SOLAR RADIATION INTERCEPTED BY MAIZE CROPS AS FUNCTION OF SOIL TILLAGE SYSTEMS AND WATER AVAILABILITIES

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Abstract
The interception of photosynthetically active radiation (PAR) by maize crops cultivated in different soil tillage systems and water availability was evaluated in a field experiment carried out in Eldorado do Sul, Brazil. Crops were sown to no-tillage and conventional tillage systems, with full irrigation no irrigation. Continuing measurements of transmitted PAR to the soil surface and incoming PAR were taken through the crop cycle. On average, the intercepted PAR in conventional tillage system was 40% higher than in the no-tillage system. Early in plant growth the intercepted PAR in conventional tillage was twice that in no-tillage. This tendency was maintained up to maximum leaf area index. After tasseling the lowest interception of PAR occurred in the conventional tillage due to a higher rate of leaf senescence. Considering the entire crop cycle the interception of PAR by non-irrigated plants was 30% lower than by irrigated plants. It was attributed to reductions on the leaf area and to rolling up of wilted leaves due to water deficits.

Additional Keywords: photosynthetically active radiation, solar radiation, no-tillage, maize, water deficit.

Introduction
The production of dry matter by plants depends on the amount of photosynthetically active radiation (PAR) absorbed by the leaves and its efficiency of conversion into chemical energy. Otherwise, the amount of absorbed radiation depends on the efficiency of interception of solar radiation by leaves.

The efficiency of interception of PAR depends on the leaf area of the plant population (Varlet-Grancher et al., 1989) as well as on the leaf shape and inclination into the canopy. Gallo & Daughtry (1986) observed that the difference between the intercepted and absorbed PAR, along the maize crop cycle, was lower than 3.5%. In according to that, Müller (2001) showed that maize leaves absorbed 92% of the intercepted radiation by the canopy. The efficiency of interception of a canopy corresponds to the capacity of the plant population in intercepting the incident solar radiation, that is the main factor influencing the photosynthesis and the transpiration processes (Thorpe, 1978).

The efficiency of radiation interception is also influenced by the levels of nutrients in plants, mainly by nitrogen (Dewar, 1996; Scott Green et al., 2003). The water deficit reduces the interception of solar radiation due to rolling up the leaves (Müller, 2001). If the water deficit is prolonged, the number and size of leaves may be reduced or else the total leaf area may decrease, reducing the interception of radiation as a consequence (Collinson et al., 1999).

The adoption of the no-tillage system leads to alterations on the soil physical and hydrological properties as well as on the conditions of its surface (Dalmago et al., 2003). Hence, plants growing on this system may present a more favorable water condition than in conventional tillage, moreover in high atmospheric evaporative demand (Bianchi et al., 2003). Therefore, plants may increase its growth rate, expanding its leaf area, and avoiding or delaying the rolling up of leaves, resulting in a higher interception of solar radiation.

This study takes into accounting the important role of the no-tillage in agricultural systems, the importance of the interception of PAR for crop production, focusing the necessity of new indexes to elaborate and adjust crop models for crop monitoring. Its main objective was to evaluate the interception of PAR in maize crops submitted to different soil tillage systems and water availability.

Materials and Methods
A field experiment was carried out in the Agronomic Experimental Station of the Universidade Federal Rio Grande do Sul, in Eldorado do Sul, Brazil (30°05'S 51°39'W, altitude 40 m), in the summer season of 2002/2003. The regional climate is a humid subtropical Cfa type (Köppen classification), that prevails in the South Region of Brazil. The annual mean precipitation is 1440mm and an average of 425mm occurs from November to February, in

the experimental period. Maximum global solar radiation corresponds to December, as a mean of 26MJ m^{-2} dia^{-1} (Bergamaschi et al., 2003). The soil was classified as a Paleudult.

The experimental area has around 0.5ha, cultivated in two tillage systems: no-tillage and conventional tillage since 1995. Both of then were cultivated with a mixture of *Avena strigosa* and *Vicia sativa* during the winter 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 0.75m and population of 65,000 plants ha^{-1}. The soil fertilization followed the recommendation of the extension services, in order to obtain a grain yield around 10,000kg ha^{-1}.

In the middle of the experimental area, between the two tillage systems, a line of sprinklers spaced of 6m each other was installed. So, a full irrigation treatment was applied close to the sprinkler line, and a non-irrigation level was maintained along the lateral strips. The irrigation control was proceeded through the soil water potential, measured by mercury tensiometers, and the amount of water applications was quantified in a weighing lysimeter.

The photosynthetically active radiation was measured from the beginning of the plant growth to the physiological maturity. The incident PAR (PARinc) was measured by means a quantum sensor LI-COR installed above the crop, while the transmitted PAR (PARt) was measured at 0.05m above the soil surface, using four sets of sensors each one consisting of five photo-voltaic cells. All sets of sensors were connected to a multiplexer, which was connected to a Campbell CR10 datalogger, plugged to a storage module. Measurements were taken each 30s, while its mean values were stored each 15min. The portion of intercepted PAR (PARint) was calculated by the equation:

$$PARint = PARinc - PARt$$

The leaf area index (LAI) was estimated through the plant height by the Gompertz model that was adjusted for the same hybrid and treatments, in the previous summer season.

