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SIAKWAH GIDEON NARTEH

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MAGYAR AGRÁR- ÉS
ÉLETTUDOMÁNYI EGYETEM

Hungarian University of Agriculture and Life Sciences

Szent István Campus

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EFFECT OF IRRADIANCE ON THE DEVELOPMENT OF INTERCROPS IN AN AGROFORESTRY SYSTEM

Primary supervisor:	Mihaly Jancso scientific researcher
Author:	**Siakwah Gideon Narteh** IPKE4G
Institute:	Institute of Genetics and Biotechnology Department of Plant Biotechnology

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TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The world population is increasing at an exponential rate which needs to be fed by the land that never increases. Humans have been trying for centuries to find ways to increase production to feed the ever-growing population of the world.

Various techniques have been employed in recent years to modify plants in terms of their growth habit, water requirement, rate of light absorption, as well as their climatic requirement. In whichever way plants have been modified, the production of crops on large scale requires a large area of land for such cultivation.

These crops usually have to compete with forest trees, animals, human settlements as well as other important land uses. Sustainable agriculture is one of the best ways to increase crop production on a never-growing land.

A system that integrates plant and animal production in relation to site-specific production and will ultimately meet human demand for food and other agricultural products is known as sustainable agriculture (Bene *et al* 1977).

In order to ensure forest trees and cultivated crops coexist in an array system, as is typically done in Europe and America, and in a random mixture, as is typically done in Africa's forested areas, agroforestry is one of the sustainable land use methods. This ensures that cultivated crops, animals, and soil living organisms benefit greatly from these forest trees, from organic matter fixation to soil moisture conservation.

In the world, maize is frequently grown in monoculture on huge land areas. Most of the two-season African nations harvest maize during the monsoon since the crop cannot continue to grow if the nighttime temperature falls below 15.6°C or 60°F. This makes up around 85% of the entire area planted in maize. All stages of the growth cycle of maize are sensitive to frost, with the exception of dried seed. (Miedema 1982). It needs 60 cm of rain each year that is uniformly distributed throughout the growing season for maize to flourish. During 30 to 35 days after tasseling, corn requires more than 50% of its total water requirements. A lower yield with shriveled kernels is the result of insufficient soil moisture during grain filling.

Maize needs bright sunny days for its accelerated photosynthetic activity and rapid growth of plants. Long periods of cloud cover are bad for the maize crop, but it's thought that periods of sunshine and clouds with rain are best for maize growth.

Though maize can be cultivated on a variety of soils, deep fertile soils that are rich in organic matter and well-drained are preferable. Maize grows well on medium-textured soils with good water-holding capacity. The optimal soil types needed for maize growth are loam or silt loam surface soil as well as brown silt clay loam with fairly permeable sub soil because the crop is particularly susceptible to flooding or water logging. The required pH range is between 6.5 and 7.5, combined with a base saturation range of 70% to 90%, a bulk density of 1.3 g/cc, and a water retention capacity of roughly 16 cm per meter of depth (Esilfi 2017). Due to maize's need for sunlight, most farmers, particularly in Africa, choose to clear forest areas before cultivating the crop, which does not result in sustainable agriculture output but rather in deforestation and its adverse impacts on the global climate.

In the quest to solve the aforementioned problems, different researchers all over the world have been employing different agroforestry methods to incorporate crops into the growing of important forest trees.

1.2 Problem Statement

Agroforestry system trees have an impact on microclimate stability (Hartemink 2005). These trees may shield crops from water stress throughout the drier parts of the season because it has been demonstrated that they can protect relative humidity, soil moisture, and temperature (Lin et al. 2008; Verchot et al. 2007). It is often difficult to discuss how these trees affect agricultural crops (Somarriba and Beer 2011; Tscharntke et al. 2011), as it is not yet clear which characteristics, and which individual shade trees promote or inhibit the growth and yields of agricultural crops. Trees used in agroforestry system influences microclimatic stability (Hartemink 2005). These trees may shield crops from water stress throughout the drier parts of the season because it has been demonstrated that they can protect relative humidity, soil moisture, and temperature (Lin et al. 2008; Verchot et al. 2007). It is often difficult to discuss how these trees affect agricultural crops (Somarriba and Beer 2011; Tscharntke et al. 2011), as it is not yet clear which characteristics, and which individual shade trees promote or inhibit the growth and yields of agricultural crops. According to studies (Lin et al. 2008; Verchot et al. 2007), these trees have the capacity to protect relative humidity, soil moisture, and temperature, which may shield crops from water stress during drier seasons. Although it is not yet clear in which aspects and which individual shade trees support or hinder arable crop growth and yields, the effects of these trees on arable crops are frequently addressed with difficulty (Somarriba and Beer 2011; Tscharntke et al. 2011).

One of the main causes of deforestation and forest degradation in West Africa over the past few decades has been attributed to the rapid spread of extensive maize growing systems that are characterized by no-shade maize farming. Precipitation and ground water levels are recently becoming issues of concern. The opportunity exists for this trend to be reversed using shade grown maize.

1.3 Objectives of the Study

1.3.1 Main objectives

The aim of this study was to assess the influence of poplar (*Populus alba*) tree on yield performance of maize (*Zea mays L.*) in the Bekes County of Hungary.

1.3.2 Specific Objectives

Specifically, the study seeks to.

1. Evaluate the effect of light absorption performance of poplar (*Populus alba) tree* on maize crop.

2. Assess the yield effect of different distances between poplar (*Populus alba)* tree and maize.

1.4 Significance of the study

1. The study will help farmers understand the effects of tree species like poplar (*Populus alba)* on their maize farm.
2. The study will also help farmers to select the right variety of maize to grow in an agroforestry system.

1.5 Limitation

1. The study was limited to a particular part of the of the country, which the results might be different from other parts of the country.
2. Time and cost were other limitations in the study.

3. The study excluded other tree species such as *Moringa oleifera, Entandophragma anglense, Grevillea robusta*, and other species which may have different influence on light interception and yield of maize.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Maize

According to legend, 7000 years ago, a wild grass in central Mexico gave rise to *Zea mays*, also referred to as maize or corn. Maize was enhanced by Native Americans to become a more nutrient-dense food source. The top three growers account for more than 563 of the 717 million metric tons of annual production of maize that is grown worldwide. On 139 million acres, the world currently produces 594 million tons of grain (FAOSTAT 2000). Maize has an energy density of 365 Kcal/100g and approximately 72% carbohydrate, 10% protein, and 4% fat. Domesticated maize was created through human selection, will, and cultivation of naturally occurring recombinants between two wild grasses with specific features. These traits were desired by humans as food. The simple flowering spike of the wild ancestors of maize is thought to have been transformed into the fruitful grain-bearing ear after a few generations of intergenomic recombination between teosinte and Tripsacum (Eubanks 2001).

2.2 Botany of maize

The corn plant is an upright, tall annual grass with robust stems. Large, narrow leaves with wavy margins alternately cover the opposing sides of the stem. Staminate (male) flowers are produced on the tassel that completes the stem's main axis. Each row of paired spikelets in the pistillate (female) inflorescences is usually followed by two rows of grain; these spikes have larger axes and bear paired spikelets in longitudinal rows. The edible ears develop when these spikes reach maturity. The most popular corn kinds are yellow and white, despite the fact that some have red, blue, pink, or black kernels that are commonly banded, speckled, or striped. Each ear is covered by modified leaves called shucks or husks.

2.3 Climate Requirement of maize

The crop is grown in temperate to tropical areas when the mean daily temperature is over 15°C and there are no frosts. The ability of species to adjust to varied environments varies substantially. When mean daily temperatures surpass 20°C, early grain varieties mature in 80 to 110 days and medium varieties in 110 to 140 days. When grown as a vegetable, certain varieties mature in 15 to 20 fewer days. Depending on the kind, every 0.5°C drop in mean daily temperatures below 20°C causes the days to maturity to rise by 10 to 20 days. The maize grain crop takes 200 to 300 days to mature at 1.5 °C. Most maize is grown as a fodder crop in areas with mean daily temperatures between 10 and 15 °C. 18 to 20°C is the optimal range for germination, with 10°C as the lowest mean daily temperature. According to FAO (2000), the crop can tolerate hot, dry weather as long as the plant has access to enough water and the temperature is under 45°C. However, the crop is particularly vulnerable to cold, especially when it is in the seedling stage.

2.4 Trend of maize production in Hungary

One of the most prominent crops in Hungary is maize, which also plays a large part in the cereal industry. In 2020, the production areas for both wheat and maize were essentially the same (22%). These two are the most important arable crops by a wide margin. Rapeseed and different fodder crops are classified in a different category representing (42%), with sunflower representing around half (14%) of the two cereals. The area used for maize cultivation makes up 21-29% of all the arable land in Hungary used for cereal production; this percentage is identical to that of wheat. Over the past 11 years, the average yield has dramatically increased in terms of production, rising by 33.23%. (HCSO, 2021a). The good weather is one of the most significant factors in this value. Contrarily, conditions like droughts led to a large reduction in yield. Negative weather patterns in 2012, which included drought and unusually warm temperatures, resulted in a significant crop loss. It is important to take into account the possibility of a considerable yield loss due to the decline in groundwater. It is conceivable that in the near future, even the best production record will be surpassed in Hungary thanks to the adoption of more effective seeds, advanced farming techniques, and fertilizer use.

2.5 Importance of maize to the Economy

As one of the main grains, maize is consumed in the majority of African nations and is used as animal feed in Europe, America, and other continents. In Hungary, corn is consumed directly as food when boiled in its natural state or after being industrially processed to make sugar, maize flour, canned corn, etc. In addition to being used in animal breeding, maize is also used in the production of distiller's grains and ethanol, which both produce soluble as a byproduct (Mizik and Rádai 2021). In addition to being significant agronomic value, maize has long served as a foundational model organism for fundamental science. The genetic system of maize has received the greatest attention among grain species. Because of its traits, such as a huge number of mutant stocks, large heterochromatic chromosomes, significant nucleotide diversity, and genic collinearity within grass families, the maize plant is a focus for genetic, cytogenetic, and genomic research. A few of the extensive biological research that employ maize as a model organism include those on plant domestication, genome evolution, developmental physiology, epigenetics, pest resistance, heterosis, quantitative inheritance, and comparative genomics (Strable and Scanlon 2009). Corn has recently been used to manage cadmium-contaminated soils by phytoremediation because of its high biomass output and cadmium accumulation.

2.6 Concept of Agroforestry

While efforts were made to define agroforestry in the middle of the 1970s, these efforts swiftly evolved as study on the variety and breadth of agroforestry approaches started. American economic geographer J. Russell Smith first provided a comprehensive definition of agroforestry in his book Tree Crops: A Permanent Agriculture at the turn of the 20th century. According to one definition, agroforestry is a dynamic, environmentally conscious system for managing natural resources that diversifies and sustains output for greater social, economic, and environmental gains (Leakey 1996; ICRAF 2007).

