radiation corresponds to December, as a mean of 26 MJ m^{-2} day^{-1} (Bergamaschi *et al*., 2003). The soil was classified as a Paleudult.

The experimental area has around 0.5 ha, divided in two plots, whose management are no-tillage and conventional tillage since 1995. Both plots used to be cultivated with a mixture of *Avena strigosa* + *Vicia sativa* during the winter season and maize in summer season. In the no-tillage system the winter mixture was dissected with herbicide (glyphosate) and the straw was rolled to the soil surface. In the conventional tillage the green biomass was incorporated to the soil by plough, in the same day of the herbicide application.

An early maize hybrid (Pioneer 32R21) was sown in November 25th of 2002, in a row spacing of 0.75 m and population of 65000 plants per hectare. The soil fertilization followed the recommendation of the extension services, in order to obtain a grain yield of around 10000 kg ha^{-1}.

A line of sprinklers with a spacing of 6 m was installed in the middle of the experimental area, between the two tillage systems. So that, a full irrigation treatment (field capacity) was applied close to the sprinkler line, and a non-irrigation level was maintained along the lateral strips. The irrigation control follows the water potential at 0.45 m dept in the soil, measured by mercury tensiometers. The amount of water applications was quantified in a weighing lysimeter.

Summing the evaporation at the soil surface and the plant transpiration calculated the ETc. In ord sap flux in the steam (absorption/transpiration) in a system using the heat pulse as a tracer of the sap velocity. The sensors were installed on the base of the plant steam (second internod). The cross section area of the steam was calculated through its averaged diameter. This area was multiplied by a calibration factor, in order to estimate the effective area for the transpiration flux. A Campbell datalogger model CR21X, plugged to a storage module, monitored the measuring system. Details of this methodology were described by Santos *et al*., (1999).

During the first experiment the transpiration was measured on eight plants in each tillage system, from silking stage to grain filling. In the second year, measurements were taken on four irrigated plants of each tillage system, from elongation of the first internode to the end of grain filling. The transpiration was calculated according to adjustments proceeded by Santos *et al*. (1999). The leaf area of each plant normalized its values, in order to reduce the variability among plants and systems. The leaf area was determined by measuring its width and length.

Comparisons between the tillage systems were made considering three different periods: vegetative growth, tasseling-silking period, and end of grain filling. It was possible to proceed taking into account simultaneous data of evaporation and transpiration taken in several selected cycles of soil drying. Comparing the two tillage systems, taking the conventional tillage as the standard system made the analysis.

Results and Discussion

Since the crop ETc was determined in high leaf area conditions, the plant transpiration was its main component. Hence, the plant transpiration defined differences on ETc, when comparing the tillage systems. Considering all the analyzed period, the plant transpiration represents 80 to 90% of the ETc. However, the contribution of the transpiration on the total ETc by the end of vegetative growth and flowering periods was higher than in the grain filling. The leaf senescence during the grain filling increased the evaporation on the soil surface due to the transmission of solar radiation throughout the canopy.

The crop ETc was 13% lower in no-tillage than in conventional tillage systems, just before the flowering stage (Figure 1). It was attributed to the differences in plant transpiration, since the evaporation on the soil surface was equivalent in both the systems. Moreover, the leaf area index was the same in the two tillage systems. Differences in the root activity (root growth and water absorption) as function of the soil tillage may explain the tendency on plant transpiration during that crop stage. Since the green biomass and fertilizers were incorporated to the soil by plough, the nitrogen availability to plant must be higher in the conventional system than in no-tillage, early in crop cycle. Besides, the soil physical conditions would be a second reason to explain the observed plant responses among the tillage systems.

