# COMPARISON OF LEAF AREA OF SOYBEAN UNDER UNLIMITED WATERING AND RAIN-FED CONDITION

*Brigitta Simon*, Gábor Soós, Tamás Kucserka, Johanna Németh-Koczó, Angéla Anda*

*University of Pannonia, Georgikon Faculty, Department of Meteorology and Water Management*

*Festetics Str 7, Keszthely, H-8360 Hungary*

*simonbrigitta.georgikon@gmail.com

***Abstract***

Different methods have been used to measure leaf area of soybean (*Glycine max* L.). In this study, high resolution photos of soybean leaves were processed using a histogram-based threshold method. Leaf area was measured for soybean in the growing season of 2018 at the Agrometeorological Research Station, Keszthely, Hungary, in evapotranspirometers (unlimited watering) and on the field with natural water supply (rain-fed plots). The experiment was carried out with two varieties (*Sinara* and *Sigalia*). During the investigation period leaf area was measured weekly. The results showed that there was no significant difference in leaf area between the two varieties. Optimum water supply for *Sigalia* resulted in significantly higher leaf area compared to natural water supply.

**Key Words:** soybean, *Glycine max* L., leaf area, unlimited watering, natural water supply

## *Összefoglalás*

A szója (*Glycine max* L.) levélterületének mérésére különböző módszereket alkalmaznak. Vizsgálatunkban a szója leveleket fotóztuk, és hisztogram alapú szegmentálással dolgoztuk fel. A szója levélterületét 2018 tenyészidőszakában mértük a Keszthelyi Agrometeorológiai Kutatóállomáson, evapotranspirométerekben (korlátlan öntözés) és a természetes vízellátású szántóföldi körülmények között. A kísérletet két szójafajta bevonásával (*Sinara* és *Sigalia*) végeztük. A vizsgálati időszak alatt a levélterületet hetente mértük. Az eredmények azt mutatták, hogy a két fajta levélterülete között nem volt szignifikáns különbség. A *Sigalia* optimális vízellátása szignifikánsan magasabb levélterületet eredményezett a természetes vízellátású parcellán mért levélterületekhez képest.


**Kulcsszavak:** szója, *Glycine max* L., levélterület, korlátlan vízellátás, természetes vízellátás

## *Introduction*

Soybean yield is highly dependent on weather conditions (Sentelhas et al., 2015). Most of the Hungarian soybean crops are grown under rain-fed conditions. Based on previous observations, the local effects of climate change are increasingly detectable. Additionally, worldwide crop productivity under rain-fed conditions will need to be enhanced to meet increasingly growing demand for food (Bhatia et al., 2008).

Gas exchange processes (mainly $CO_2$ and water vapour) between the atmosphere and the canopy occur through the leaves. From the size of the leaf area the crop biomass and final yield of the plant can be deduced (Kross et al., 2015). However, there are many environmental factors affecting the leaf area and yield, especially the available water and air temperature.

Climate change gives a high importance of local leaf area measurements for monitoring crop growth conditions on the fields (Canisius et al., 2010; Liu et al., 2010a). The leaf area can be directly or indirectly measured by several methods (Gower et al. 1999; White et al. 2000, Asner et al. 2000), using either a leaf area meter or a specific relationship of dimension to area via a shape coefficient (Grace, 1987; Barclay, 1998; Sellin, 2000). Using high-resolution digital cameras and image processing software are a relatively new method of determining leaf area.

In this study, the temporal dynamics of leaf area during the growing season of 2018 were measured in two soybean varieties (*Sinara* and *Sigalia*) of two different water supply levels (unlimited watering and rain-fed plots).

## *Materials and Methods*

Experiments were conducted at the Agrometeorological Research Station, Keszthely, Hungary in the growing season of 2018. The study was carried out in evapotranspirometers (unlimited watering plots) and under field conditions (rain-fed plots). Prior to planting, 150 kg NPK $ha^{-1}$ was applied during early spring. The two varieties of indeterminate soybeans (*Sinara* and *Sigalia*) were planted with 24 cm row spacing on 26 April 2018. Leaf area was weekly estimated from leaves taken from 10-10 plants in the two water supplies and two varieties.

Direct methods can provide reasonable estimates of leaf area. Digital photography is a popular, affordable and easy to use tool, which can be used to obtain field information. Proving the efficiency of digital photo analysis, Liu and Pattey (2010a) determined leaf area indexes (*LAI*) with a Li-Cor LAI-2000 Plant Canopy Analyser and vertical gap fractions derived from digital photographs, and they found a strong logarithmic relationship between the two methods ($R^2$ = 0.84).