In the late 1970s and early 1980s, there were too many definitions and a general lack of understanding owing to ignorance, which hurt the future of agroforestry. A conceptual framework for studying complex practices and systems has been established as a result of the earlier struggles to condense a large new field of research. The foundation for the study of agroforestry is outlined, at least in an early definition. Agroforestry is therefore described as a sustainable system of land management that boosts overall production, integrates agricultural crops with forest plants and/or animals either simultaneously or sequentially, and uses land management techniques in line with the cultural patterns of the local population (Bene et al., 1977). The following definitions of the art and science of agroforestry may be deemed the most acceptable, despite the fact that there have been numerous attempts to do so: Agroforestry is the intentional planting of trees or other woody perennials in crop or animal production fields in order to profit from the ensuing ecological and economic interactions (Nair, 2007). Despite the limitations of the aforementioned definitions, the following crucial concepts can be inferred from them: The use of native, multipurpose trees and shrubs is prioritized in agroforestry, which is a distinctive land-use strategy that protects the resource base, is particularly well-suited to low input situations and fragile environments, involves the interaction of socio-cultural values more than most other land-use strategies, and is structurally and functionally sound. Despite this, ICRAF has been defining agroforestry when new research results are found. The term "agroforestry" is no longer a "new term," as it is sometimes described as "a new label for an ancient technique" in the 1996 definition of the term published by ICRAF. Agroforestry increases social, economic, and environmental advantages for land users at all levels by diversifying and sustaining productivity on farms and in agricultural landscapes. According to Gold and Garrett (2009), agroforestry is a sort of intensive land-use management that maximizes the benefits (physical, biological, economic, and social) from biophysical interactions caused when trees and/or shrubs are intentionally integrated with crops and/or livestock. It is now widely acknowledged as a type of land use that involves purposefully fusing trees with either crops or animals.

2.7 Agroforestry systems

Farms may consciously plant trees or maintain them there to enhance, diversify, and sustain productivity for better social, economic, and environmental advantages. Agroforestry is the name of this practice. An agroforestry system can be categorized according to its ecological compatibility, levels of management input, function of woody perennials, and vegetation structure. Agroforestry approaches, rather than systems, are used as the analytical unit in an ecological classification that is based on the role of trees in agricultural landscapes (Atangana et al 2014). There are numerous varieties of agroforestry systems that can vary slightly between ecological regions. The Food and Agriculture Organization's agroforestry systems are among the most commonly discussed ones (FAO 2021).

Home gardens and alley cropping are examples of agrisilvicultural systems that mix crops and trees. Domesticated animals are grazed on pastures, rangelands, or on-farm while forestry is mixed in silvopastoral systems.

In what are known as agrosylvopastoral systems, the three elements — trees, animals, and crops — can be mixed; examples include animal-filled home gardens and strewn trees on croplands used for grazing after harvests (FAO 2021). Over the world, various agroforestry systems have been created. They can first be divided into agrosilvicultural systems based on the primary management components of those systems: annual plants, trees, and crops; Silvopastoral systems: Animals and trees in a pasture or cut fodder; Trees, crops, pasture / cut fodder, and animals make up agrosilvopastoral systems; According to the United States Department of Agriculture (USDA 2014), a management method must normally meet all four "i"s: intentional, intensive, integrated, and interactive, in order to be referred to as agroforestry. Windbreaks, riparian forest buffers, alley cropping, silvopasture, and forest farming were the five agroforestry systems that the USDA divided into. Alley cropping is the practice of growing crops in between rows of trees to generate income as the trees ripen. The system can be set up to generate a variety of products, including cereals, flowers, herbs, fruits, vegetables, feedstock for bioenergy, and grains. When the trees and crops are not in clearly defined rows and alleys, this type of system may also be referred to as intercropping. In addition to other products, culinary, medicinal, botanical, or ornamental crops are grown in forest farming operations under a forest canopy that is managed to provide the right amount of shade. Forest farming is often referred to as multi-story cropping. Silvopasture combines trees with animals and forage on a single piece of land. The trees reduce the stress on the animals from the sweltering summer sun, bitter winter winds, or a downpour by offering shade and protection for cattle and their forages, as well as lumber, fruit, feed, or nuts. Linear agroforestry practices were used to characterize the other two.

Riparian forest buffers are natural or restored areas with trees, shrubs, and grasses along rivers and streams. These buffers can help filter farm runoff and fortify the banks of streams, rivers, lakes, and ponds to stop erosion. These websites not only help animals, but they can also make money. Windbreaks shield crops, animals, structures, and soil from wind, snow, dust, and scents. These websites not only help animals, but they can also make money. They are also known as vegetated environmental buffers, shelterbelts, hedgerows, and living snow fences.

2.8 Trees used in Agroforestry Systems

2.8.1 *Moringa oleifera*

Tropical fast-growing trees like the moringa can reach heights of up to 15 meters. The immature pods are edible, and the leaves are a fantastic source of protein, calcium, vitamins, and minerals. The tree's crown is loose, and it can be utilized as a windbreak, a living fence, or a hedge. Northwestern India is home to the Moringa tree, sometimes referred to as the Horseradish Tree. But moringa is also widely grown in other tropical regions of the old and new worlds, such as tropical Asia, various parts of Africa, Indonesia, and South and Central America.

2.8.2 *Acacia colei, A. elecantha, A. torulosa, A. tumida*

The majority of edible acacia seed species are found in Australia's northern semi-arid regions and range in size from small, single-stemmed bushes to big, multi-stemmed trees. Numerous species of Edible Acacia have been successfully introduced into semi-arid areas of Africa including Niger and Senegal.

2.8.3 *Acacia mangium*

Australia, Indonesia, and Papua New Guinea are the original home of *Acacia mangium*. It is a low-elevation tree species found near the edges of rainforests and in disturbed, acidic soils with good drainage. One of the most common fast-growing leguminous plants utilized in plantation forestry initiatives across Asia and the Pacific is *Acacia mangium*. It regenerates quickly and fixes nitrogen. It starts out growing swiftly and can eventually reach a height of 30 meters (100 feet) with a diameter of more than 60 cm (24 inches). It naturally occurs close to mangrove stand limits, at the confluence of rivers, woodlands, and grasslands, as well as in recently disturbed ecosystems, particularly those damaged by fire.

2.8.4 *Grevillea robusta*

Australia's southern and eastern forested regions are home to the *Grevillea robusta* plant commonly known as silk oak. It is now widely grown in Niger and other Sahel countries of West Africa, as well as in India and Eastern Africa. The species can withstand six months of dryness and is semi-deciduous in its natural habitat, losing the majority of its leaves during the dry season. Medium to large in size, Grevillea robusta grows to a height of 12 to 40 meters (40 to 130 feet), with dense branches extending upward.

2.8.5 *Calliandra calothyrsus*

Calliandra is a robust, nitrogen-fixing, bushy tree that may develop quickly in unfavorable soil conditions. The tree takes coppicing well, makes good fuelwood, and the leaves make great feed. Calliandra is used to stabilize steep slopes and enhance the soil.

2.8.6 Poplar

In the willow family (Salicaceae), the genus Populus contains about 35 species of trees that are indigenous to the Northern Hemisphere. The cottonwoods, aspens, and balsam poplars are the three broad categories into which the native poplar species of North America are grouped. The leaves have fine to coarsely serrated margins and an alternating, oval or heart-shaped form (leaf edges). Because of their flat petioles, the leaves typically shake in the wind (leaf stalks).

2.8.7 *America.Entandrophragma angolense*

Entandrophragma angolense belongs to the Meliaceae family. It is a big deciduous tree with extensive roots (Hawthorne, et al 2006). With a girth of almost 4.6 m above buttresses, it is one of the emerging trees in the high forest. Compared to other Entandrophragma species, the stem is typically not as straight. The deciduous season lasts from roughly mid-September to late November, though some trees begin to lose their leaves in August (Hall et al. 2004). Fresh leaf flushing and flowering begin in December and remain until February, however, some flowering can be seen after this period (Hawthorne, et al 2006; Hall et al. 2004).

2.8.8 *Newbouldia laevis*

The Bignoniaceae family includes this particular species of tree. The tree has a modest stature with a narrow crown. It has a deep root system and is an evergreen plant (Hawthorne, et al 2006).

2.8.9 *Terminalia ivorensis*

The Combretaceae family includes this species of tree. A large deciduous tree with dense foliage, black bark, and whorled branches, it is a common sight in secondary forests. Just before the end of February and during March, the tree becomes deciduous. In April, a rush of new leaves appears, and the blooms follow. It is a species with deep roots (Hawthorne, et al 2006).

2.8.10 *Terminalia superba*

The Combretaceae family includes this particular tree. In essence, it is a tall tree in a deciduous forest that loses its leaves throughout the dry season. Simple, alternating leaves grow in clusters at the terminals of the branches and leave recognizable markings on the branches when they are discarded. It has a deep-rooted quality (Hawthorne, et al 2006).

2.8.11 *Alstonia boonei*

Alstonia boonei is a member of the Apocynaceae family. It is a big deciduous tree that may grow up to 45 meters tall and 1.2 meters wide. Its bole is typically deeply grooved and has minor buttresses at 7 meters. Its bark is greyish-green or grey and has rough-granular slashes that show a lot of milky latex. The branches are arranged in whorls. It has a deep root system and a medium-sized canopy (Hawthorne, et al 2006).

2.8.12 *Funtumia africana*

Funtumia africana belongs to the Apocynaceae family. It is a tropical tree with a straight, cylindrical trunk and a narrow tree crown that can grow up to 30 m tall (though it is typically shorter). The bark is thin, fissured, and brown to dark in color. On mature trees, it becomes granulated. A species of a deciduous tree with a shallow root system is called Funtumia africana (Hawthorne, et al 2006).

2.8.13 *Milicia excelsa*

Milicia excelsa belongs to the Moraceae family. It is a huge, tall deciduous tree with a diameter of 2–10 m and a height of 30–50 m. It has extensive root systems (Hawthorne, et al 2006).

2.9 The benefit of Agroforestry to Plant Growth

By enhancing soil quality, decreasing the effects of erosion, and increasing water availability, agroforestry systems can benefit a variety of different types of ecosystems (Hillbrand, 2017).

2.9.1 Soil quality Improvement

Compared to traditional agricultural systems, agroforestry systems have a more extensive nitrogen cycling process that improves soil quality. The rate of nitrogen transport within the system is higher, while the amount of nitrogen leaving the system is lower (Tsonkova et al., 2012). Some Short Rotational Woody Crops (SRWCs) have deeper root systems that enable them to draw nitrogen from deeper soil layers and return it to the topsoil. Soil restoration and agricultural land fertility can both be maintained through the cultivation of short rotational woody crops (SRWC) without the need for extra fertilization (Tsonkova et al. 2012).

2.9.2 Erosion control

According to Beliveau et al. (2017), SRWCs in agroforestry systems can aid in reducing soil erosion. The stability of the soil rises while soil detachability reduces as a result of the woody crops' extensive root systems. By physically obstructing the incoming precipitation velocity and water running over the surface, trees could potentially be employed to reduce surface runoff (Tsonkova et al., 2012).

2.9.3 Water regulation

For plants to thrive, water availability is crucial, and a lack of it might hinder growth Irena (2019). As a result of the deeper root systems' hydraulic lift, SRWCs can provide nearby crops with water. In this procedure, water is discharged into the top layer of soil after being absorbed up from deeper soil layers (Burgess et al. 2001).

