THESIS

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ASSESSING THE IMPACT OF TILLAGE METHODS ON SOYBEAN PRODUCTION

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1.INTRODUCTION

Protein is a vital macronutrient that is essential for several physiological processes in all living organisms. The presence of this nutrient is necessary for the development and restoration of bodily tissues, the synthesis of vital enzymes and hormones, and the reinforcement of the immune system (Jose, 2022). With the expanding global human population, the increased understanding of nutrition, and evolving dietary choices, there is a substantial and escalating demand for protein on a global scale. Consequently, there exists a significant demand for dietary sources that are abundant in protein, including meat, dairy products, legumes, and nuts (Henchion *et al.*, 2017). Furthermore, the significance of protein in sustaining a nutritious dietary regimen resulted in the emergence of substitute protein sources, such as plant-derived proteins like soybeans (Kumar *et al.*, 2022)

Currently, approximately 75.5 million hectares of arable land worldwide is allocated for the cultivation of soybeans. Soybean expansion is occurring at a notably accelerated pace as compared to other prominent grains or oilseeds. From 1990 to 2016, there was a notable increase in soybean harvested acres, amounting to 121% growth. This expansion in the acres subsequently led to a substantial rise in worldwide soybean production, exceeding 237% (Voora et al., 2020).

Only 7% of soybean protein is ingested directly by individuals in the form of soy-based food items, including tofu, soy milk, edamame beans, and tempeh. Approximately 16% of the global soybean production is allocated for utilization in biofuel production, industrial applications, or the extraction of vegetable oils. With the exception of a minute proportion, the remaining 77% is subjected to processing in order to produce soybean meal, which is subsequently utilized as animal feed for livestock, including poultry and pigs (De Maria *et al.*, 2020). The demand for soybeans can be understood as a derived need resulting from the desire for meat. The increasing consumer demand for meat has resulted in the significant emergence of soybeans as a key agricultural product. There is a shift observed among consumers as they transition from the consumption of cereal-based items such as rice and wheat to the consumption of meat and other animal-derived products.

On a global scale, the mean yearly per capita consumption of pork and poultry was recorded as 8.02 kg in 1961, and subsequently experienced an approximate double increase, reaching 15.6 kg by the year 2003 (FAO, 2005). The transition from cereals to meat is mainly occurring in particular nations characterized by rapidly shifting eating habits. During the period from 1996 to 2006, the annual consumption of chicken in India and China experienced a significant increase of over 15%, resulting in corresponding quantities of 1.54 million tons and 14.7 million tons (FAO, 2007). Similar developments occurred with pork. Over the course of the previous decade, the Philippines and Vietnam have shown a consistent annual growth rate of over 10% in their consumption, resulting in an annual quantity above 1.1 million tons.

Growing demand for soybeans as a vital protein source in both human and animal diets necessitates a significant increase in soybean output (Terzic and Vasileva, 2018). The cultivation of soybeans is closely linked to climate changes due to its vulnerability to various environmental circumstances (Kisman *et al.*, 2021). The global trend of climate change possesses the capacity to have a substantial influence on the production of soybeans, thereby affecting both the amount and quality of yields (Araji *et al.*, 2020).

Climate change can have a substantial impact on the tillage methods used in soybean farming. Changes in precipitation patterns, soil erosion hazards, increasing temperature, and heat stress are some of the implications of climate change on soybean tillage techniques (Kvaternjak *et al.*, 2008). These implications of climate change can lead to the need for farmers to adopt different tillage practices in order to mitigate the negative effects, for example, farmers may need to implement conservation tillage methods, such as no-till or reduced tillage, to reduce soil erosion and preserve moisture in drier conditions (Lenka and Lenka, 2014)

It's important to assess the effects of tillage on soil physical parameters in soybean production. This is important because sustainable agriculture relies on this since it affects soil structure, compaction, and water retention. In this study our aims are as follows:

- Effect of tillage on soil penetration resistance (0-15 cm, 15-30 cm and 30-50 cm).
- Effect of tillage on soil moisture content (0-15 cm, 15-30 cm and 30-50 cm).
- Effect of tillage on carbon dioxide (CO_2L and CO_2Q) released from the soil.
- Effect of tillage on clod%, crumb%, small crumb% and dust% ratio.
- Effect of tillage on soybean yield.

The study intends to identify tillage strategies that maximize soybean output while avoiding soil degradation. This information will help farmers and policymakers choose sustainable agriculture strategies. The study's findings can also help build long-term soybean production and soil health guidelines.

2. LITERATURE REVIEW

2.1. Origin and distribution

The soybean (*Glycine max L.*) is a leguminous plant indigenous to East Asia, particularly China. Historical and geographical data suggests that soybean cultivation was initiated in China approximately 4,000 to 9,000 years ago (Singh et al, 2020). The cultivation of soybeans originated in ancient China, where it was primarily grown for its seeds due to their notable protein and oil composition (Kumar *et al.*, 2022). The cultivation of soybeans has gradually expanded to different regions of East Asia, including countries such as Japan and Korea. In Japan, soybeans have significant importance as a primary component in traditional culinary preparations like tofu and miso soup. On the other hand, in Korea, soybeans are utilized in the production of a fermented soybean paste known as doenjang (Dupare *et al.*, 2008).

The spread of soybean across the globe can be attributed to the processes of commerce, exploration, and colonization following to its origination in East Asia (Kumar *et al.*, 2022). The spread of soybean seeds to many regions across the globe was facilitated by European travelers and explorers, who transported these seeds to their respective countries (Dupare *et al.*, 2008). The introduction of soybean to Europe occurred during the 18th century, while its arrival in North America took place in 1765. Central and South America witnessed the introduction of soybean during the mid-to-late 1900s (The and Crop, 1956). Soybeans have emerged as a significant global crop, with extensive applications ranging from animal feed and cooking oil to the production of biofuels (Güzeler and Yildirim, 2017).

2.2 Taxonomy

The taxonomic categorization hierarchy of soybean, formally referred to as *Glycine max*, includes various levels, often including the following *Table 1*:

Table 1: taxonomy of soybean as reported (Wang and Qiu, 2018)

Order	*Fabales*
Family	*Fabaceae (Leguminosae)*
Subfamily	*Papilionoideae*
Tribe	*Phaseoleae*
Subtribe	*Glycininae*
Genus	*Glycine Willd*

Subgenus	*Soja (Moench) F.J. Herm.*
Specie	*Glycine max (L.) Merr*

2.3. Nutritional Value

The utilization of soybean seed in human and animal nutrition is attributed to its high levels of crude protein (37–39%) and fat (18–20%) (Kökten et al, 2013). The value of whole beans increases when they are separated into their constituent proteins, carbohydrates, and oils (Sindelar, 2014). The soybean flakes have a protein level of 16% (Tuğay, 2007). The nutritional composition of soybeans is shown in *Table 2* below.

