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RESULTS OF SOIL MICROCLIMATE RESEARCH IN FORESTRY INTERCROPPING SYSTEMS IN HUNGARY

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ABSTRACT

A special form of alley cropping system is the intercropping of forest, which is traditional and still used nowadays worldwide in afforestation. In Hungary this practice is used mostly on the non-protected areas of the Great Hungarian Plain. The aim of this study was to examine the extent to which intercropping modifies the development of seedlings compared to the current practice of reforestation. Measurements and observations have been proceeded in two trial sites: Hajdúhadház and Kapuvár, and in both cases, control areas were also designated, close to the trial site, with similar parameters. The experimental areas have different ecological features, but in both cases intermediate cultivation has been applied. The Hajdúhadház experimental area was established in 2015 and measurements were carried out until 2017, while in Kapuvár, the experiment started in 2019. At both sites, soil temperature, conductivity and growth parameter measurements were performed. The two examined areas are different regarding to tree species and plantation structure, but the main purposes of both forestry companies were to maximize the utilization of available space, protect seedlings and ensure the success of afforestation. The research results so far show that soil microclimate is more favourable in the intercropping system, which contributes to the better development of seedlings. By using maize as an intercrop in the alleys, fodder production for animal stock and game management was also feasible. Further investigations on yield and microclimate are planned in the area of Kapuvár Forest Office in the next three years.
Keywords*:* agroforestry, alley cropping, afforestation, maize, microclimate

INTRODUCTION

A special form of intercropping is still applied in artificial reforestations on non-protected forest areas in the Great Hungarian Plain and all over the world. (*Chamshama et al.*, 1992; *Kang et al.*, 1995; *Watson*, 2014; *Fan et al.*, 2006; *Haggar et al.*, 2003; *Muwamba et al.*, 2015; *Gichuru and Kang*, 1989; *Helton et al.*, 2010) As documented in Debrecen's municipality records dating back to the 1820's, forestry intercropping systems have a long history in sandy soil areas in eastern Hungary. (*Miklós*, 1974) These systems had a main purpose that afforestation was implemented at very low prices by poverty-stricken peasantry. They planted agricultural and horticultural plants between rows with the aim to ensure the cost of living. (*Balogh*, 1936) As these systems had lost their initial aim by now, thus the lifestyle ended even though the practice is pursued to apply in initial years of afforestation. According to observation, the forestry alley cropping systems would have a prosperous future. The experience shows the intercropping can improves the efficiency of artificial afforestation and allows maximum use of limited space. We carried out measurements in areas of two forestry companies to verify observations and provide scientific evidence of the success of young forest intercropping systems. This study addresses measurements and observations performed in two trial sites: Hajdúhadház in eastern Hungary and Kapuvár in north-western Hungary. Control areas with similar parameters were designated near the trial sites in both locations.

MATERIALS AND METHODS

Initial data for the systems under investigation

The microclimate experiment was extended to two surveying plots. The first plot is located in the area of Hajdúhadház Forestry Office of Nyírerdő Forestry Co. (eastern part of Hungary) (*Vityi et al.*, 2016), the other plot is in the area of Kapuvári Forestry Office of Kisalföld Forestry Co. (north-western part of Hungary). The effects of intercropping was surveyed in a variety of stands where the tree species and plantation structures were different (*Table 1* and *Table 2*), but the objectives of forestry companies operating in both locations are essentially the same: utilizing available space, protecting seedlings and ensuring successful afforestation. In both areas, using maize as intercrop in alleys made fodder production for animal stock and game management feasible. Control and agroforestry sites close to each other and of similar site conditions were involved in the experiment in both cases

Table 1

Basic data of the experimental areas in Hajdúhadház

	Alley cropping system	**Control**
Area	0,66 ha	4,0 ha
Plant	Oak (*Quercus robur*) and corn (*Zea mays*)	Oak (*Quercus robur*)
Row spacing (cm)	90-70-90	250
Orientation of row	North-south	North-south
Irrigation	No	No
Physical characteristics of soil	Sandy soil with humus	Sandy soil with humus
Period	3 years	-