2.9.4 Windbreaks

Particularly in windy places, agroforestry trees serve as windbreaks for planted crops. During severe winds, crops with long, flimsy stems frequently lodge or even shatter. Growing crops alongside trees greatly aids in preventing these adverse consequences.

2.10 Effects of Light on Plant Growth

Understanding the climate effect has been a continuing effort to enhance agricultural machinery and management plan in order to decrease the negative effects of climate change and to increase corn production (Smith 1903). Light, one of the most important environmental factors, can change little throughout particular plant growth phases and result in a huge fluctuation in crop yield. Plants primarily absorb light with a wavelength between 400 and 700 nanometers. The photosynthetically active radiation is in this region of light. Red lights have the longest wavelength and the least amount of energy, whereas violet and blue lights have the shortest wavelengths and the most energy. The majority of the energy that the chlorophyll pigment, which is responsible for light absorption, absorbs is in the violet-blue and orange-red wavelengths. Plants' capacity to absorb light is aided by a variety of adaption traits. Understory plants frequently have broad leaves and narrow leaf blades for straightforward light absorption. Taller plants often reflect the far-red (FR) component of light so that the understory can absorb it through their leaves (Holmes and Smith 1977). Sunflecks, which can make up to 80% of the total irradiance of the forest floor, are essential to many understory species (Chazdon and PEARRCY 1988).

Energy is transformed during plant growth, turning incident solar radiation into the more useful form of chemical potential energy present in the invested parts, such as seeds, grains, and tubers. Plants must be able to absorb solar radiation through their leaf canopy and then change it into chemical potential energy in order to go through this transition. The final step is dividing the dry matter produced between the harvested components and the remaining, less significant plant parts (Essilfie 2017).

During germination, various seeds respond to light in various ways. Some seeds show positive photoblastic morphology (absolutely requires light to germinate). Exposure to light hinders the growth of other seeds. Those seeds that meet this criterion are known as negative photoblastic seeds.

Plants absorb light for photosynthesis, but they also have an impact on a number of regulators of plant development.

In nature, light acts as both a wave and a particle. While the particle aspect is expressed in quota or photons, the wave nature is expressed in wavelength. The eye perceives wavelengths between 400nm and 800nm as light. Plants need these wavelengths for photosynthesis. All visible light is absorbed by chlorophyll in photosynthetic cells, with the exception of green, which is reflected and is therefore visible (Essilfie 2017).

Various plants or plant species respond to light in different ways. Top leaves absorb more incident light than lower leaves, which explains why. The shape of a plant's leaf determines how light interacts with its canopy. According to J. M. Chen and Black (1992; GCOS 2011), LAI is often defined as the proportion of total green leaf area per unit horizontal ground surface area. LAI is commonly defined as half of the total green leaf area per unit horizontal ground surface area (J. M. Chen & Black 1992; GCOS 2011). The architecture of the plant affects the leaf area index (LAI), which is the proportion of a plant's leaf area to its ground area. Less than 1% of the forest trees' leaves are fully exposed, and their LAI value is around 12. Under very low light irradiance levels or darkness, seedlings tend to be etiolated with long and weak stems, and pale and small leaves (sometimes no leaf) which results in reduced photosynthesis. Less sun radiation results in lower photosynthetic production capacity and insufficient assimilate accumulation. At the same time, insufficient solar radiation causes ear development to be limited, male and female ear growth to be uneven, the grain filling period to be shortened, and the final yield to fall. Weak plant growth and an increase in lodging risk are both caused by a decrease in solar radiation (Guo et al. 2022). This effect can lead to seedling death. On the other hand, seedlings grown in light have a short and strong stem, green stem, and leaves as well as early development of leaves for photosynthesis.

When a plant is growing, it needs enough light. Shade plants typically photosynthesize at higher rates than other species do at very low irradiance levels. Because they have a very low light compensation point, shade plants can thrive in an environment where other plants dominate the understory. This trait is present in some hybrids of agricultural crops, making them appropriate for use in agroforestry systems. Plants need enough light to restore the energy or carbohydrates lost or utilized during respiration in order for them to survive (Gert 2017).

Plants depend on a variety of elements, including the relative lengths of light and darkness, during the flowering process. Whether a plant has short or long days affects how much light it needs during the flowering stage. Short-day plants only flower when the period of illumination is shorter than the critical length, whereas long-day plants only do so when the illumination lasts longer than a critical length. During specific stages of development, the photoperiod can be used to alter the length of a plant's life cycle. When grown in an environment where the day length is greater than 12 hours or when the length of the dark phase is less than 12 hours, short-day plants' life cycles can last longer. When grown in roughly 16 hours of photoperiod (for example, throughout the summer), the photoperiod sensitive maize genotype has a longer life cycle than when grown in approximately 11 hours of photoperiod (during winter).

Photoperiod effects on life cycle duration can be observed in three phases (Essilfie 2017).

Phase 1 is typically referred to as a photoperiod-insensitive phase; it begins with sowing and has no effect on when flowers will bloom during the juvenile stage.

Phase 2 is an inductive phase that is photoperiod sensitive. This phase starts when the juvenile phase ends, and the flowering process starts. The photoperiod during this stage can extend flowering.

Phase 3 is a post-inductive photoperiod phase. The first, second, or both phases may be included in this. The length from flower initiation to physiological maturation may be influenced by the photoperiod during this phase.

From germination through around the 4-leaf stage-juvenile stage, maize plants are not photoperiod sensitive, according to Essilfie (2017). The photoperiod-sensitive inductive phase begins at the stage of four leaves and ends at the stage of tassel initiation. The short season maize hybrid experiences this between the 7th and 8th leaf tip (LT) stage. Generally speaking, the length of the day following tassel initiation has no impact on the development of maize, despite the paucity of published experimental data to the contrary.

For example, the influence of photoperiod on the total number of started leaves per plant mediates the effect of photoperiod on maize development. There are around five leaf initials in the maize kernel embryo. After imbibition, leaf initiation begins and lasts until the tassel emerges. An increase in day length lengthens the photoperiod-sensitive inductive phase's duration. The number of leaves that have been initiated at tassel initiation increases with an increase in photoperiod since photoperiod has no effect on the rate of leaf initiation. Within a species, different cultivars respond differently to the photoperiod. In contrast, sensitivity appears to diminish from tropical to temperate and from temperate to short-season maize genotypes. For instance, tropical maize genotypes are extremely sensitive (photoperiod increases the number of leaves).

Photosynthesis, a plant process that converts solar energy into chemical energy, is powered by light. Water is split during photosynthesis in a chemical reaction that separates it into oxygen and hydrogen and converts carbon dioxide into sugar. According to a general principle, 1% additional light will result in a corresponding percentage increase in plant growth, which will result in 1% more yield (Gert 2017).

2.11 Methods and Equipment of irradiance measurement

Irradiance is the amount of energy released at each wavelength from a radiant sample, such as LED, a laser, or the sun. Different irradiance measurement tools have been created over time. The type of experiment being conducted, and the researcher's financial status are two factors that affect the equipment that will be used.

Here are some of the factors to consider when choosing instruments to measure solar power or irradiance according to Raul (2021).

2.11.1 Determine what you would like to measure.

You must be particular about the amount of radiation you want to measure now that you are aware of the tools that are available for doing so. Solar radiation has a wide range of applications, and several measurement methods are available for each use.

2.11.2 Quantum Sensors

Another important consideration is the area where you intend to use the sensor. If you choose to utilize pyranometers, for instance, choose areas free of any obstructions. Their entire hemispherical field of view is the cause of this. Basically, while choosing a place, make sure to consider the sun's trajectory throughout the year.

2.11.4 Pyranometer

The most used tool for measuring hemispherical sun irradiance is this one. Broadband solar radiation is what that is. This device performs well over a 180-degree field of vision.

The thermopile sensors of a typical pyranometer are concealed under a glass dome. Since it doesn't need any power, it is simple to use. The sensors absorb the radiation in the field, and they provide an output voltage that is proportionate to the radiation they are exposed to.

Pyranometers are frequently positioned on top of or next to solar panels to ensure the best panel positioning. Digital Pyranometers, made possible by technical breakthroughs, are used to record and analyze irradiation data.

The digital Pyranometers are capable of serial data output. They may fit on your hand and are tiny. As a result, they are frequently used handheld for taking measurements in the field.

2.11.5 Quantum Sensors

The visible spectrum, which photosynthetic organisms can employ as a band of solar energy, is measured by quantum sensors, which are specialized instruments.

The photosynthetic photon flux density (PPFD) from sunlight is measured by quantum sensors. This knowledge is helpful in agriculture since it influences where to locate cropland. Additionally, it aids growing house maintenance for farmers. They are especially beneficial because 89% of Americans support solar farms.

The data has a wide range of uses because oceanography uses it to determine the ocean's sunshine zones. Data is produced by these sensors using photovoltaic technology.

2.11.6 Pyrheliometer

Similar to a pyranometer, a pyrheliometer monitors solely the sun irradiance from the direct beam. Because of this, they are rarely utilized in pyranometer applications.

Through the heliometer's built-in lenses, the sun's rays will pass through. To a thermocouple that is housed inside the apparatus, the lens will direct sunlight. The little voltage produced by a thermopile is transformed into watts via a pyrheliometer.

2.11.7 Solarimeter

An instrument used to gauge the flow of solar radiation is called a solarimeter (also known as a silicon cell pyranometer). It measures the quantity of solar radiation that reaches a specific surface using the photovoltaic effect. Similar to a photovoltaic system, a solarimeter that uses the photovoltaic effect generates an electrical signal in reaction to incident light. It responds mostly to visible light, and the output is influenced by the cell's temperature. It can collect light rays between 330 and 1100 nm. The values measured by a photovoltaic cell solarimeter must be modified to account for temperature in order to provide a temperature-independent reading. A thermocouple can be used to take this measurement. The correction factor needs to be quite precise.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was conducted at a research field of the University of Agriculture and Life Sciences, Institute of Environmental Sciences (IES) Research Center for Irrigation and Water Management (ÖVKI) in Szarvas-Hungary located in Central Europe (Fig. 3.0). Szarvas is a town in Bekes County, Hungary covering a land area of about 161.6km^2. It has a population of 16,954 as recorded by the 2011 population census.

Fig. 3.0 Districts map of Szarvas with the Agroforestry research site

Source: Google Earth

Usually lasting 6.8 months (209 days), the growing season in Szarvas runs from about March 31 to about October 26. It hardly ever begins before March 9 or ends after April 24 or before October 10 or after November 11.

3.1.1 Temperature

The warm season, which has an average daily high temperature above 73°F, lasts for 3.7 months from May 24 to September 14. With an average high temperature of 82°F and low temperature of 61°F, July is the hottest month of the year in Szarvas. The cold season lasts from November 23 to March 1 and the average daily maximum temperature is below 45 degrees Fahrenheit during that time. The coldest month of the year in Szarvas is January, with average lows of 26°F and highs of 36°F. The experimental period was dry and hot from the end of April to the end of August in 2022.