Table 2: Nutritional composition of soybean (in 100 g) (Elden, 2009)

Protein	36.5 g
Carbohydrate	30.2 g
Fat	19.9 g
Saturated Fatty Acid	2.9 g
Unsaturated Fatty Acid	15.7 g
Fiber	9.3 g
Moisture	8.59 g
Ash	4.9 g
Magnesium	280 mg
Calcium	277 mg
Isoflavones	200 mg
Ferrous	15.7 mg
Energy	416 kcl

According to FAO, soy proteins are recognized as significant providers of linoleic and linolenic acids, including all essential amino acids, except for methionine and tryptophan (Kesenkaş et al, 2013).

2.4. Usage of soybean

Soybean oil and soybean meal are widely recognized and extensively utilized products derived from soybeans (The and Crop, 1956). Soybean oil is widely recognized as the dominant edible oil on a global scale, while soybean meal holds utmost significance as a primary protein and energy source in animal feed formulations (Güzeler and Yildirim, 2017). Soybean oil serves as a commonly utilized cooking oil and serves as the foundational component for shortening, margarine, salad dressings, and mayonnaise. Soybean oil possesses the capability to undergo a refining process, hence enabling its utilization in the production of paints, varnishes, soap, lubricants, sealants, and medicinal oil (Amusat and Ademola, 2013). Soybean oil finds application in various industries, including the production of anticorrosion materials, cement components, construction materials, concrete additives, care oils, disinfectants, dust control agents, electrical insulation, metal coating and ink, resin and plastic, fungicides (fungal toxins), confectionery products, imitation chocolate, coffee whiteners, creams, imitation cheese, and frozen desserts (Hammond et al, 2005).

Soybean meal is considered a superior product due to its elevated caloric content, consistent composition, and exceptional digestibility (Dunstan, 1936). Dehulled soybean meal, when subjected to appropriate processing methods, serves as a highly commendable protein reservoir. Consequently, it finds extensive application in the formulation of animal feed for various livestock categories, including pigs, poultry, fish, beef, and dairy cattle, as well as specialist animals like those in the pet food industry (De Maria *et al.*, 2020).

2.5. World Production

As world statistics shows (*Table 3*), Brazil and U.S.A appear as big producer of soybeans makes around 69% of the world production.

Table 3: Soybeans world production. (USDA,2023)

World production	401,325 (1000MT)	
Country	Production (1000MT)	Production share
Brazil	163,000	41%
USA	112,837	28%

Argentina	48,000	12%
China	20,500	5%
India	12,000	3%
Rest Of the World	44,146	11%

The provided visual representation, shown as *Figure 1*, illustrates a pie chart that displays the distribution of soybean production across the globe.

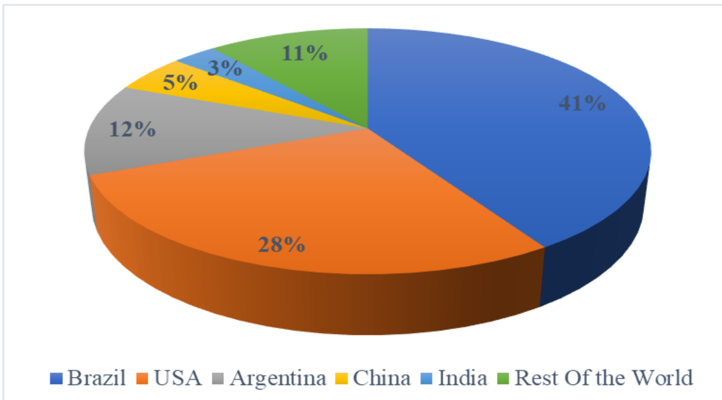

Figure 1: World production.

2.6. Morphology

The soybean plant is a vertically oriented, densely branched, herbaceous perennial with the capacity to reach a maximum height of 1.5 meters. t is an erect, bushy annual herbaceous plant with a 1.5 meter height potential (OECD, 2006). Soybean cultivars exhibit three distinct growth patterns, namely determinate, semi-determinate, and indeterminate (Bernard and Weiss, 1973). Indeterminate genotypes exhibit continuous vegetative growth during the blooming phase, while determinate genotypes cease their vegetative activity during the transformation of the terminal bud into an inflorescence, occurring at both the axillary and terminal racemes (Ningsih et al., 2019). Semi-determinate varieties exhibit indeterminate stems that undergo a sudden cessation of vegetative growth later to the conclusion of the flowering period (Nurrohman et al., 2017). Not all soybean cultivars exhibit frost hardiness, rendering them susceptible to the adverse effects of severely cold winters (Jańczak-Pieniążek *et al.*, 2021).

The initial foliage consists of unifoliate leaves that are positioned opposite each other and possess an oval shape. The subsequent foliage comprises trifoliate leaves that are arranged alternately. Additionally, compound leaves containing four or more leaflets may occasionally be observed

(OECD, 2006). The emergence of the lateral root system in a nodulated root system originates from the primary root (KSU, 2016). Most cultivars of plants possess a dense covering of fine trichomes, while there are also occurrences of glabrous types (Rao and Chaitanya, 2019). The papilionaceous flower has a tubular calyx including five sepals, a corolla consisting of five petals, namely one banner, two wings, and two keels. Additionally, it possesses one pistil and nine stamens that are fused together, with one stamen being distinctly positioned at the posterior(Jańczak-Pieniążek *et al.*, 2021). On the day before pollination, the stamens undergo elongation and congregate in a circular arrangement in the lower part of the stigma. in this stage, the elevated anthers encircle the stigma (Wang and Qiu, 2018). The length of the pod varies between two and seven centimeters, showing a straight or slightly curved shape. It consists of two carpels that are fused together at both the dorsal and ventral sutures (Rao and Chaitanya, 2019). The morphology of seeds in different kinds can vary, ranging from almost spherical to elongated and flattened (KSU, 2016).

2.7. Cultivars Selection

The selection of a soybean cultivar is a critical and challenging decision faced by soybean growers (Río, 2019). The selection of a cultivar for a certain field should be made with careful consideration of yield variability observed in state variety tests. It is important to note that picking a cultivar that is not well-suited for a given field might have a negative impact on a farmer's profitability (Palmer, 1990). The planned diversification of genetics is of utmost importance in order to encompass a suitable spectrum of maturities and herbicide resistance, while simultaneously mitigating site-specific stressors and maximizing yield potential (Carrão-panizzi *et al.*, 2009). The strategic use of diverse crop varieties that are well-suited to the specific growing conditions is crucial in mitigating potential risks, as it significantly influences the ultimate yield achieved (Río, 2019). When choosing a cultivar, keep the following things in mind.