Table 2

Basic data of the experimental areas in Kapuvár

	Alley cropping system	**Control**
Area	5,13 ha	4,24 ha
Plant	Poplar (I-214)(*Populus euramericana* cv.) and maize (*Zea mays*)	poplar (I-214)(*Populus euramericana* cv.)
Row spacing (cm)	~90 -75-75-75- ~90	400
Orientation of row	Northwestern-southeastern	Northwestern-southeastern
Irrigation	-	-
Period	1 year	

Measurements in Plot 1: Hajdúhadház

Based on the monitoring results of the first year (2015), an initial research plan was developed for the following year, focusing on the measurement of soil temperature and soil conductivity as well as the development of plant biomass. (*Table 3*) Parameters of soil microclimate were measured for one month, in the statistically driest and hottest period of summer which is a critical and stressful period of the year for the plants. Based on soil conductivity, comparison of soil moisture in the two areas is feasible, due to a strong correlation between the soil's electrical conductivity and the soil moisture content. (*Nagy*, 2014) Soil parameters of the sites at Hajdúhadház were tested in two sampling points per area in 2016.

Sampling points were designated to have the same site conditions, thus ensuring the comparability of the samples. Due to its sloping terrain, the control area has tendency to soil erosion and leaching, thus sampling points were selected lowland, in a more fertile part of the area with similar site conditions of alley cropping. Also the distance between two sampling points, and thus covering of the sampled area, was equal.

In order to increase the reliability of the results, the number of soil sampling points were raised to 17 in each plot equally distributed in 2017. The height of seedling was measured once by measuring tape. (*Table 3*)

Table 3

Measured parameters of the experimental plots in Hajdúhadház (August 2016, 2017)

Examined parameter	Soil temperature	Soil conductivity	Growth parameter
Period	01. Aug. - 02. Sept.	01. Aug. - 02. Sept.	02. Sept.
Data collection	systematic sampling design technique		systematic sampling design technique with random starting point
Sampling points	2 points/plot (2016) 17 points/plot (2017)		5×10 meters/plot
Test method and equipment	Soil temperature and conductivity meter (Hanna HI 98331)		Height measurement with measuring tape

Measurements in Plot 2: Kapuvár

Measurements were carried out every second day during August and September. We focused on soil temperature and conductivity at two different depths (on the surface and 10 cm below surface). The survey was more complex compared to the one carried out at Hajdúhadház, as it included air humidity and temperature testing in three different heights. In addition, three different features of seedlings were recorded (diameter at the base (Db), diameter at breast height (DBH) and height of trees (H)).

Table 4

Measured parameters of the experimental plots in Kapuvár (August, September 2019)

Examined parameter	Soil temperature	Soil conductivity	Growth parameter	Air humidity and temperature
Period	Aug. 01-Sept. 30.	Aug. 01-Sept. 30.	Aug. 05.-Sept 25.	Aug. 01-Sept. 30.
Sampling points	5 horizontal and vertical segments/plot 10 points/segment (2019)		10 trees/plot 2 trees/segment (2019)	5 vertical segments/plot 3 points/vertical segment (2019)
Data collection	Systematic sampling design technique		Once per month, systematic sampling design technique	Systematic sampling design, stratified sampling procedure
Test method and equipment	Soil temperature and conductivity meter (Hanna HI 98331)		Height measurement with measuring tape	Air humidity sensor

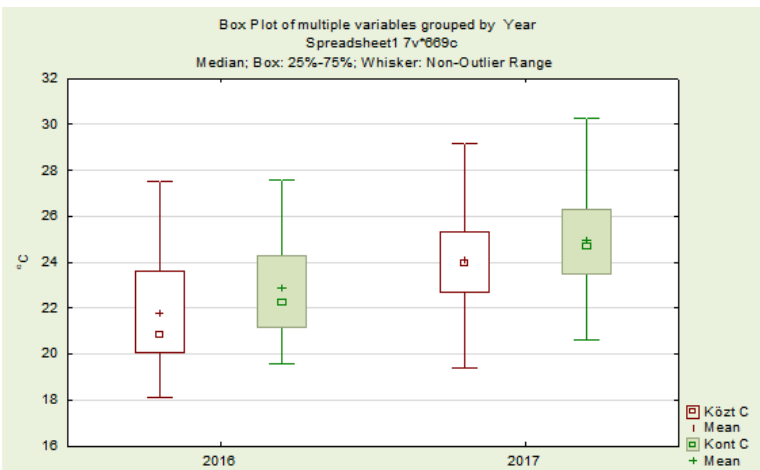
RESULTS

Plot 1: Hajdúhadház

The results show that the daily average soil temperature data in the agroforestry (AF) plot were below the soil temperature mean values of the control plot, which indicated a moderated soil microclimate in the intercropping system. (*Figure 1*)