3.1.2 Rainfall

A day is deemed wet if there is at least 0.04 inches of liquid or liquid-equivalent precipitation. From April 21 to August 7, the 3.6-month wetter season, has a greater than 22% chance of precipitation on any given day. The wettest month in Szarvas is June, which has an average of 8.7 days with at least 0.04 inches of precipitation. The drier season, which lasts 8.4 months from August 7 to April 21. January is the month with the fewest wet days in Szarvas, with an average of 4.5 days with at least 0.04 inches of precipitation. Rainy days can be divided into three categories: those with only rain, those with only snow, and those with both. June is the wettest month in Szarvas, with an average of 8.7 days. This classification indicates that rain alone will be the most common kind of precipitation on June 13 with a high likelihood of 31%. The depth of the ground water typically varies between its lowest and highest points during the months of fall and spring. The Szarvas region experienced moderate to severe droughts 50% of the time, severe droughts 10% of the time, and drought-free years 30% of the time, according to Csengeri (2022). In the experimental year, the region had severe drought period which caused a significant yield loss of rainfed corn (Fig. 3.1.).

3.1.3 Humidity

The average amount of sky that is covered by clouds in Szarvas fluctuates greatly from season to season. The clearer season in Szarvas begins on May 26 and lasts about 4.4 months, ending around October 6. In July, the clearest month of the year in Szarvas, the sky is clear, mostly clear, or partially overcast 71% of the time. The cloudier part of the year begins about October 6 and lasts for 7.6 months, ending around May 26. The cloudiest month of the year in Szarvas is December, when an average of 63% of the sky covered with clouds. During the 2.5-month period from June 8 to August 24, which is the wettest part of the year, the comfort level is oppressive, dismal, or muggy at least 3% of the time. The month of July has the most humid days in Szarvas, with 2.7 of those days being muggy or worse.

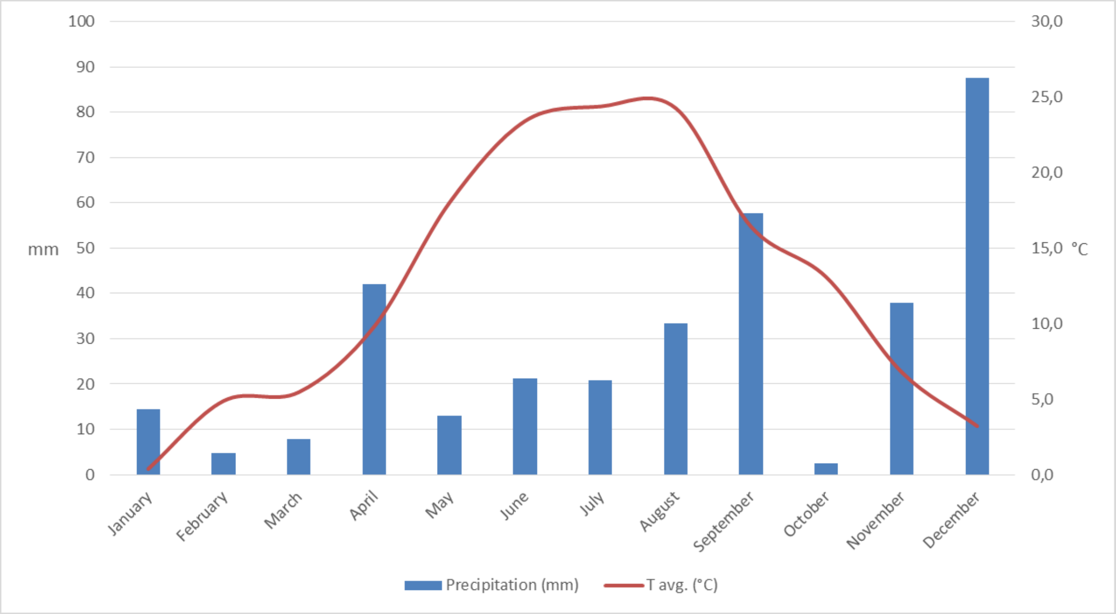


Fig. 3.1. Monthly average temperature (°C) and precipitation in 2022 (Szarvas, Hungary)

The meteorological data were collected with an automatic weather station (Agromet Solar, Boreas Ltd., Hungary) at the MATE ÖVKI Lysimeter Station in a 1 km distance (Fig. 3.1.).

3.1.4 Soil

According to the national soil map of Hungary (EUDASM), the soil type prevalent in the Bekes County where Szarvas is located is mainly made up of sodic soils with moderate clay characteristics. It consists of mostly illite, kaolinite, chlorite, and sometimes smectite.

3.1.5 Vegetation

The vegetation is mostly composed of trees, shrubs with grasses. Examples of plants commonly found in szarvas are the Hungarian oak, European white Elm, rosemary, jointed goat grass, yellow star-thistle, Goldenrain tree, common yarrow, white mulberry, common reed, English lavender, large-leaved lime, lambsquarters, Cotinus, alfalfa, Siberian elm. Some of the most cultivated crops are maize, rice and sunflower.

3.2 Data Collection Method

3.2.1 Site selection and Preparation

The agroforestry system of the MATE Institute of Environmental Sciences (IES) Research Center for Irrigation and Water Management (ÖVKI) in Szarvas is the alley system where trees are grown in one lane and crops in a different lane in an alternating order.

A total land area measuring 10m × 100m was used in this study. The length of the plot starts from the south to the north and the breadth from the east to the west so that the sunrise will faces the entire fields from the longer side. On both sides of the plot is a row of poplar trees whose height were maintained at about 2m tall.

3.2.2 Sowing of Seeds

The seeds were sowed on the 19th of May 2022 using a tractor with a seed Sower attached to its rear end. The seeds were sowed in 8 rows keeping 255cm distance between the first row of poplar and the first row of maize seed line. The distance between seed rows is 75cm and 220cm between row 8 and the last row of poplar as shown in Fig. 3.1 below. The numbers 1,2,3,4,5,6,7 and 8 in Fig. 3.1 represent the plant rows. The seeds were sowed at a spacing of 35cm within rows with four seeds per hill.

Hybrid MG390/22 seeds from the first filial generation of MG 22/32 were used for this study. Seeds were treated with Redigo-M fungicide. The field were watered after the sowing and repeated on the third day. The weeds were sprayed with a non-selective herbicide a day after sowing.

3.2.3 Research Design

This section discusses how data for this study was collected and analyzed. These included the data collection through selection of field for survey, measurement of parameters, sampling methods and frame and data analysis. The study was conducted through the field survey work.

3.2.4 Data Collection

Twenty (20) plants were sampled from each row from the middle part of the plot for data collection. Data were collected on five different parameters namely plant height, irradiance, plant weight at harvest, plant biomass and nutritional analysis of the maize kernels.

3.2.5 Data Collection Methods

Data on plant height were collected at three different times. The first was on the 14th July 2022, the second on the 4th of August 2022 and the last measurement on the 14th of October 2022 using a ruler in cm. The measurements were taken from the ground level to the apex of the last leaf.

Fig. 3.2 Experimental layout with the distances between rows (treatments)

The spectral characteristics of 10 plants within the 20 sampled plants were measured using CI-710s SpectraVue Leaf Spectrometer (CID Biosciences, USA). The equipment was used to measure the reflectance, absorbance and the transmittance of the plant leaves.

Fig. 3.3 sowing of seed (May 18, 2022)

Fig. 3.4 Measuring of plant height (July 14, 2022)

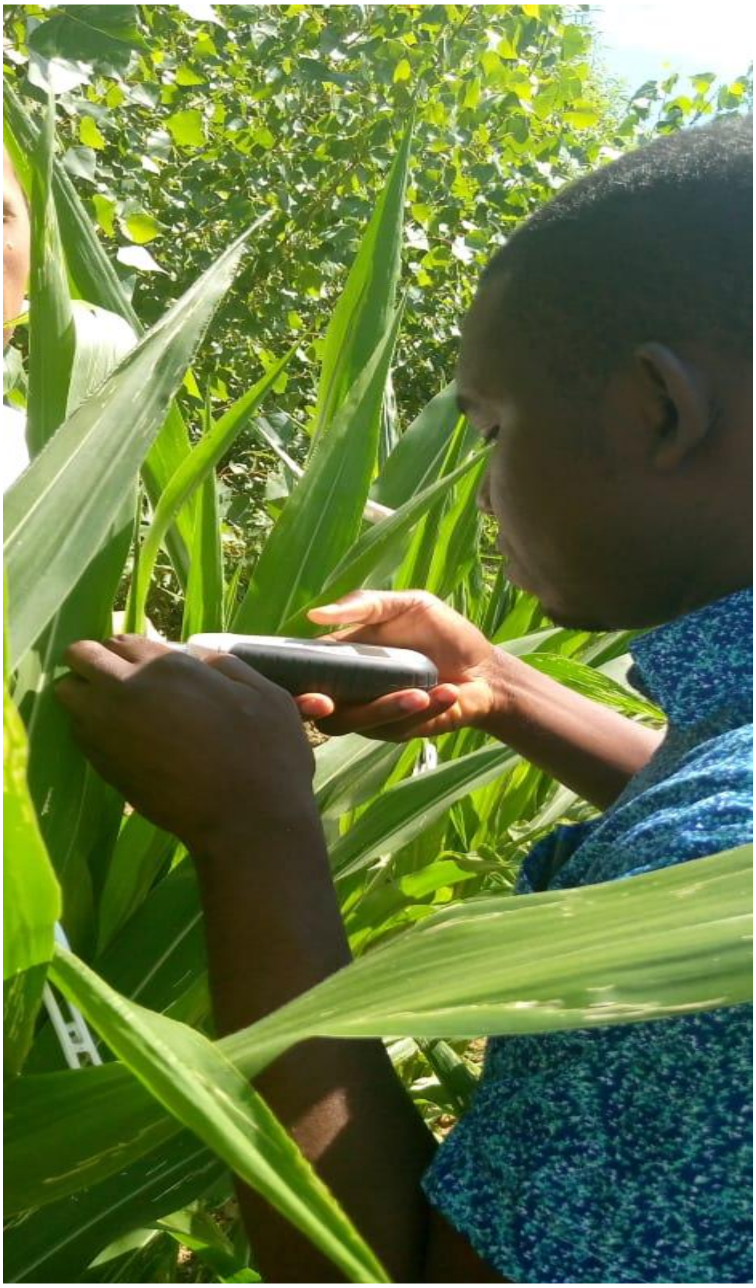


Fig. 3.5 Measuring of total irradiance (July 14, 2022)

Measurement on plant weight (above ground biomass) were taken in grams (g) on the 14th of October 2022 using an electronic digital weighing balance from Nangra AFD Scale Co. LTD. The plants were placed horizontally on the balance and the measurements recorded.

Fig. 3.6 Measuring of total plant weight (October 14, 2022)

Sample grains were taken to the laboratory for analysis to measure the moisture content, the protein content, the starch content, and the oil content. The analysis was done for each row using the FOSS Infratec equipment manufactured by the FOSS company (Denmark).