2.7.1. Maturity Group (MG)

The maturity group of a cultivar plays a crucial role in determining the extent of vegetative development before flowering, the timing of pod-set, and the duration of frost-free days needed for its life cycle completion (Ortel *et al.*, 2020). The process of soybean blossoming is significantly influenced by photoperiod (Song *et al.*, 2019). The timing of the planting process and the prevailing weather conditions are influential factors that might impact the flowering process.

However, it is important to note that the duration of the night or darkness period significantly serves as the primary stimulus for initiating flowering (Adie and Krisnawati, 2018). In contrast to a soybean variety that exhibits a slower maturation rate, commonly referred to as "late-maturing," which necessitates an extended duration of darkness to initiate the flowering process, a soybean variety that matures relatively fast, also known as "early," demonstrates sensitivity to a reduced period of nighttime darkness (Gesch et al., 2023). The growth and development of plants are influenced by temperature and stressors, making the selection of planting dates and consideration of seasonal climate crucial in determining the duration till maturity (Wang and Shannon, 1999).

2.7.2. Herbicide Traits

In order to enhance the management of weeds, a variety of trait packages have been developed that provide herbicide resistance. These trait packages are readily accessible in the market and can be employed either individually or in combination with one another (Eck, 2013) . While the majority of soybean varieties available in the market are genetically modified, there are also conventional types that suit to those who want non-GMO products (da Silva *et al.*, 2021). When making decisions on the selection of herbicide tolerance features, it is important to take into account the potential occurrence of drift on neighboring crops (Nandula *et al.*, 2009). Consider the potential impact of drift from neighboring fields on the safety of your crops, particularly in places where inversions or physical spray drift are common phenomena (Zanatta *et al.*, 2020). In certain situations, the inclusion of specialty crops in the agricultural rotation can pose challenges in terms of adhering to plant-back limits for subsequent crops (Ali *et al.*, 2022). The most effective approach to mitigate the occurrence or endurance of herbicide-resistant weeds is primarily centered around the implementation of herbicide mode of action (MOA) rotation (da Silva *et al.*, 2021).

2.7.3. Stress Factors

Soybean cultivars are commonly evaluated for various biotic stressors, either through numerical or categorical assessments. The categorization typically includes designations such as resistant (R), moderately resistant (MR), moderately susceptible (MS), and susceptible (S) (Yan *et al.*, 2020). It is uncommon for cultivars to exhibit total tolerance towards a disease or pest. Rather, the degree of tolerance or survivorship is typically represented by a number scale (Poudel *et al.*, 2023). Seed companies may provide varying ratings based on the prevailing diseases in different regions of the country (Cho, 2013). For example, soybean cultivars in a particular location or nation are assessed for their susceptibility to white mold, whereas cultivars from another region or country are evaluated for their resistance to frog eye leaf spot (Giordani *et al.*, 2019).

2.7.4. Abiotic Stress Factors

The concept of "abiotic stress" encompasses several environmental stressors, such as drought and flooding (Araújo *et al.*, 2015). While there may exist variations among plant species in their capacity to endure drought or flooding, it is not customary for seed companies to disclose such ratings. However, it is worth noting that certain land-grant institutions may provide regional ratings in this regard (Alsajri *et al.*, 2019). Chloride toxicity and iron deficiency chlorosis are two other abiotic stresses (Fuganti-Pagliarini *et al.*, 2020). There are cultivars that can withstand both circumstances (Arya et al., 2021). Soybean cultivars can be classified into two groups, namely "includers" and "excluders," based on their response to chloride (Sabagh *et al.*, 2019) . Soybean roots that possess the ability to exclude chloride salts can effectively limit their uptake, but roots that lack this exclusion mechanism are unable to prevent chloride uptake (Pi *et al.*, 2016). Elevated soil chloride levels can have detrimental effects on both "includer" and "excluder" plant species. However, under conditions of high chloride concentration, it is crucial to prioritize the cultivation of excluder plant varieties (Xu *et al.*, 2023). In regions where the presence of chloride in water is attributed to seawater intrusion or flooding, or in cases where substantial quantities of potassium chloride fertilizer have been employed, it may become essential to take certain measures (Yan *et al.*, 2020).

2.7.5. Yield Potential and Stability

The absence of a singular correct or optimal cultivar implies that yield is not the predominant criterion for selection (De Bruin and Pedersen, 2008). The term "yield potential" refers to the highest quantity of output that a specific cultivar may generate under a given environment (Milioli *et al.*, 2018). The concept of yield stability refers to the performance of a cultivar over diverse situations, including factors like soil characteristics, management practices, weather patterns, and the passage of time (Krisnawati and Adie, 2019). In order to ensure a precise assessment of yield gene expression, it is important to conduct comparative evaluations of cultivars (Hunde *et al.*, 2019).

2.7.6. Other factors include.

2.7.6.1. Lodging: The issue of standability arises due to a range of genotypes and production circumstances (Kitabatake *et al.*, 2019). Soybeans have increased susceptibility to lodging when planted at higher seeding rates, in irrigated locations, or in areas characterized by elevated fertility levels, leading to enhanced plant height (Bai *et al.*, 2022). If the concern is lodging, it is advisable to select cultivars with a high lodging score (Mueller et al., 2019).

2.7.6.2. Shattering: Although modern genetics has largely mitigated this concern, it is worth noting that specific varieties exhibit differential susceptibility to fragmentation (Krisnawati *et al.*, 2020). The careful selection of cultivars exhibiting favorable shattering scores is of crucial significance in such conditions, as pod shattering is commonly associated with delays in the harvesting process (Mohammed *et al.*, 2014).

2.7.6.3. Seed Cost: In order to optimize total earnings, it is essential to achieve a harmonious equilibrium between the expenditure on seed purchasing and the expected yield (Murphy *et al.*, 2009). It is not always the case that cultivars with higher yields are the most economically beneficial (Mueller et al., 2019). The selection of seed characteristics adapted to the specific stressors present in a particular field can lead to a reduction in seed prices (Morsy *et al.*, 2017).

2.8. Ecological Needs

The ecological demands of soybeans pertain to the specific environmental conditions and resources necessary for the optimal growth and prosperity of soybean plants. These requirements include.

2.8.1. Rainfall

Soybeans have the potential to be cultivated throughout the year in tropical and subtropical regions, depending upon the availability of water. Specifically, soybean crops necessitate a substantial water supply ranging from 400 to 500 mm throughout the course of a single growing season (Gim et al., 2017). During the stages of germination, flowering, and pod production, a significant need for moisture is crucial. However, during the ripening phase, dry weather becomes necessary (Willaarts et al., 2011). Soybeans have the ability to tolerate short durations of waterlogging;

however, the rainy season is a notable challenge due to the potential for seed deterioration (Nimje, 2017).