Figure 1

The change of daily average of soil temperature in Hajdúhadház (August 2016, 2017)



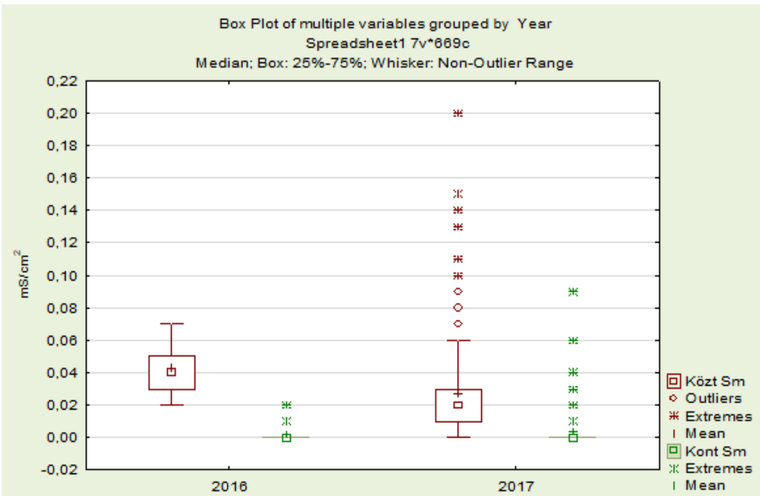
Közt C: agroforestry system; Kont C: control system)

In the average daily soil temperature there was a difference of about 0.2-2.0 ° C between the AF and the control plots, which influenced the evaporation intensity and the growth of the plants. Based on the results under the same soil conditions, we can infer that due to the presence of the intercrop, the soil moisture conditions of the two systems were different.

The conductivity values of the soil in comparison with the distribution of precipitation show massive correlation, but in the intercropping system the soil conductivity exceeded the values of the control plot in concluding that the agroforestry parcel had more favourable soil moisture values during the drought period. (*Figure 2*)

Figure 2

The change of daily average of soil conductivity (August 2016, 2017)



Közt C: agroforestry system; Kont C: control system)

The assessment involves developing parameters of sampling trees. The survival rate of seedlings shows that there is a significant difference between the agroforestry and the control systems. In 2015 the mortality rate was 50% in the control plot, requiring double plant replacement, on the contrary in the agroforestry parcel no drought damages were recorded (both systems are non-irrigated). Additionally, in the following years, the trees in the intercropping plot showed significantly better growing in height, 18 cm on average (2016) and 21 cm difference (2017) compared to the control parcel. ($t<0,05$; $p=0,0023$)

Plot 2: Kapuvár

The results are under processing, but the observations at the agroforestry site is overly positive if the two areas are compared. The values of temperature and air humidity measured during August and September were more balanced in the intercropping area (2019).

EVALUATION OF THE TEST RESULTS, CONCLUSIONS

Based on the results, the water balance of agroforestry system proved to be better than the control area in the examined drought periods. Significant difference was found between the data of the two afforested parcels in terms of soil microclimate. The daily mean temperatures of the forest intercropping area in the arid period were significantly lower than the values of the control area. The more favourable microclimate resulted in a significantly stronger growth of alley cropping area. There was no noticeable drought damage in the agroforestry experimental field and the growth parameters of the plants were more favourable, so it can be concluded that in the cultivation system associated with maize the development of the stand was more prosperous in all respects.

Based on our experience and measurements, application of intercropping can significantly increase the efficiency of (artificial) afforestation, reduce the drought damage, and improve the survival and growth parameters of seedlings. By maximising the utilisation of the available area to serve other purposes (production, ecosystem services), the afforestation may be coupled with resource efficiency and economic returns.

Further investigations on yields and microclimate are planned in the Kapuvár Forest Company area in the next three years.

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