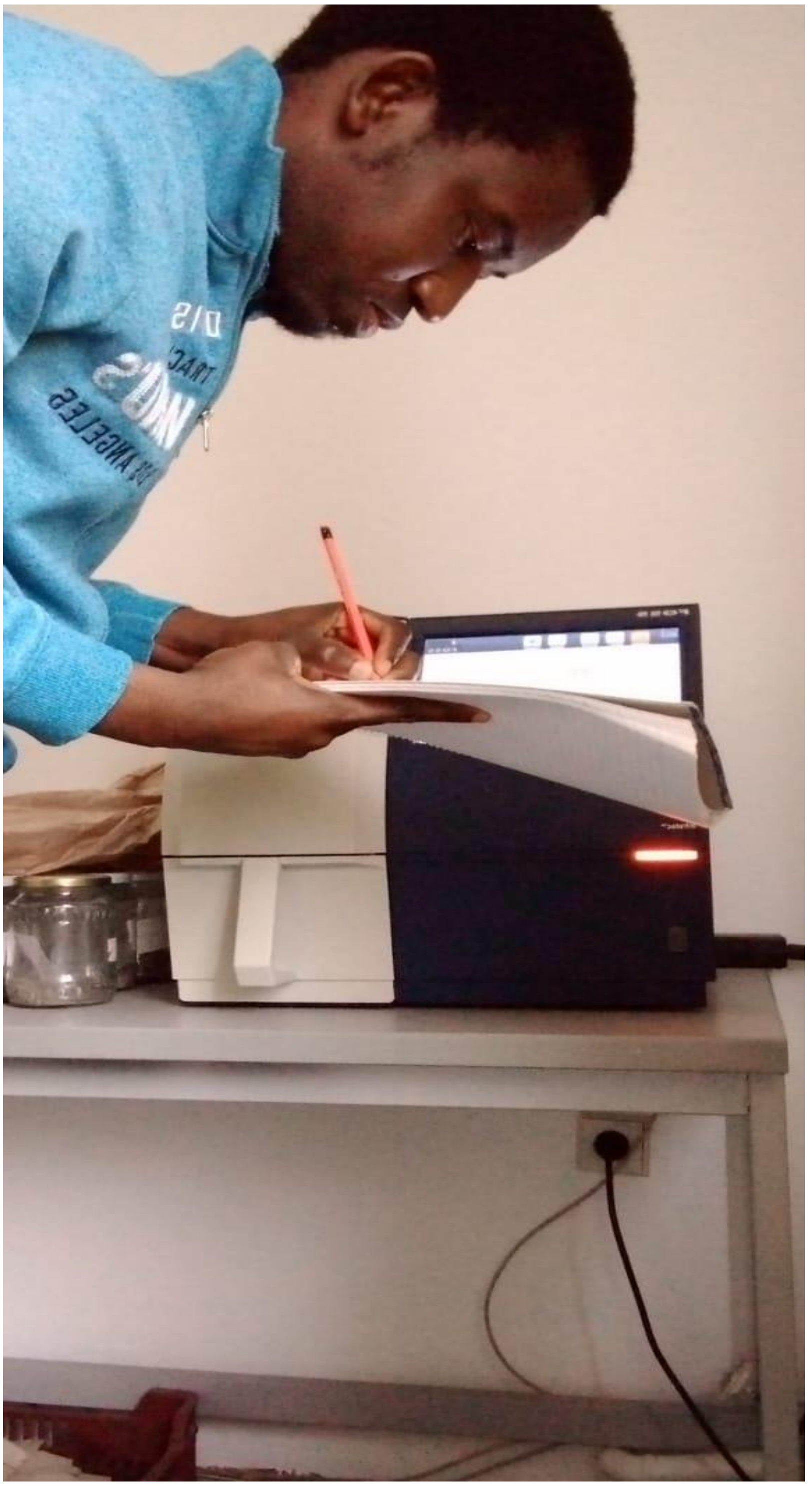


Fig. 3.7 Measuring of Grain quality parameters with a NIR instrument (2023)

3.2.6 Data Analysis

Bar charts, scatter plots, and tables were used in the descriptive analysis of the data obtained. Tables, graphs, and diagrams were created using statistical tools (SPSS version 26 and MS Excel version 2019) with all the data pre-coded before the analysis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1. Irradiance Index and other Parameters

All results were obtained from a single agroforestry field used for the study located in Szarvas, Hungary. Data collected were obtain from eight rows 75cm apart between two rows of poplar under the following parameters: plant height, plant weight, number of plants, yield, nutrient content, and irradiance. Rows 1 and 8 are the closest to the poplar trees with row 4 and 5 in the middle of the field. Twenty plants were selected from each of the rows. Data obtained on the parameters were analysed using descriptive analysis with the Turkey's Test at 95% confidence level to check the significance between the treatments (Rows). Parameters that show significance difference between the row are further analysed using the Pearson correlation to check if there is any relationship or correlation between the irradiance and those parameters showing the significant difference between the rows. From the statistical analysis, 0.05 and below indicates significant difference and above 0.05 means there is no significant difference between the treatments.

4.2.1 Plant height

Tests of Between-Subjects Effects

Source	Source	Source	Source	Source	Source
Corrected Model	52864,191^{a}	7	7552.027	14.708	.000
Intercept	9710848.682	1	########	18912.921	.000
Row	52864.191	7	7552.027	14.708	.000
Error	160196.557	312	513.451		
Total	9923909.430	320			
Corrected Total	213060.748	319			

Table 4.0 Plant height -Tests of Between-Subjects Effects

Tukey HSD^{a,b}

Plantheight

Row	N	Subset				
		1	2	3	4	5
4	40	152.22				
5	40	160.00	160.00			
3	40		167.95	167.95		
2	40		174.42	174.42	174.42	
1	40			177.89	177.89	
6	40			182.59	182.59	182.59
8	40				183.83	183.83
7	40					194.72
Sig.		.788	.088	.078	.581	.247

Table 4.1 Plant height -Tukey HSD^{a,b}

From table 4.0, it can be observed that there is significant between the treatments which were further described with the Turkeys Test as shown in table 4.1 above. From table 4.1, it can be seen that there is no significant difference between row 4 and 5 but significantly different from the rest of the rows. Rows 5,3,2 under subset two are significantly different from the rest of the subsets, 3,2,1,6 under subset three are significantly different from the rest of the subsets, 2,1,6,8 under subset four are significantly different from the rest of the subsets, and lastly row 6,7,8 under subset five are significantly different from the rest of the subsets.

4.2.2 Weight at Harvest

Tests of Between-Subjects Effects

DependentVariable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1542823,847[a]	7	########	22.955	.000
Intercept	33072705.078	1	########	3444.455	.000
Row	1542823.847	7	########	22.955	.000
Error	2995738.075	312	9601.725		
Total	37611267.000	320			
Corrected Total	4538561.922	319			

Table 4.2 Weight at Harvest -Tests of Between-Subjects Effects

Weight at Harvest

Tukey

HSD[a,b]

Row	N	Subset				
		1	2	3	4	5
8	40	228.75				
2	40	253.73	253.73			
1	40	254.38	254.38			
3	40		312.88	312.88		
7	40			324.78	324.78	
6	40			369.00	369.00	
4	40				388.25	388.25
5	40					440.13
Sig.		.940	.127	.174	.077	.261

Table 4.3 Weight at Harvest -Tukey HSD[a,b]

From table 4.2, it can be observed that there is significant between the treatments which were further described with the Turkeys Test as shown in table 1.1 above. From table 4.3, it can be seen that there is no significant difference between the treatment under the same subset. Contrary, those under different subsets are significantly different from each other. The weight of subset 1,2,3,4 and 5 is from the lowest to the highest respectively.

4.2.3 Number of Plants

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1098,000[a]	7	156.857	12.899	.000
Intercept	12321.000	1	12321.000	1013.181	.000
Row	1098.000	7	156.857	12.899	.000
Error	681.000	56	12.161		
Total	14100.000	64			
Corrected Total	1779.000	63			

Table 4.4 Number of Plants -Tests of Between-Subjects Effects

From table 4.4, it can be observed that there is significant between the treatments which were further described with the Turkeys Test as shown in table 4.5 above. From table 4.5, it can be observed that there is no significant difference between row 4 and 5 but significantly different from the rest of the rows under subset two. Those rows under subset two are also not significantly different from each other but significantly different from those under subset one. Those rows under subset one shows the fewer number of plants as compared to those under subset two.

Number of Plants

Tukey HSD[a,b]

Row	N	Subset	
		1	2
5	8	6.50	
4	8	7.63	
3	8		13.75
7	8		15.13
6	8		16.00
2	8		16.50
8	8		17.13
1	8		18.38
Sig.		.998	.159

Table 4.5 Number of Plants -Tukey HSD[a,b]

4.2.4 Yield/meter

Tests of Between-Subjects Effects

DependentVariable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	694559,885[a]	7	99222.841	28.000	.000
Intercept	########	1	########	3853.520	.000
Row	########	7	99222.841	28.000	.000
Error	########	56	3543.648		
Total	########	64			
Corrected Total	########	63			

Table 4.6 Yield/meter -Tests of Between-Subjects Effects

Yield/meter

Tukey HSD^{a,b}

Row	N	Subset		
		1	2	3
8	8	338.2750		
5	8	339.6625		
4	8	354.8125		
2	8		468.5500	
3	8		474.4500	
1	8		535.7500	
7	8		538.7125	
6	8			645.1250
Sig.		.999	.282	1.000

Table 4.7 Yield/meter -Tukey HSD^{a,b}

Table 4.6 shows significant difference between rows in yield/meter which is represented in table 4.7. From table 4.7, three subsets were observed representing the different significant groups. There is no significant difference between 8,5,4 under subset one as the lowest. This applies to 2,3,1,7 under subset two and row 6 under subset three being the highest.

4.2.5 Protein content

Tests of Between-Subjects Effects

Dependent variable:

Source	Type III Sum of Squares	df.	Mean Square	F	Sig.
Corrected Model	14,215^{a}	7	2.031	45.149	.000
Intercept	3162.656	1	3162.656	70316.1	.000
Row	14.215	7	2.031	45.149	.000
Error	2.519	56	.045		
Total	3179.390	64			
Corrected Total	16.734	63			

Table 4.8 Protein content -Tests of Between-Subjects Effects

Tukey HSD^{a,b}

Row	N	Subset			
		1	2	3	4
2	8	6.5000			
3	8	6.6625	6.6625		
5	8	6.7875	6.7875		
4	8	6.7875	6.7875		
6	8		6.9625	6.9625	
1	8			7.2000	
7	8			7.2250	
8	8				8.1125
Sig.		.141	.108	.227	1.000

Table 4.9 Protein content -Tukey HSD[a,b]

From table 4.9 it can be observed that the protein content in the grains in row 8 under subset four has the highest value followed by row 7,1,6 under subset three, 6,4,5,3 under subset two, and 4,5,3,2 under subset one respectively.