Soybeans have the capacity to achieve yields with a minimum of 180mm of in-crop rainfall; nevertheless, it is important to note that under less-than-perfect conditions, a substantial loss in yield ranging from 40% to 60% can be anticipated (Molden, 2007). The optimal range for annual precipitation is between 500 and 1000 millimeters (Rockström et al., 2009). Crop failure is a probable outcome in the event that the crop is subjected to a precipitation level below 180mm. The specific kind of soil and the quantity of pre-existing soil moisture are factors that influence this outcome (Allan, 1998).

2.8.2. Temperature

The optimal conditions for soybean growth involve warm and humid weather. It is recommended that soil temperatures exceed 15°C to ensure proper germination, while temperatures ranging from 20 to 25 °C is desirable for growth (Setiyono *et al.*, 2007).

The cultivation of this crop occurs in regions characterized by tropical, subtropical, and temperate climates, where warm temperatures prevail (Tenorio, 2016). Soybeans exhibit the capacity to thrive in extreme temperature conditions, encompassing both elevated and reduced ranges. However, it is noteworthy that their development rates demonstrate a deceleration when subjected to temperatures of 35°C and below 18°C (Neumann, 2011). In certain cultivars, the beginning of flowering may be delayed when exposed to temperatures below 24°C (Tacarindua, 2013). In order to facilitate optimal crop production, it is recommended that minimum temperatures of 15°C and 10°C be maintained for growth (Major *et al.*, 1975).

2.8.3. Soil

Soybeans exhibit optimal growth on a range of soil types, including sand, clay loams, and fertile alluvial soil (Ghulamahdi et al., 2009). It is recommended that the soil have a pH range between 5.6 and 7.0, possess fertility, contain ample calcium, and demonstrate effective drainage (Nimje, 2017).

The germination of seeds is impeded by soils that have high levels of sodium and salinity (KSU, 2016). Water logging also has a detrimental impact on the crop (Almeida *et al.*, 2018). An increase in soil pH from 4.5 to 7.0 resulted in a 20% increase in protein concentration and a 16% decrease in oil concentration (Nimje, 2017).

Soybeans have the ability to withstand soil conditions that are slightly acidic (IFAD, 2019). However, the presence of aluminum (Al) and manganese (Mn) toxicity in these soils makes them unable to withstand highly acidic conditions, specifically those with a pH level below 4.5 (Pannar, 2006). On the contrary, it is not recommended to cultivate soybeans in soils characterized by a pH level over 8, as this poses a potential threat of micronutrient deficiencies, particularly in zinc (Zn) and iron (Fe) (Almeida *et al.*, 2018).

2.8.4. Photoperiod

The timing of blooming in soybean plants is regulated by their response to changes in daylength or photoperiod (Setiyono *et al.*, 2007). Various varieties of soybeans exhibit distinct responses to changes in photoperiod (Palmer and Gibbons, 2018). While many species of plants require longer daylight periods to initiate the flowering process, there are other types that may commence flowering even with comparatively shorter durations of daylight (Asis *et al.*, 2022).

Soybeans, classified as short-day plants, exhibit a blooming pattern that is restricted to specific intervals of sunlight, corresponding with the gradual reduction in day length (Harrison *et al.*, 2021). Every variety possesses a specific minimum duration of time that must elapse before it initiates the process of flowering (Setiyono *et al.*, 2007). The duration of daylight hours exhibits variation across different geographical locations and regions, hence exerting an influence on the developmental stage of the species one opts to produce (Acock et al., 1994). The soybean plant can be classified as a short-day plant, although its response to day length is contingent upon factors like variety and temperature. Furthermore, cultivated soybean varieties are only suitable for relatively minor variations in latitude (Zheng et al., 2009).

The length of the day has an impact on the rate of crop development. In the case of crops with shorter day requirements, extended day lengths might result in delayed blooming and the growth of taller and more nodular plants (Lemes *et al.*, 2021). Flowering in late-maturing cultivars is accelerated by the presence of short days (Merr and Quebedeaux, 1975).

2.8.5. Nutrients Requirement

The nutritional requirements of a soybean crop are contingent upon various factors, including soil composition, climatic conditions, cultivar selection, yield potential, cropping methodology, and management practices (Agriculture and Horticulture Development Board, 2019). The table below (*Table 4*) lists the roughly equivalent amounts of nutrients absorbed by the soybean crop. While the nutrients in the grain are taken out of the soil, the nutrients in the stubble are recycled and made accessible to the following crop (Bagale, 2021). The elements that are most readily absorbed include nitrogen, phosphorus, and potassium (Zhang *et al.*, 2019). In order to extract 240 kg of nitrogen, 45 kg of P2O5, and 100 kg of K2O/ha from a soybean crop yielding 3000 kg/ha (Sharanappa, 2021).

Table 4: Nutrient demand/uptake/removal by soybean crop. (IFA ,1992)

Nutrient	Grain only	Total
	Kg/mt grain	
N	65	81
P2O5	14	14
K2O	23	33
MgO	5	18
CaO	4	24
S	2	3
	g/mt grain	
Fe	n.a	366
Mn	20	90
Zn	17	61
Cu	16	25
B	n.a	39
Mo	n.a	7

2.9. Production Methods

2.9.1. Emergence

Soybean germination can commence once the seed has imbibed water amounting to approximately 50% of its weight. The initial structure to emerge from the seed is referred to as the radical, which is alternatively recognized as the primary root. Subsequently, the cotyledons, commonly referred to as seed leaves, are propelled by the elongating hypocotyl, or stem, which subsequently emerges and initiates growth in the direction of the soil's uppermost layer (Zou and Hou, 2017). Once it emerges, the hypocotyl's hook-like structure gradually straightens out as the cotyledons lengthen. The duration of emergence might vary from five to 10 days, depending on factors such as cultivar type, moisture levels, temperature, and planting depth. In addition, the lateral roots of the primary root are initiating a process of expansion. Root hairs become visible within a span of five days after the planting process. These initial days are crucial as the root hairs play a pivotal role in absorbing nutrients and water, serving as the principal organs for this purpose in plants (Department of Agriculture, 2012). The taproot will undergo further growth and branching, facilitating the lateral roots' penetration towards the central region of a 30-inch row of plants throughout a span of five to six weeks. The predominant distribution of soybean plant roots is observed within the uppermost 6 to 12 inches of soil, with subsequent growth extending to a depth ranging from 4 to 8 feet. Soybeans should be sown using a range of 1 to 112 inches, with an upper limit of 2 inches (Nimje, 2017). Planting seeds at a greater depth can potentially decrease the germination rate and overall stand count, as soybeans sometimes have difficulties in penetrating compacted soil. The utilization of rotary hoeing can be beneficial for both the initial control of weeds and facilitating the emergence of seeds by breaking through compacted soil surfaces. In the event that soils remain cold, the application of minimal quantities of fertilizer (phosphorus or potassium, if deemed required) in a lateral arrangement positioned slightly beneath the seed has the potential to enhance initial plant development (Lamichhane *et al.*, 2020). Salt damage can result from fertilizer put too close to the seed or in the furrow. Salt affects soybeans more than maize. If the field has not been planted in soybeans in four years or has been flooded, the seed should be inoculated with Rhizobium japonicum bacteria (such as Brady) to create nodules on the roots of the soybean plants that will supply a significant portion of their nitrogen (Hata and Futamura, 2020).