In the study a digital camera (Canon EOS 7D) was used. Colour photos were weekly taken *in situ* on the study site from above the soybean leaves looking downward vertically. The leaves were placed in front of a red cardboard, then photographed, from a distance of approximately 0.2 m above the leaves, using automatic exposure and maximum resolution (Figure 1).

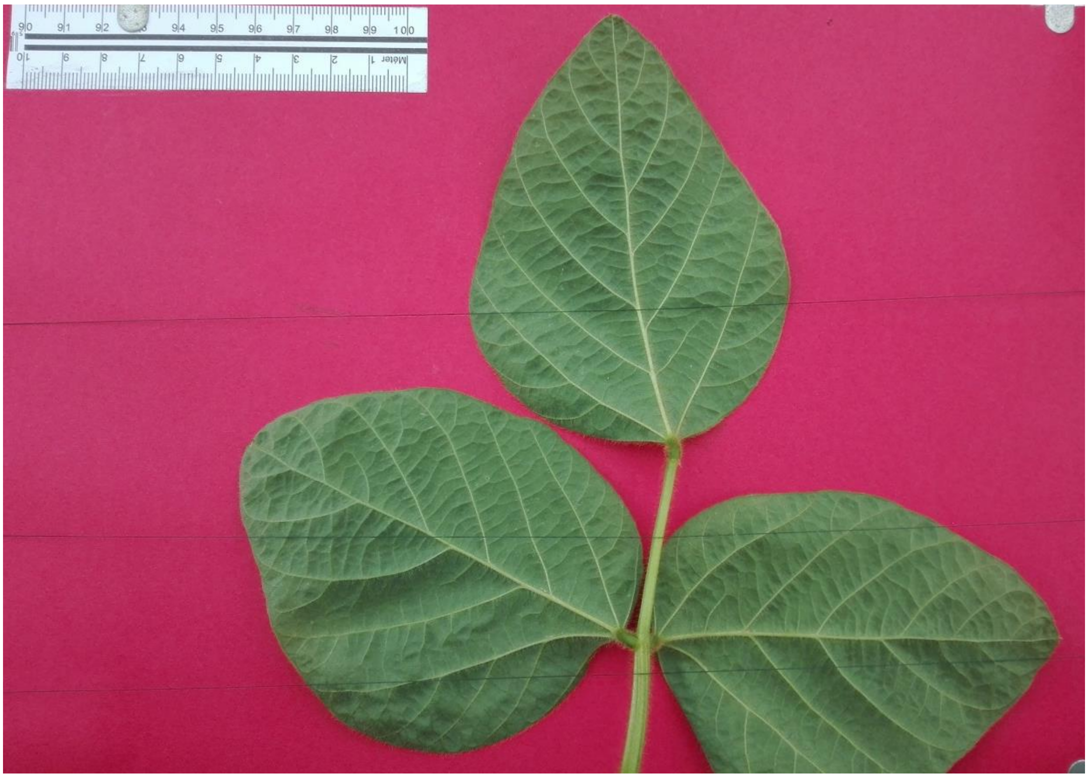

*Figure 1. A soybean trifoliate on a red cardboard*

The colour images were recorded in .jpeg formats. Each pixel of a photo consists of three digital numbers which are light intensity quantized in the red, green and blue bands. The photos were processed using a histogram-based threshold method to separate the green leaves from the red cardboard, using the SGDIP 0.1 program (Soós, 2010). The great advantage of the method is that the digital camera is an affordable way to acquire field information, furthermore the recorded images can be stored for later reviews (Liu and Pattey, 2010b).

***Results and Discussion***

Weekly mean leaf area in the growing season of 2018 (Figure 2) ranged from 168.2 ± 33.2 $cm^2$ (June 1, *Sigalia*) to 1955.35 ± 152.3 $cm^2$ (July 20, *Sinara*) in evapotranspirometers. *Sinara* has a higher leaf area like a tendency, although there was no significant difference between the two varieties (p=0.804).