4.2.6 Starch content

Tests of Between-Subjects Effects

DependentVariable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29,047[a]	7	4.150	13.848	.000
Intercept		1			.000
Row	29.047	7	4.150	13.848	.000
Error	16.781	56	.300		
Total		64			
Corrected Total	45.829	63			

Table 4.9.1 Starch content -Tests of Between-Subjects Effects

Starch content

Tukey HSD^{a,b}

Row	N	Subset		
		1	2	3
8	8	71.6875		
1	8	72.4000	72.4000	
7	8		72.9750	72.9750
5	8			73.3875
6	8			73.4500
4	8			73.5250
3	8			73.6375
2	8			73.7750
Sig.		.177	.427	.087

Table 4.9.2 Starch content -Tukey HSD^{a,b}

Three subsets of significant levels were observed on the starch content from table 4.9.2. Row 7,5,6,4,3,2 shows no significant difference between them but significantly different from those under subset two and subset one. Row 1 and 7 under subset two shows no significant between them but significantly different from those under subset one and three. Rows 8 and 1 are significantly different from those under subset two and subset three. Row 1 and 8 shows the lowest starch content with rows 7,5,6,4,3,2 under subset three showing the highest starch content.

4.2.7 Oil content

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,047[a]	7	.007	.955	.472
Intercept	741.201	1	741.201		.000
Row	.047	7	.007	.955	.472
Error	.393	56	.007		
Total	741.640	64			
Corrected Total	.439	63			

Table 4.9.3 Oil content Tests of Between-Subjects Effects

Oil content

Tukey

HSD[a,b]

Row	N	Subset
		1
5,00	8	3.3500
3,00	8	3.3875
2,00	8	3.4000
6,00	8	3.4000
7,00	8	3.4000
1,00	8	3.4125
8,00	8	3.4250
4,00	8	3.4500
Sig.		.267

Table 4.9.4 Oil content - Tukey HSD[a,b]

From table 4.9.3 and table 4.9.4, it can be observed that there exists no significant difference between the treatment (rows) with respect to the oil content of the grains.

4.2.8 Spectral indices in the different maize rows

Five indexes namely water band index (WBI), photochemical reflectance index (PRI), absorbance difference index (IAD), chlorophyll content index (CCI), and chlorophyll normalised difference vegetation index (CNDVI) obtained from the reflectance, absorbance, and the transmittance were analysed under the measurement with the spectrophotometer. No significant differences were observed between the treatments on the indexes (Appendices VI-IX) except the WBI (measured from the reflectance) using the Turkeys test.

WBI

Tests of Between-Subjects Effects

DependentVariable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,002[a]	7	.000	4.198	.001
Intercept	74.723	1	74.723	########	.000
Row	.002	7	.000	4.198	.001
Error	.004	72	5.857E-05		
Total	74.729	80			
Corrected Total	.006	79			

Table 4.9.5 WBI -Tests of Between-Subjects Effects

Tukey HSD^{a,b}

Row	N	Subset	
		1	2
7,00	10	.9588	
8,00	10	.9601	
2,00	10	.9659	.9659
6,00	10	.9663	.9663
4,00	10	.9685	.9685
1,00	10	.9688	.9688
5,00	10	.9694	.9694
3,00	10		.9738
Sig.		.051	.306

Table 4.9.6 WBI -Tukey HSD^{a,b}

Due to the significance shown in the WBI, the Pearson correlation was used to check if there is a correlation between the reflectance index (WBI) and the other parameters that shows significant difference between the treatments. The result from the Pearson correlation is shown in the table below.

4.2.9 Pearson’s correlation between WBI and other measured parameters

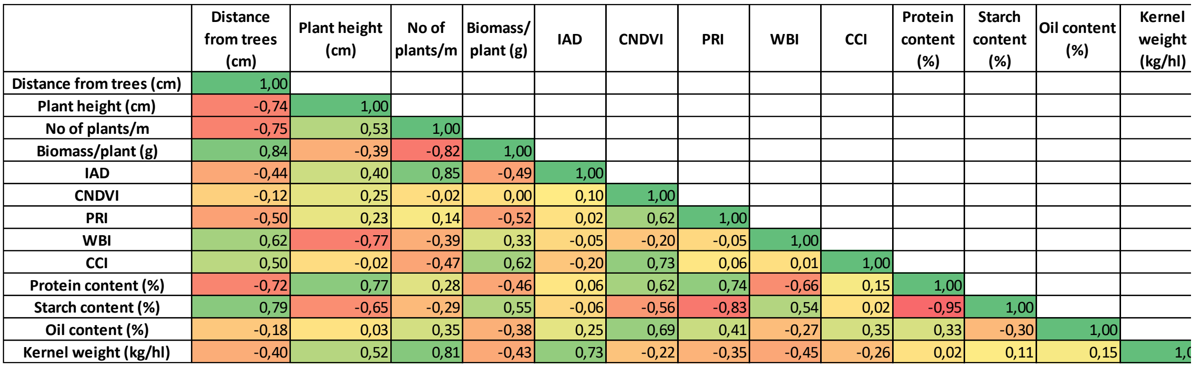
	Row	Protein	Starch	Plant height	Weight at harvest	Yield/m
WBI	1	-0.541	0.158	-0.286	0.103	0.146
	2	0.521	-0.249	-0.251	0.145	$.836^{**}$
	3	-0.113	-0.407	-0.416	$.755^{*}$	0.517
	4	-0.509	0.082	-0.403	$.723^{*}$	0.454
	5	-0.539	0.291	-0.281	0.259	-0.077
	6	0.458	$.758^{*}$	-0.233	0.662	0.568
	7	-0.587	0.058	0.627	-0.106	0.137
	8	-0.079	$-.773^{*}$	0.087	-0.009	0.660

Table 4.9.7 Pearson’s correlation between WBI and other measured parameters

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

4.3.1 Spectral indices’ relationship with Other Parameters



	Distance from trees (cm)	Plant height (cm)	No of plants/m	Biomass/ plant (g)	IAD	CNDVI	PRI	WBI	CCI	Protein content (%)	Starch content (%)	Oil content (%)	Kernel weight (kg/hl)
Distance from trees (cm)	1,00												
Plant height (cm)	-0,74	1,00											
No of plants/m	-0,75	0,53	1,00										
Biomass/plant (g)	0,84	-0,39	-0,82	1,00									
IAD	-0,44	0,40	0,85	-0,49	1,00								
CNDVI	-0,12	0,25	-0,02	0,00	0,10	1,00							
PRI	-0,50	0,23	0,14	-0,52	0,02	0,62	1,00						
WBI	0,62	-0,77	-0,39	0,33	-0,05	-0,20	-0,05	1,00					
CCI	0,50	-0,02	-0,47	0,62	-0,20	0,73	0,06	0,01	1,00				
Protein content (%)	-0,72	0,77	0,28	-0,46	0,06	0,62	0,74	-0,66	0,15	1,00			
Starch content (%)	0,79	-0,65	-0,29	0,55	-0,06	-0,56	-0,83	0,54	0,02	-0,95	1,00		
Oil content (%)	-0,18	0,03	0,35	-0,38	0,25	0,69	0,41	-0,27	0,35	0,33	-0,30	1,00	
Kernel weight (kg/hl)	-0,40	0,52	0,81	-0,43	0,73	-0,22	-0,35	-0,45	-0,26	0,02	0,11	0,15	1,

Table 4.9.8 Spectral indices’ relationship with Other Parameters

Table 4.9.7 shows different correlations between the WBI index of the various treatments with the other measured parameters. From the table, the negative values represent negative correlation whilst the positive values represent positive correlation. values with a single star (*) represents significant correlation and those with two stars (**) represent highly significant correlation at 0.05and 0.01 levels respectively. The correlation between the protein and the WBI either shows positive or negative correlation but all of which are insignificant. The starch content in rows 6 and 8 are positively and negatively significant correlation with the WBI respectively. The rest of the rows under starch content are correlated with the WBI but shows no significant level. Plant height has no significant correlation with the WBI in all the treatment. Plant weight shows significant correlation with the WBI in treatment 3 and 4 whilst the other treatments show no significant correlation. It can also be seen from the table that the yield per every meter in row 2 has a highly significant correlation with the WBI and the rest of the rows show no significant correlation with the WBI.

From the measured spectrophotometer indexes, all the indexes with the exception of water band index (WBI) have no significant difference between the treatment and hence has no correlation between the treatment with respect to plant height, weight/biomass, protein, starch, oil content of the grains. However, there were significant differences between rows with respect to the water band index which is sensitive to changes in canopy water status. The insignificant correlation observed between treatments under plant height and the WBI may be so because all rows were irrigated equally. Contrary, there would have been a significant correlation between them if irrigation was provided at different rates and plant moisture content differ. (Oktem, A. 2008; Lubajo et al. (2021).

The highly significant correlation value recorded in the second row under the yield/m may be due the other yield influencing factors such as the soil nutrient and soil drainage since plants in the seventh row has the same treatment but the correlation between row 7 and WBI is insignificant. This can also be seen from Table 4.9.7 which has the highest WBI value from row 3 since increase in WBI increases photosynthesis as stated in the study of Lawlor and Cornic (2002).

The significant correlation observed in row 3 and 4 with respect to weight at harvest is because they are in the centre of the field where they received higher sunlight. Without water stress, plants in no shade area have strong and bigger above ground biomass than those in the shade since they do not undergo etiolation. (Esilfie 2007). Row 5 however shows no significant correlation from Table 2.6 even though it exists in the centre of the field may have been influenced by other biotic and abiotic factors.

The nutrient composition of maize grain is genetically motivated rather than being under the influence of non-genetic factors even though nitrogen application is sometimes known to have influence on the protein content of the kernels (Kindomihou et al. 2011). This study shows no significant correlation between treatments and the WBI. This may be so because all treatment consists of the same variety. The starch content however shows negative and positive significant correlation in row 8 and row 6 respectively.

Spectral indices' relationship with Other Parameters were also checked as represented in Table 4.9.8. Strong positive correlations were represented in the table with green colours whist negatively strong correlations were represented by red colour.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The effect of irradiance on spectral parameters of maize in an agroforestry system conducted in Szarvas located in the Bekes County of Hungary was not significant even though few significant correlations were found in relation to the Water Band Index (WBI). Out of five spectrometer indexes considered namely water band index (WBI), photochemical reflectance index (PRI), absorbance difference index (IAD), chlorophyll content index (CCI), and chlorophyll normalised difference vegetation index (CNDVI) from the reflectance, absorbance, and the transmittance measurement, only the Water Band Index (WBI) shows significance differences between the treatments. Most of these observed significant correlations of measured parameters with the WBI do not follow a specific order using the statistical analysis. It is always difficult to explain the effect of trees used in an agroforestry system (Somarriba and Beer 2011; Tscharntke et al. 2011). Even though insignificant effects have been found between the treatment, the study shows a positive effect in terms of the germination of seed when the number of plants within every 12 meters were counted within the treatments. Higher number of plants were recorded in the rows closer to the tree species which may be due to the reduced evaporation aided by the trees in the drought period of 2022. There were positive and negative correlations between the indexes and the other measured parameters even though no significant levels were found. The result of the study shows minimal effect of spectral indices on the maize plants, but the poplar trees used helped in soil and water conservation as well as improving biodiversity. This shows that trees used in agroforestry system can improve soil moisture and nutrients conservation during drought conditions for good crop yield.