2.9.2. Weeding

The competition between weeds and soybeans for essential resources such as light, moisture, and nutrients, particularly during the first stages of growth, has emerged as a significant factor impeding soybean productivity (Seid et al., 2021). Perennial grasses have been identified as the primary weed species that pose significant challenges to soybean cultivation (Prachand et al., 2015). They are challenging to control and do substantial harm (Rüdell *et al.*, 2021). In the production of soybeans, broad-leaved weeds are not as harmful as grasses and sedge (Hock *et al.*, 2006).

During the initial stages of the season, the prevalence of weeds surpasses that of soybeans due to their relatively weaker competitive abilities (Perkasa et al., 2015). The presence of weeds in the field during harvest might also contribute to a decline in the quality of grades (Seid et al., 2021). Weeds exert an influence on fertilizer utilization as a result of their competition with crops for nutrients (Gawęda *et al.*, 2020). It is advisable to refrain from using fertilizers until after the initial weeding process due to their potential to stimulate weed growth (Prachand et al., 2015). Weed management encompasses both direct and indirect approaches, targeting the control of weeds and the manipulation of the soil and agricultural system (Caldas *et al.*, 2023). There are several potential approaches for weed management, including preventive, cultural, mechanical, and chemical strategies (Debela *et al.*, 2023).

In order to ensure the sustainability of agricultural systems, it is imperative to integrate management approaches while considering the soil, climatic, and socioeconomic characteristics of the producer (Lee, 2015). The prevention of weed entry into a new region is often considered more favorable due to the increased difficulty and cost associated with eradicating weeds once they have already spread (Agahiu AE, 2020). The initial step in achieving successful crop cultivation is the careful selection of suitable cultivars (da Silva *et al.*, 2013).

The cultivation of a single crop over an extended period or the adoption of identical management practices for a group of crops can lead to the dominance of a limited number of weed species within the ecosystem, ultimately posing significant challenges for their eradication (Plus, 1997). The implementation of crop rotation as a management approach has been found to enhance soybean productivity (Metwally et al., 2009). Herbicides have demonstrated efficiency in weed control; nevertheless, their use may accidentally promote the development of resistant biotypes, increasing the problem within the local region (Perkasa et al., 2015). The maintenance of a weed program necessitates the implementation of measures to prevent weed seed production, minimize the transmission of weed seeds through harvesting machines, and utilize uncontaminated seeds for all crops in the rotation (Agahiu AE, 2020). The utilization of multiple weed control techniques can be advantageous in mitigating weed damage to levels that fall below the economic threshold (Seid et al., 2021).

2.9.3. Harvest

It is important to immediately harvest soybeans after they have reached maturity, as delays in harvesting might result in increased losses due to the rapid drying of the soybeans (Herbek, 2006). The optimal timeframe for harvesting soybeans with minimal loss is limited to a few days because to the rapid variability in moisture content (KSU, 2016). The optimal moisture content for harvesting soybeans ranges from 13 to 15 percent, although a broader acceptable range is between 11 and 20 percent (Herbek, 2006). A generally accepted guideline is to start the process after the moisture content reaches a range of 14-16%, and to sustain it until the field is harvested (Department of Agriculture, 2012) . The increase in seed damage and combination shattering losses is observed as the moisture content decreases (Idaryani *et al.*, 2021).

It is essential to start the harvesting process promptly when the moisture content attains a level of 13 % and to ensure its completion before reaching a threshold of 11% (Pannar, 2006). Below this threshold, there is a substantial increase in shatter losses and seed damage losses (Ni *et al.*, 2023).

2.9.4. Storage

The post-harvest system includes an essential stage known as storage (Capilheira *et al.*, 2019). During this phase, soybeans are subjected to storage practices in order to guarantee their accessibility during periods when crops are not being cultivated, and to maintain their quality for an extended duration(Shelar et al., 2008).

The primary functions of soybean storage include facilitating a delay of soybean utilization, guaranteeing the availability of seeds for subsequent crop cycles, ensuring a consistent and uninterrupted supply of raw soybeans for processing enterprises, and maintaining equilibrium between soybean supply and demand, thereby promoting market price stability (Mabehla et al., 2018).

The quality of all grains, including soybeans, begins to deteriorate upon harvesting, storage, or processing (Capilheira *et al.*, 2019). The post-harvest management of soybeans is influenced by various factors, including biological aging, microbiological contamination, and insect infestation (Liu, 1997). In order to mitigate the fluctuations in soybean quality that occur during storage, it is essential to regulate environmental elements such as temperature, moisture, and pests, as well as manage inventory through the implementation of efficient stock rotation strategies (Mbofung *et al.*, 2013).

The storage and handling of soybeans can lead to measurable losses (Arends-Kuenning *et al.*, 2022). The greatest source of damage to soybeans during handling and shipping is freefall, which increases the susceptibility of the beans to moisture absorption, enzymatic activity, and mold growth (Mbofung *et al.*, 2013).

3.MATERIALS AND METHODS

3.1. Location

The field experiment was conducted at Szárítópuszta, Gödöllő town of Hungary. The Experimental and Training Farm of the Hungarian University of Agriculture and Life Sciences is located about 2 km east of the Hungarian University of Agriculture and Life sciences at (N 47° 35' 44", E 19° 22' 10") longitude and latitude respectively. The data was collected from the end of spring, summer, and autumn (May, June, July, August, September, and October). The figure below (*Figure 2*) shows the studying field where the research was conducted.