Results and Discussion

The intercepted RFA had similar trends in all the treatments (Figure 1). The interception of PAR follows the leaf area increasing (LAI) up to maximum (which ranged from 4,5 a 5,0 m^2 m^{-2}) around 65 days after the plant emergence. Sivakumar & Virmani (1984) obtained similar results with maize and sorghum, in analyzing the percentage of intercepted PAR as function of the leaf area index.

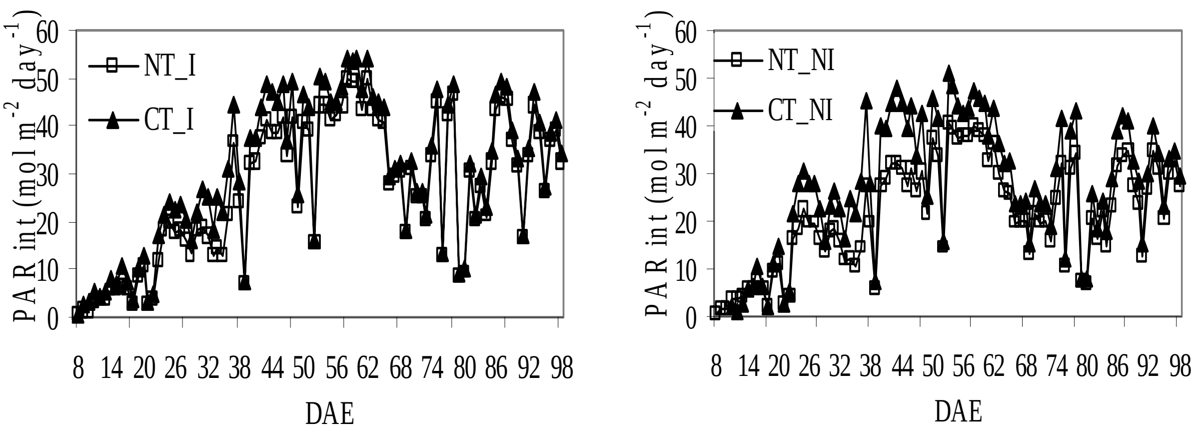


Figure 1. Intercepted photosynthetically active radiation (PARint) in function of days after the plant emergence (DAE) in maize crops submitted to no-tillage (NT) and conventional tillage (CT) systems irrigated (I) and non-irrigated (NI). Eldorado do Sul, Brazil. 2002/2003.

After maximum LAI the interception of PAR was almost constant, but showing lower values in comparison to the PARint observed at maximum LAI. It can be attributed to reductions in RFAinc due to clouds occurred in a rainy period, besides of the natural reduction of the incoming solar radiation along the summer season. The interception of PAR showed variations following the incoming solar radiation, as a consequence of the weather conditions in the period. Since the maximum LAI the interception of PAR by the crop reduced following decreasing of LAI caused by the leaf senescence (Maddoni & Otegui, 1996 e Collinson et al. 1999).

Before maximum LAI the interception of PAR was twice in conventional tillage, in comparison to no-tillage system. After maximum LAI, PARint remained higher in conventional tillage than in no-tillage system, its difference was lower than in the vegetative period, ranging from 1.1 to 1.2 times, for irrigated and non-irrigated plots, respectively.

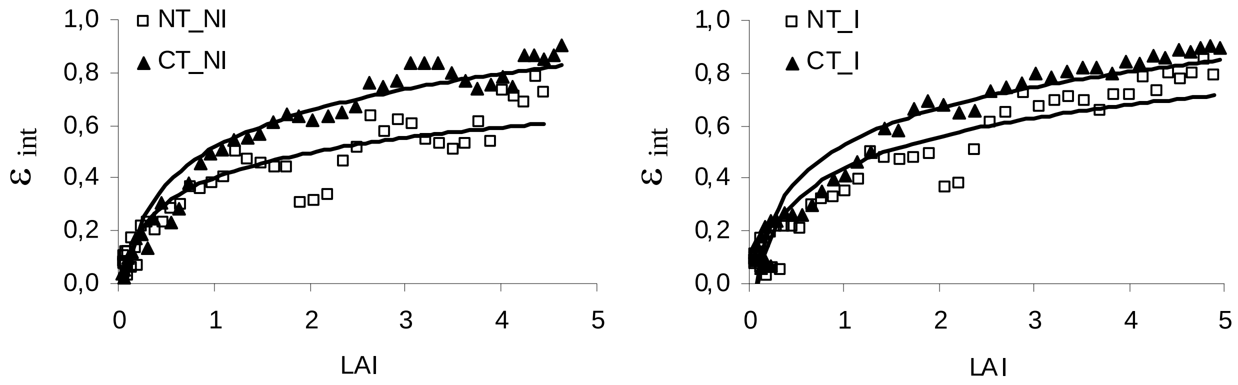


Figure 2. Efficiency of interception of PAR (ε_{int}) in maize crops submitted to no-tillage (NT) and conventional tillage (CT) systems, irrigated (I) and non-irrigated (NI). Eldorado do Sul, Brazil. 2002/2003.