5.2. RECOMMENDATIONS

5.2.1. Research Institutions and Universities

The creation and implementation of a digital database containing the names of plant species (woody and herbaceous) encountered by trainees in the field as well as other related research projects would be of great interest. Doing so would increase the effectiveness and credibility of research findings by taking advantage of multiple experimental sites located in the same nation where maize is grown. I also recommend that different tree species should be used for the study to select the best tree species for any given crop in an agroforestry system. Also, different agroforestry system must be studied to help farmers choose the most favourable one. Different varieties of maize should be used for this study as well since different varieties may react differently to this system.

5.2.2. Public Services

To boost the output and caliber of maize and other field crops in Hungary, the public service is advised to hold farmer training seminars on efficient management and operation of their agroforestry areas. In order to educate these farmers about the value of the species present in their plantations beyond the shade effect, they should also make it a regular routine to visit some of these farmers who engage in agroforestry.

5.2.3. Farmers

The farmers are recommended to use agroforestry systems to increase production by incorporating not only forest trees but fruit trees to benefit from the fruits as well as the field crops used in the agroforestry system. This will help farmers to increase profit instead of neglecting free spaces between their fruit trees for weeds to occupy.

ABSTRACT

Despite Hungary's large cultivation of maize, average yield is low due to current climate challenges. For this reason, policymakers and practitioners recommend climate smart agriculture of which agroforestry is key. The study therefore seeks to assess the effect of irradiation on intercrop development in an agroforestry system involving maize and poplar trees. The study was conducted in szarvas, Bekes County of Hungary from May 2022 to January 2023. A field measuring 100m × 10m in size was used with a row of poplar trees enclosing the field along the length of the field. Eight rows of maize plants were grown between the two rows of poplar trees with the first and the eighth rows being the closest to each row of the poplar trees. Data was collected on the plant height, number of plants, reflectance, transmittance, and absorbance on the field and biomass as well as starch, protein, and oil content of the kernels after harvest. Data collected were tested for their mean differences at 5% LSD. The study showed no significant difference (p>0.05) among the rows and tree interactions on the parameters taken. The rows closer to poplars had the highest number of plants with the highest heights. The rows in the middles of the field however recorded the highest above ground biomass weight. Four of the five indexes recorded from the spectrophotometer measurement however shows no significant differences between rows. The index that shows little significance between rows surprisingly reveals few significant correlations with the yield, weight and starch content within the rows. From these findings, it can be concluded that poplar agroforestry system does not have a significant effect on plant height, aboveground biomass weight, and the nutrient content of the kernels with respect to irradiance received by the maize plants.

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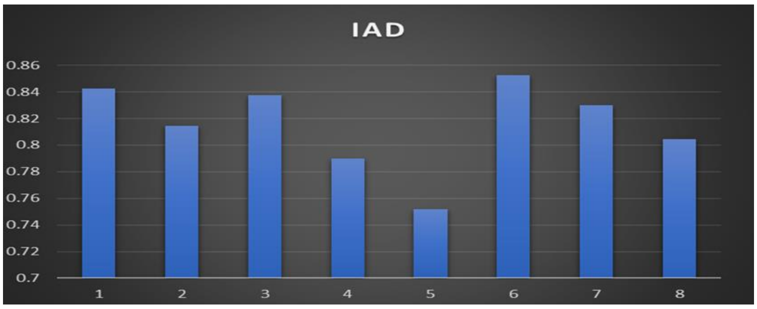
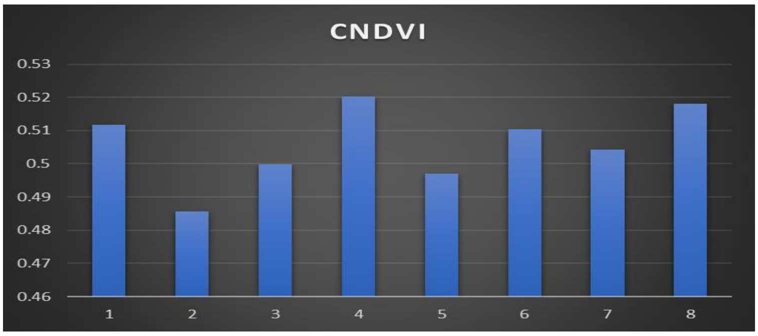
APPENDICES

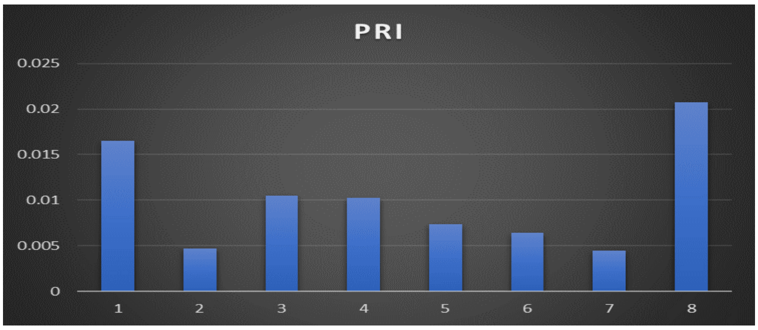
APPENDIX I: IAD between rows



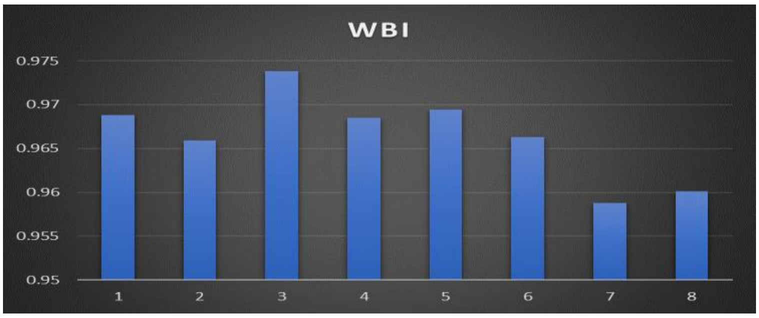
APPENDIX II: CNDVI between rows



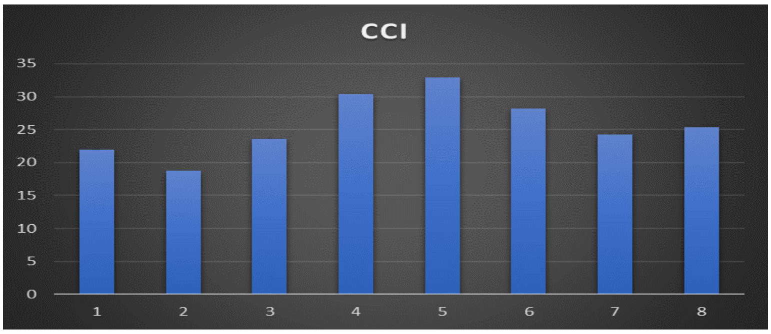
APPENDIX III: PRI between rows



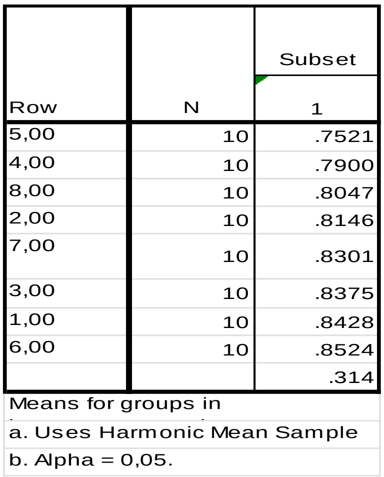
APPENDIX IV: WBI between rows



APPENDIX V: CCI between rows



APPENDIX VI: Tukey HSD^{a,b} for IAD



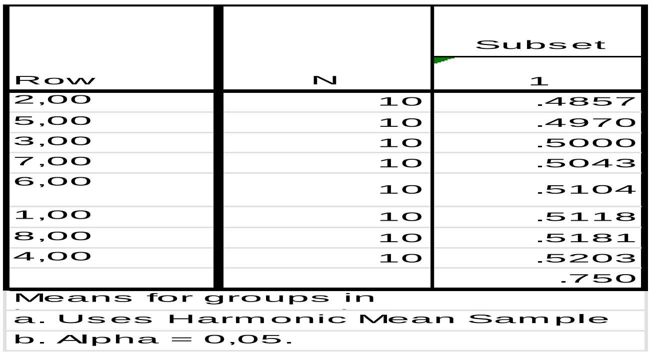
Row	N	Subset 1
5,00	10	.7521
4,00	10	.7900
8,00	10	.8047
2,00	10	.8146
7,00	10	.8301
3,00	10	.8375
1,00	10	.8428
6,00	10	.8524
		.314

Means for groups in

a. Uses Harmonic Mean Sample

b. Alpha = 0,05.

APPENDIX VII: Tukey HSD^{a,b} for CNDVI



Row	N	Subset 1
2,00	10	.4857
5,00	10	.4970
3,00	10	.5000
7,00	10	.5043
6,00	10	.5104
1,00	10	.5118
8,00	10	.5181
4,00	10	.5203
		.750

Means for groups in

a. Uses Harmonic Mean Sample

b. Alpha = 0,05.

APPENDIX VIII: Tukey HSD^{a,b} for PRI

Row	N	Subset
		1
7,00	10	.0045
2,00	10	.0047
6,00	10	.0064
5,00	10	.0074
4,00	10	.0103
3,00	10	.0105
1,00	10	.0165
8,00	10	.0208
		.127

Means for groups in

a. Uses Harmonic Mean Sample

b. Alpha = 0,05.

APPENDIX IX: Tukey HSD^{a,b} for CCI

Row	N	Subset
		1
2,00	10	18.8036
1,00	10	21.8900
3,00	10	23.6004
7,00	10	24.2688
5,00	9	25.2983
8,00	10	25.3393
6,00	10	28.1542
4,00	10	30.4294
		.229

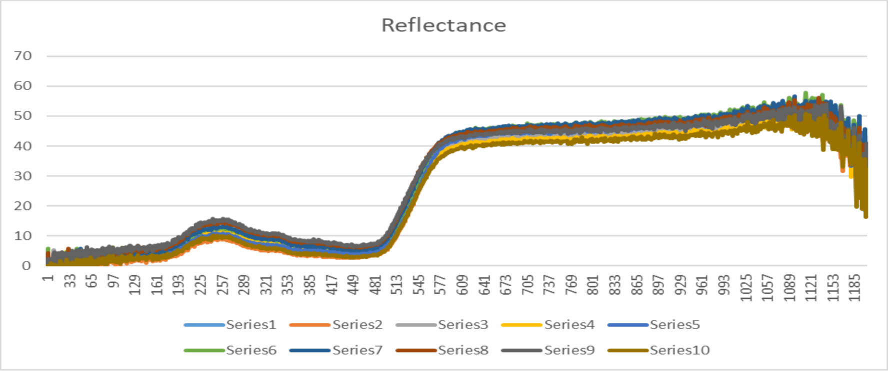
Means for groups in

a. Uses Harmonic Mean Sample

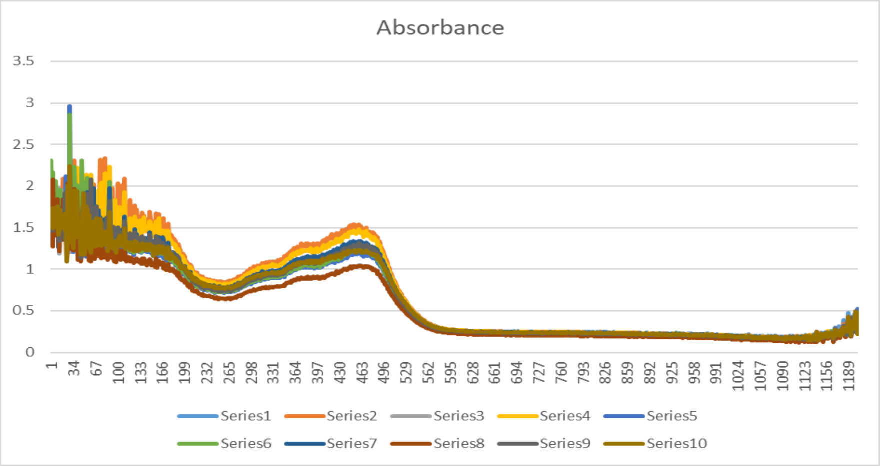
b. The group sizes are unequal.

c. Alpha = 0,05.