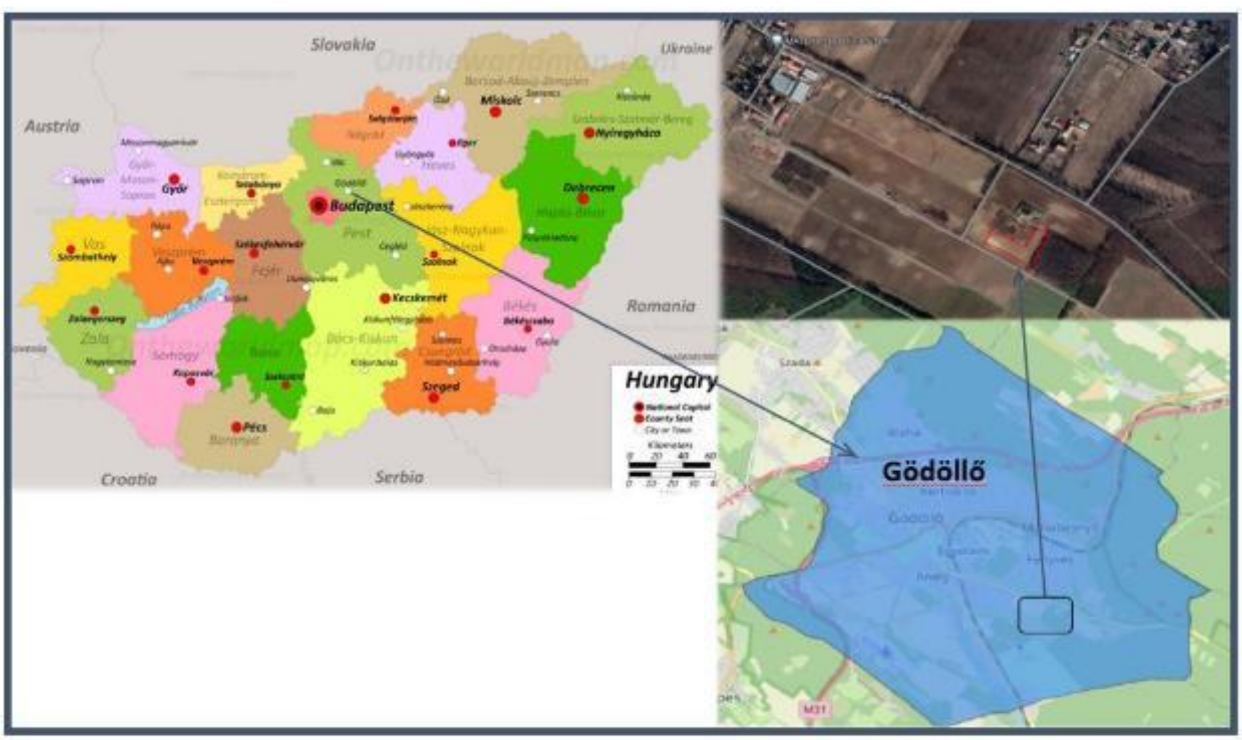

Figure 2: Map of Gödöllő to show the studying area.

3.1.1. The Soil

The Gödöllő sites are situated within the hilly Gödöllő-Monori region of the Northern Hungarian Mountain Range. The predominant soil types in the region are Luvisols, Cambisols, Arenosols, and Chernozems. The soil utilized in the experiment exhibits the subsequent physical features: Sand is observed within the first 60 cm, succeeded by a layer of sandy loam and clay loam situated at depths ranging from 200 to 300 cm beneath the surface. The layer that encompasses the humus material measures 35 centimeters in width. Calcium carbonate ($CaCO_3$) is observed at a depth of 60 centimeters. A depth of less than four meters of groundwater is submerged. Certain regions of the soil profile exhibit a limestone layer with an approximate depth of 2 meters (Tolner et al. 2010).

3.1.2. Climate data

Climatic data from the genetic experimental field, it's about 3 km-s away from experimental field. From January to December 2022. The table below (*Table 5*) show the climatic condition (rainfall and temperature) of the studying area.

Table 5: temperature and rainfall of the experimental area

Month	Temperature °C	Rainfall mm/h
January	0.9	0.1
February	4.5	0.2
March	5.9	0.1
April	9.4	0.4
May	17.4	0.2
June	22.3	0.3
July	24.0	0.2
August	23.8	0.2
September	15.3	0.6
October	12.5	0.1
November	5.9	0.3
December	1.7	0.6

The graph below (*Figure 3*) shows the amount of temperature in experimental field.

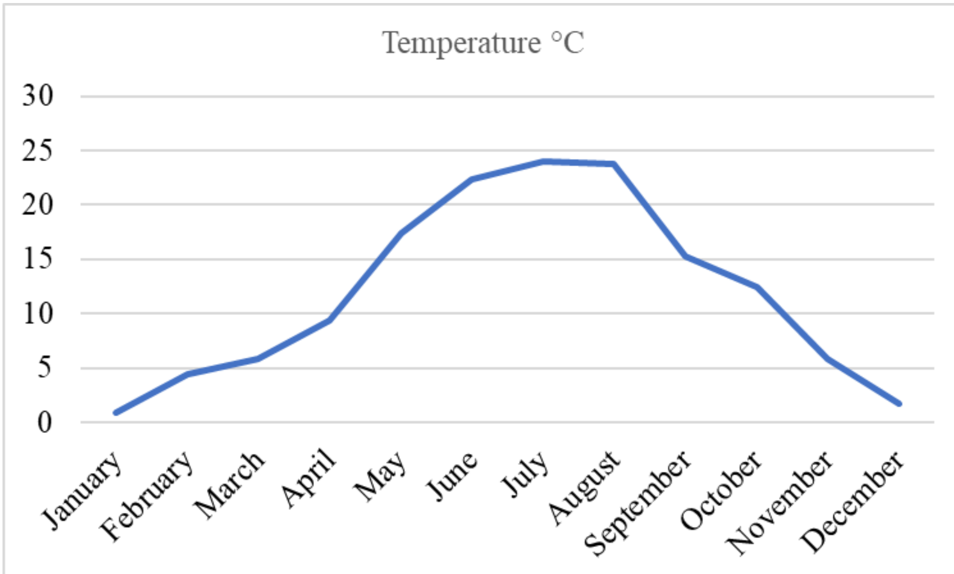

Figure 3: Temperature of the experimental area

The graph below (Figure 4) shows the rainfall trend in the experimental field.

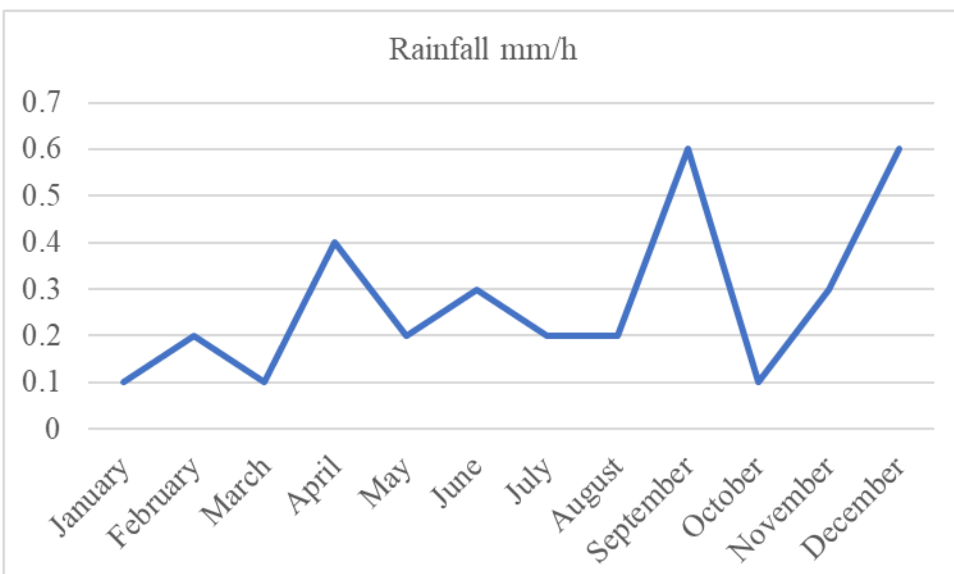

Figure 4: Rainfall of the experimental area

3.2. Experimental Setup

The study employed a randomized strip design, consisting of three replications and three treatments. The experiment involved three replicates of two tillage treatments and direct drilling, resulting in a total of 9 field plots. Each field plot was 50 meters in length and 6 meters in width. All the plots were parallel in terms of their lengths. As shown in *figure 5* below.