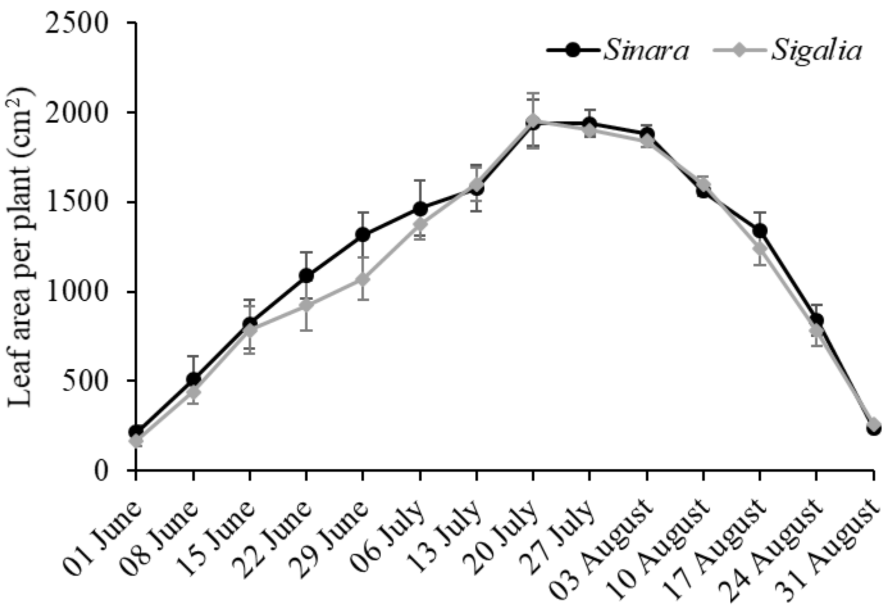


*Figure 2. The weekly variation in leaf area of varieties Sinara and Sigalia using unlimited watering plots in the growing season of 2018*

The weekly leaf area averages were also similar to that of obtained results for rain-fed plots (Figure 3). In the beginning, the two varieties of leaf area did not differ, but after June 29th the leaf area measured at *Sigalia* were lower. Overall, there was no difference between the leaf area developments of *Sinara* and *Sigalia* during the growing season (p=0.590).

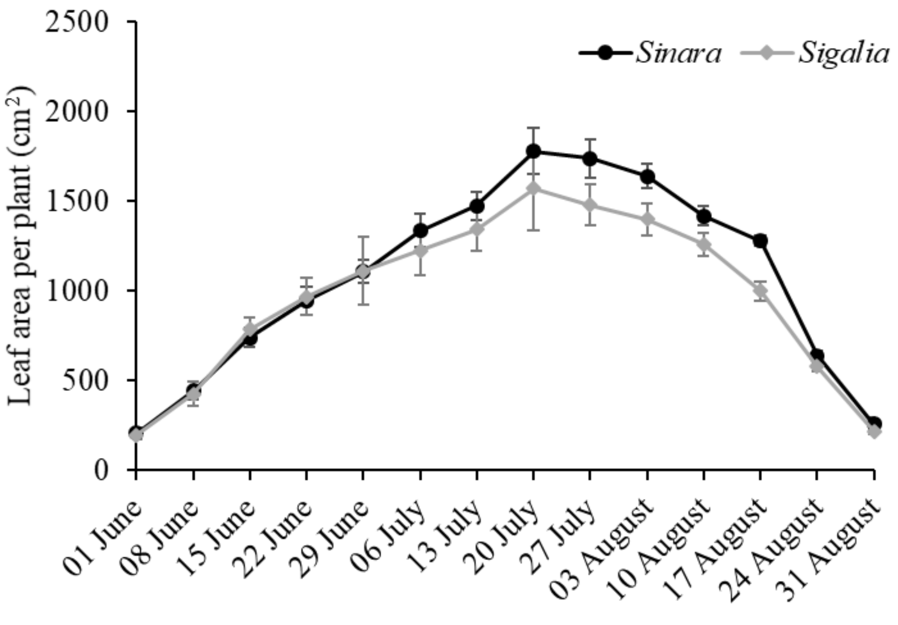


*Figure 3. The weekly variation in leaf area of varieties Sinara and Sigalia using rain-fed plots in the growing season of 2018*

When comparing the water supplies, it can be observed that for both varieties, there were larger leaf areas for unlimited watering plots than for rainfed crops. Higher maximums of leaf area, by 8.4% (p=0.572) for *Sinara* and by 19.6% (p=0.001) for *Sigalia* were measured, but the difference was only significant for *Sigalia*. In conclusion *Sigalia* - compared to *Sinara* - responds better to the changes in water supply.

Many studies deal with the exact exploration of the plant-water relationship, so there are many different results in the literature regarding soybean. Viña et al. (2011) measured 45.5% higher maximum leaf area in irrigated soybean than in natural water supply plants. In the experiment of Suker and Verma (2012) peak LAI varied from 4.4 to 5.6 $m^2$ $m^{-2}$ in irrigated soybean, and for rain-fed soybean from 3.2 to 4.6 $m^2$ $m^{-2}$. The results of Karam et al. (2005) showed, that irrigation during R5 and R7 stages of plant growth had no effect on the leaf area patterns. The low crop growth rate at the previously mentioned stages can be caused by the high carbon and nitrogen translocation rates from the leaves to the seeds (Zeiher et al., 1982, De Souza et al., 1997).


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