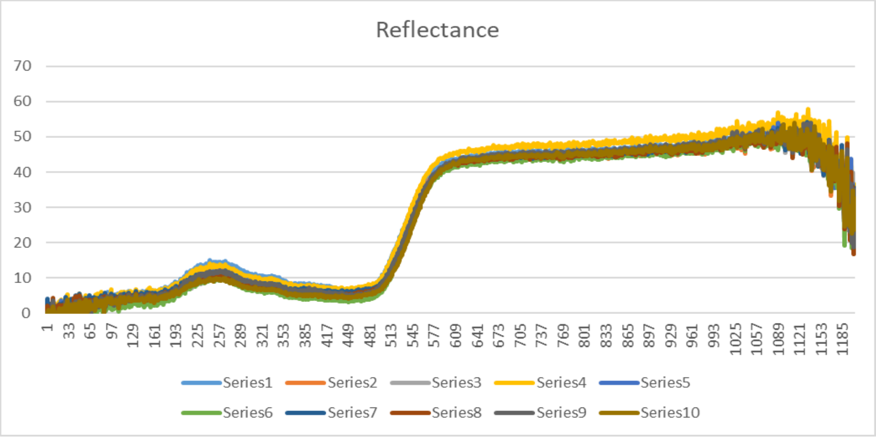
APPENDIX XI: Reflectance of row 1



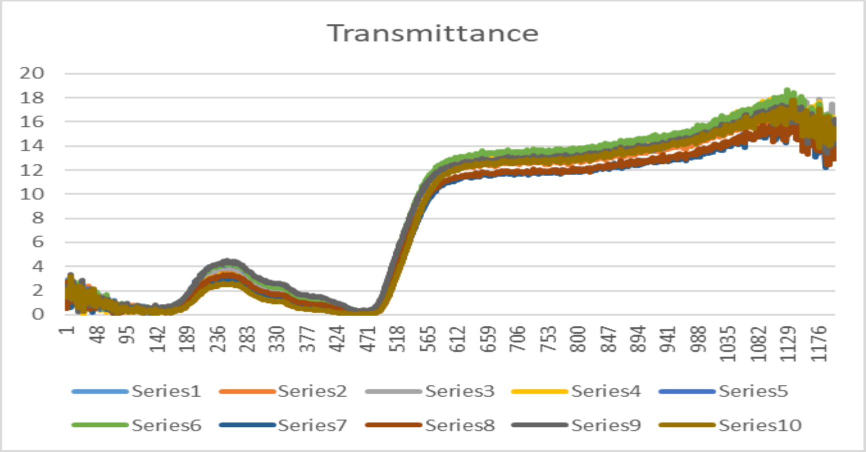
APPENDIX XI: Absorbance of rows 2



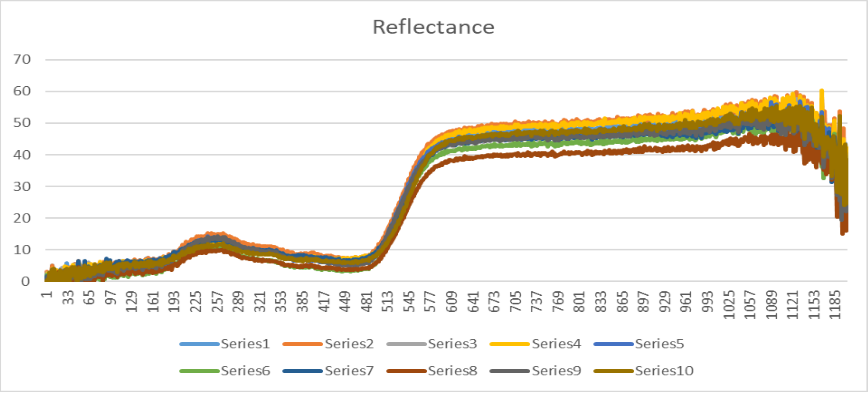
APPENDIX XII: Reflectance of row 4



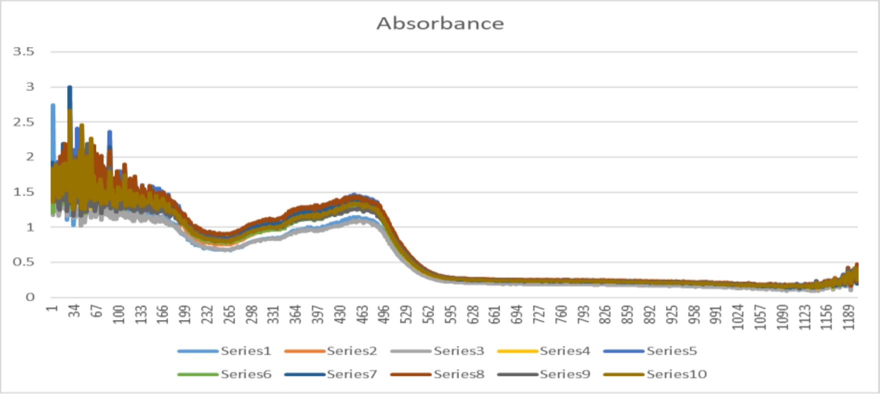
APPENDIX XIII: Transmittance of row 5



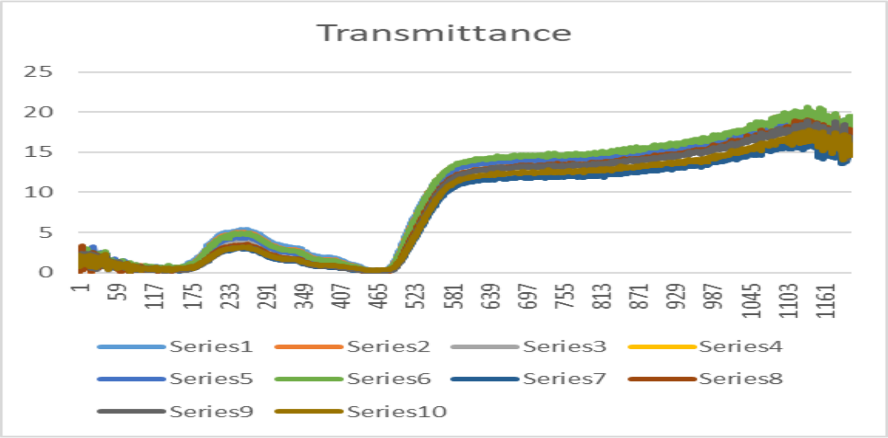
APPENDIX XIV: Reflectance of row 5



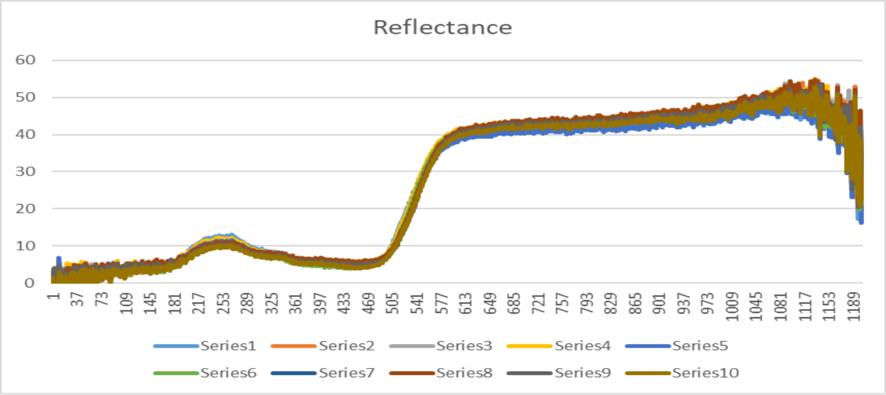
APPENDIX XV: Absorbance of rows 7



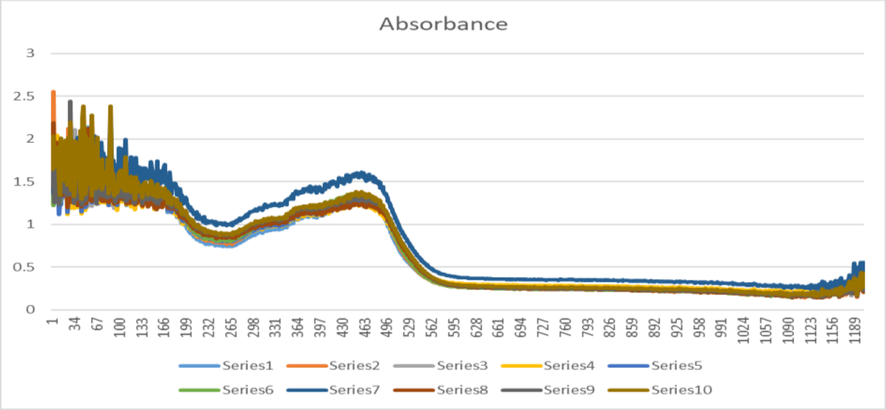
APPENDIX XVI: Transmittance of row 8



APPENDIX XVII: Reflectance of row 8



APPENDIX XIX: Absorbance of rows 8



DECLARATION

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STATEMENT ON CONSULTATION PRACTICES

As a supervisor of Siakwah Gideon Narteh (IPKE4G), I here declare that the final essay/thesis/[✓ master's thesis]/portfolio[3] has been reviewed by me, the student was informed about the requirements of literary sources management and its legal and ethical rules.

I [✓ recommend]/don't recommend[4] the final essay/thesis/[✓ master's thesis]/portfolio to be defended in a final exam.

The document contains state secrets or professional secrets: yes [✓ no]

Gödöllő. 2023-04-27

Jancsó Mihály

Internal supervisor

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CNDVI	Chlorophyll Normalized Difference Vegetation Index
PRI	Photochemical Reflectance Index
IAD	Absorbance Difference Index
CCI	Chlorophyll Content Index
WBI	Water Band Index