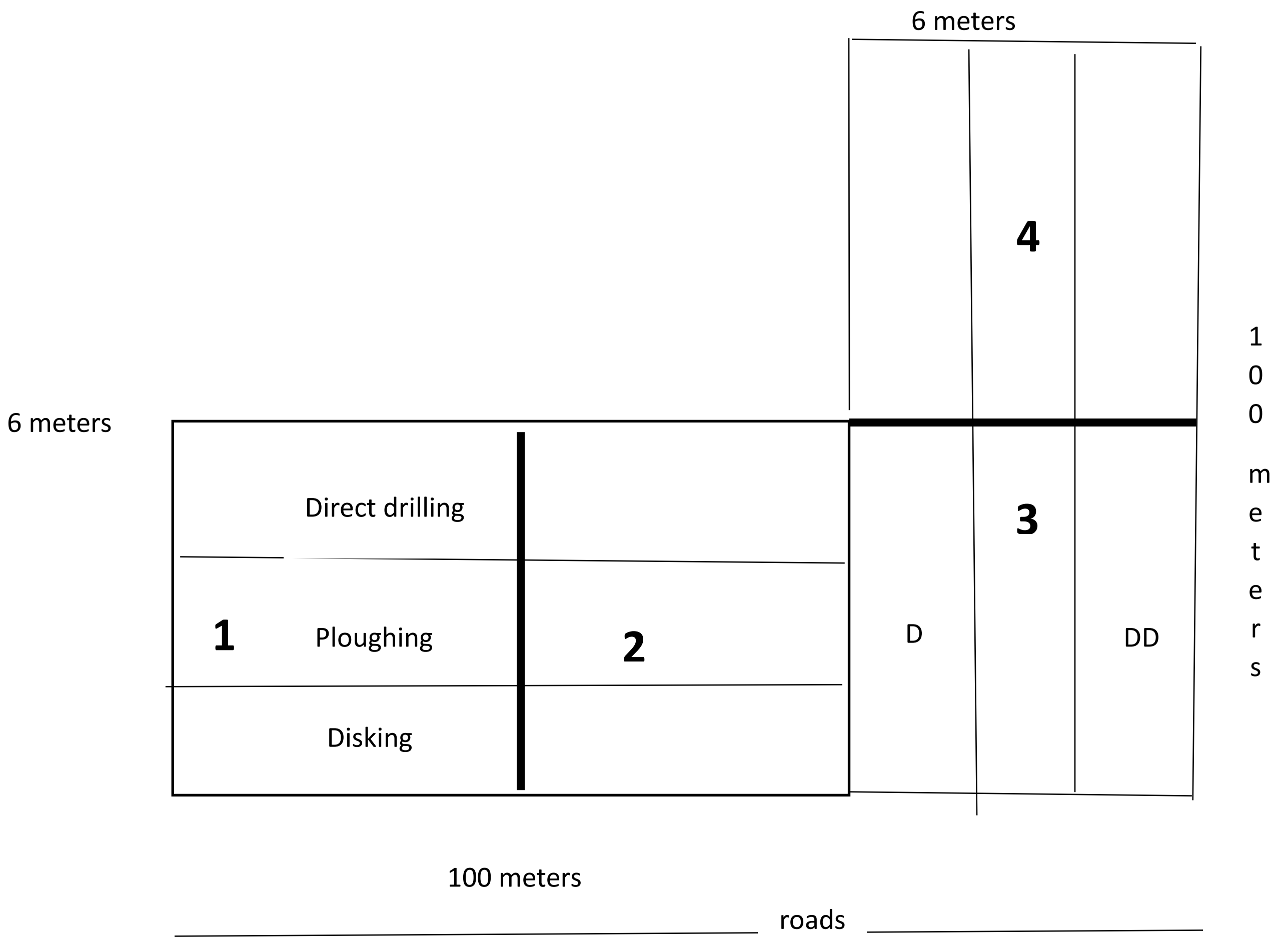

Figure 5: Experimental field setup

3.3. Treatments

3.3.1. Direct Drilling (DD)

Direct seed drills are specifically engineered to facilitate the direct placement of seeds into the residual plant material of the preceding crop while minimizing soil disturbance to a minimal 5-20% of the soil surface that is actually cultivated. Depending on the specific circumstances, this phenomenon may yield a range of benefits with varying degrees of significance (Ordóñez Fernández *et al.*, 2007).

The availability of water is a significant limitation on crop productivity in numerous regions across the globe. Direct drilling is a cultivation technique that involves leaving the soil undisturbed and allowing harvest leftovers to remain on the surface. This practice effectively protects against evaporation, hence preserving germination moisture. Economic factors also contribute to this phenomenon, as the financial feasibility of soil tillage is compromised in regions where inadequate water availability severely hampers crop productivity. By implementing a straw cover, the majority of the soil's surface can be maintained in an undisturbed state, hence providing efficient protection against erosion caused by wind and water. The process of erosion yields negative implications for both the economy and the environment due to its capacity to deplete soil and essential plant nutrients (Yan *et al.*, 2018).

3.3.2. Ploughing (P)

The plough, an agricultural implement, is employed to agitate or aerate the soil in anticipation of sowing or planting. In contemporary agricultural practices, tractors have replaced the traditional method of employing oxen and horses to push ploughs. The earth is sliced and loosened by a blade that is affixed to a plough (Heckrath *et al.*, 2006).

Throughout the course of history, farming has played a key role in various societies. The oldest ploughs were designated as "*aratrums*" by the Romans due to their absence of wheels. During the period of Roman civilization, it was the Celtic population who pioneered the utilization of wheeled ploughs. The depressions formed by the plough are commonly referred to as furrows (Kouwenhoven *et al.*, 2002).

Modern ploughed areas are dried before being harrowed and planted. Plowing and cultivating the top 12 to 25 centimeters (5 to 10 in) of soil, where most plant-feeder roots grow, evens out its composition (Stockfisch et al., 1999).