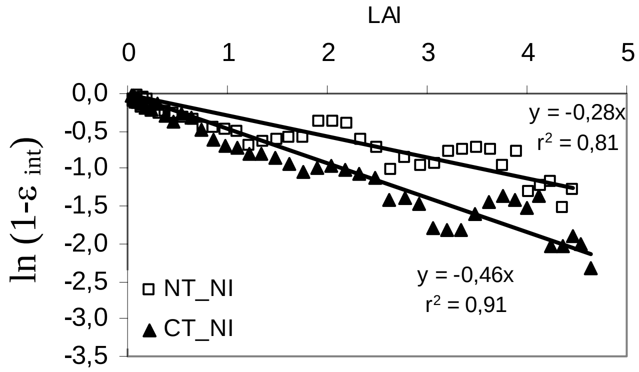
The interception of PAR by plants was more than twice in conventional tillage than in no-tillage system from its emergence to 25 days after that. It can be attributed to a higher availability of nitrogen to plants in the conventional system due to a faster mineralization of the incorporated organic matter in the soil, than in no-tillage. Since the straw of the winter mixture remained on the soil surface in the no-tillage system, there was a slow mineralization and availability of nitrogen to plants. Dreecer at al. (2000) observed a direct relation between the LAI and the N content in leaves, allowing to a highest interception of radiation, combined to high N content in leaves.

Differences in RFAint among the irrigation levels were lower when comparing to the tillage systems (Figure 2), which can be attributed to a favorable condition of water availability to plants at the beginning of the crop cycle, up to 40 days after its emergence. When the soil available water was reduced in non-irrigated plots, the effect of this treatment increased.

Plants cultivated in conventional tillage had a higher efficiency of PAR interception than in no-tillage, and this can be explained by alterations on the leaf inclination. Working with several maize hybrid, Maddoni & Otegui (1966) also observed variations on the efficiency of energy interception, for a same LAI, that was attributed to differences in the angle of leaf inclination.

The efficiency of PAR interception by the maize plants in conventional tillage reached to 1.0 and 0.9 when irrigated and non-irrigated, respectively. Considering the same irrigation treatments, maximum efficiency of PAR interception by plants at no-tillage sowing reached to 0.8 and 0.7. Therefore, the maize populations installed on no-tillage system should have a higher LAI than on conventional tillage in order to have the same PAR interception.

The results allow to conclude that maize crops sown on no-tillage system tend to present a more compact leaf architecture, with prevailing erect leaves, permitting a higher PAR transmission to soil surface if compared to those cultivated on conventional tillage. On the contrary, maize plants growing on conventional tillage tend to have an open leaf architecture, prevailing an horizontal shape on leaves, so taking a higher space into the canopy and intercepting a higher amount of PAR than in no-tillage system. This tendency appeared to be clear when analyzing the extinction coefficient for PAR, that was lower on crops sown in no-tillage systems than in conventional sowing system, irrespective the level of irrigation (Figure 3). The regression coefficients of each model in Figure 3 represent the extinction coefficients for PAR of the maize on each applied treatment. Varlet-Grancher et al. (1989) and Scott Green et al. (2003) showed a similar tendency when relating the angle of leaf inclination to the extinction coefficient. It may lead to cogitate, as an hypothesis, the convenience of increasing the plant population or reducing the row spacing in maize crops sown on no-tillage system, in order to compensate reductions on its extinction coefficient for PAR.



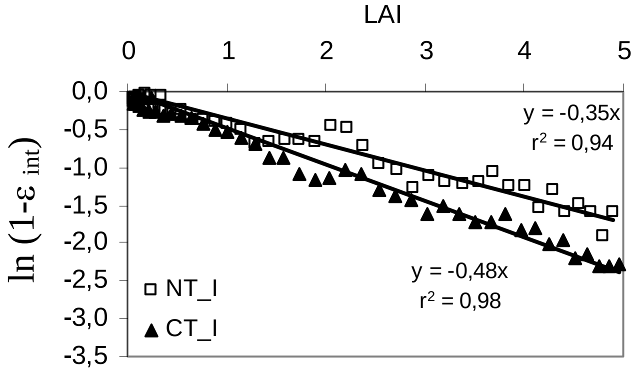


Figure 3. Relations between ln (1 - ε_{int}) and LAI in maize crops submitted to no-tillage (NT) and conventional tillage (CT) systems, irrigated (I) and non-irrigated (NI), in that ε_{int} is the efficiency of interception of PAR. Eldorado do Sul, Brazil. 2002/2003.

Conclusions

Considering the entire crop cycle, the interception of photosynthetically active radiation by the maize plants is higher when cultivated in conventional tillage than in no-tillage system. Water deficit reduces (PARint), irrespective of the tillage system. The efficiency of interception and the extinction coefficient for PAR are higher in maize crops cultivated on conventional tillage than on no-tillage system, irrespective of water supply.

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