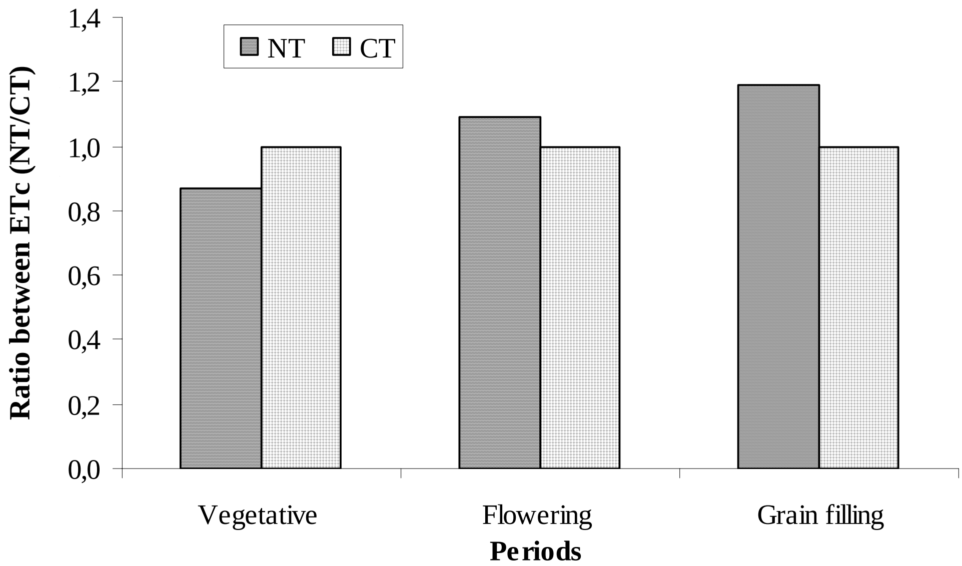

Figure 1. Ratio between the maize crops evapotranspiration (ETc) submitted to no-tillage (NT) and conventional tillage (CT), at different periods of the crop cycle, considering the conventional tillage as the standard system. Eldorado do Sul, Brazil – 2002/03.

The tendency observed just before the flowering stage should be quite different at the beginning of the vegetative growth. Considering a low leaf area index, the evaporation on the soil surface should be increased in such conditions. Hence, since the evaporation on the soil surface was higher in no-tillage than in conventional tillage (Dalmago *et al*., 2003a), it would be possible even an inverted tendency between the two system, mainly in the irrigated area.

After the silking stage, the ETc was higher in the conventional tillage than in no-tillage system in about 10% (Figure 1). It can be attributed to increasing on the water storage into no-till soil, mainly in the superficial layers. This aspect is very important considering the flowering stages as the critical period to grain yield of maize crops. Both evaporation and transpiration processes were higher in no-tillage than conventional tillage after silking stage, but differences on evaporation decreased, comparing to the vegetative period, due to the soil shading by plants.

The no-tillage system may increase the soil water availability to plants during the flowering period that permits suitable conditions for pollination and starting of grain formation. Besides, the high transpiration on plant cropped in no-tillage system means high stomatal conductance and intense photosynthesis, that permits increments on the production of carbohydrates for the grain filling (Dalmago *et al*., 2003c).

During the grain filling the ETc was 15 to 20% higher in no-tillage than in conventional system (Figure 1). Differences among the tillage treatments experienced an increasing, in relation to the prior stages, due to the leaf senescence that was faster in conventional tillage than in no-tillage. The leaf senescence permitted an increasing on the evaporation, because of reductions on the interception of solar radiation. Therefore, the evaporation on the soil surface had a higher participation on crop evapotranspiration during the grain filling than in the previous analyzed periods. Nevertheless, the plant transpiration continued to be the main component of the crop evapotranspiration.

The observed tendencies are representative for similar conditions of soils, climate and, mainly of crop management. In comparing the two tillage systems it is also important to consider the history of the cropped area. Different results may occur depending on the environmental conditions, where it is reasonable to expect increasing or decreasing effects on the water relations in the soil-plant-atmosphere system and hence in the crop responses.

However, it is probable that the tendencies observed in the present experiment will repeat even altering periods into the crop cycle or even in other vegetal crops. The same aspects may be expected both in irrigated and non-irrigated crops. Otherwise, no differences between no-tillage and conventional tillage may occur if having frequent rain precipitation, due to the high water availability in the entire soil profile. On the other hand, differences among tillage systems may be decreased also during long dry periods, because of the water deficit in the soil. Consequently, clear differences between no-tillage and conventional tillage must be expected in intermediary conditions of soil water supply.

Most of crop indexes and models used to be adjusted on conventional tillage. Results showed the necessity to adjust those parameters for maize cropped in no-tillage systems. As an example, the crop coefficient (Kc) must be adjusted because the crop evapotranspiration is modified by the tillage system. However, this necessity must be analyzed case-by-case.

Conclusions

The maize crop evapotranspiration is lower in no-tillage system than in conventional tillage during the vegetative growth. The contrary occurs during the flowering period (critical stage) and grain filling .

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