3.3.3. Disking (D)

Disking is a soil preparation technique commonly employed subsequent to tillage, regardless of whether it was conducted at a deep or superficial level. The formation of furrows and ridges in the soil can be attributed to the actions of plowing, granulation, and inversion (Shavazov et al., 2022). Moreover, the process of disking serves to eliminate clods and crusts present on the surface of the soil, so improving soil granulation, promoting surface uniformity, and reducing the occurrence of soil erosion. The activity is consistently conducted at a depth ranging from 10 to 15 centimeters (4 to 6 inches), a shallower depth compared to plowing (Birkás *et al.*, 2002).

Dredging is the finest way to handle soybean and maize stalks after harvest. Crop residue is chopped and mixed into the soil to accelerate plant matter decomposition and improve soil management. Adding agricultural lime to soil is a great disking farm management practice to improve ph. (Birkás *et al.*, 1999) .

3.4. Parameters

3.4.1. Soil Penetration Resistance (SPR)

Soil penetration resistance, also known as soil compaction or soil strength, is the measure of force or resistance encountered during the process of soil entry using a penetrometer or any other relevant instrument. The variable in question holds significant importance in tillage and agricultural practices due to its influence on root development, seedling emergence, water infiltration, and overall crop output (Vaz *et al.*, 2011).

The soil penetration resistance was assessed using a penetrometer. The penetrometer probe was inserted into the soil vertically, with a slow and steady motion, at several depths ranging from 0-15 cm, 15-30 cm, and 30-50 cm. Maintaining a steady, vertical attitude is crucial in order to achieve precise readings. As penetrometer penetrates the soil, the resistance displayed on the penetrometer's gauge or screen. This force indicates the soil penetration resistance at the specific depth. These penetration measurements were repeated three times in each treatment (Souza *et al.*, 2021).

3.4.2. Soil Moisture Content

The moisture content of soil is a significant factor in the field of agriculture due to its direct influence on the well-being of crops, their productivity, and the growth of plants. Soil moisture content is defined as the ratio of the weight of water contained in the soil to the total weight of the soil and is widely utilized as an indicator of the soil's water content. In order to enhance the efficiency of irrigation practices, it is important to carefully select appropriate timings and quantities for irrigation, while also ensuring the avoidance of excessive or insufficient watering of crops. This necessitates the monitoring and management of soil moisture content (Heathman *et al.*, 2003).

The tensiometer is comprised of three main components: a ceramic tip, a vacuum gauge, and a tube filled with water. The ceramic probe was carefully put into the soil at specific depths, namely 0-15 cm, 15-30 cm, and 30-50 cm. Subsequently, the gauge was employed to quantify the tension necessary for water extraction from the soil. Vacuum gauge will display the tension required to extract water from the soil. Lower tension values indicate higher soil moisture content. Tensiometer readings provide insights into the soil moisture status. This measurement was done three times in each treatment (Bogena *et al.*, 2007).

3.4.3. Carbon dioxide flux

The emissions of carbon dioxide (CO_2) associated with tillage in the field of agriculture have garnered significant attention due to their implications for climate change and the phenomenon of global warming. Tillage is a mechanical procedure employed to disrupt the soil in order to enhance soil composition, control weed growth, and facilitate the preparation of the soil for the purpose of planting. Nevertheless, certain tillage methods have the potential to exacerbate greenhouse gas concentrations by releasing carbon dioxide (CO_2) trapped in the soil into the atmosphere (Ussiri and Lal, 2009).

The EGM-5 CO_2 Analyzer utilizes infrared absorption technology to quantify the CO_2 concentration in a given gas sample. The content of CO_2 in the gas sample is determined by the analyzer through the measurement of infrared light absorption by CO_2 molecules. The concentration is commonly expressed in units of parts per million (ppm) or percentage (%), and it will be visually presented on the screen of the analyzer. This measurement was done three times in each treatment (Zhang *et al.*, 2022).

3.4.4. Clod %, Crumb %, and Dust %

Clod - When soil is displaced from its original position within the soil profile as a result of tillage or other agricultural activities, it tends to aggregate into a clumpy or densely packed mass. Clods exhibit variations in size, hence posing potential detriments to the establishment of seedlings, the growth of their roots, and the overall integrity of the soil composition (Schapel et al., 2019).

Crumb - The term "soil crumb," sometimes known as "soil aggregate," pertains to an aggregation of small soil particles that are loosely interconnected. The utilization of these small fragments aids in creating an optimal soil composition that facilitates the penetration of roots, infiltration of water, and provision of adequate aeration. The crumb structure of soil provides valuable insights into its health, indicating the presence of abundant organic matter and thriving microbial activity (Saberian and Li, 2019).

Dust - Within the field of agriculture, the term "dust" commonly implies tiny soil particles that possess a powdery consistency and have the propensity to become airborne as a result of tillage, wind erosion, or other forms of disruption. Excessive dust can pose significant challenges due to its potential to induce topsoil erosion, soil degradation, and air quality issues (Rashki *et al.*, 2013).

The four parameters were measured by the utilization of Sampling and Sieving procedures. Soil samples were systematically collected from multiple sites throughout the experimental field, encompassing varying depths. This process was repeated three times for each treatment.

The soil samples performed a process of sieving, wherein a sequence of sieves with varying mesh sizes was employed to segregate the soil particles according to their respective sizes.

Subsequently, the soil that remained on each sieve was measured in terms of weight in order to ascertain the proportion of distinct particle sizes, which is indicative of the existence of clods, crumbs, and dust.

3.4.5. Yield

In agriculture, "yield" refers to the volume of a crop or agricultural product produced per square foot of land or per hour of labor. It is an important indicator of the effectiveness and efficiency of agricultural operations and is frequently expressed in terms of weight (e.g., kilos or bushels per acre) or other suitable units (Liu *et al.*, 2008). The harvesting was done by machine ~~i.e.~~ harvester and product was weigh in each treatment by using kg/h unit.

3.5. Data Analysis

For the statistical evaluation of the results, we used the Explore and ANOVA modules of the IBM SPSS V.23 software. The effect of tillage on different physical soil parameters and production of soybean was analyzed using one-way ANOVA at a 0,05 level of significance. Values are given as the mean ± standard deviation. LSD (least significant difference) tests were used to determine the significant difference among data. The statistical significance level was $p<0,05$.

4.RESULTS AND DISCUSSION

This chapter compiles the main result and analyses and discussion of the data and observation obtained from the experimentation.

4.1. Soil Penetration Resistance 0-15 cm (MPa)

There was a significant effect of tillage in soil penetration resistance between 0-15 cm at the $p<0.05$ level for the three treatments [$F(2, 51) = 3.45$, $p = 0.039$].

Anova result of the soil penetration resistance at the depth of 0-15 cm as shown in the *table 6* below.

Table 6: Soil Penetration Resistance at 0-15 cm (MPa)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	17.296	2	8.648	3.451	0.039
Within Groups	127.820	51	2.506		
Total	145.116	53			

The graph below (*figure 6*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against soil penetration resistance at 0-15 cm depth.

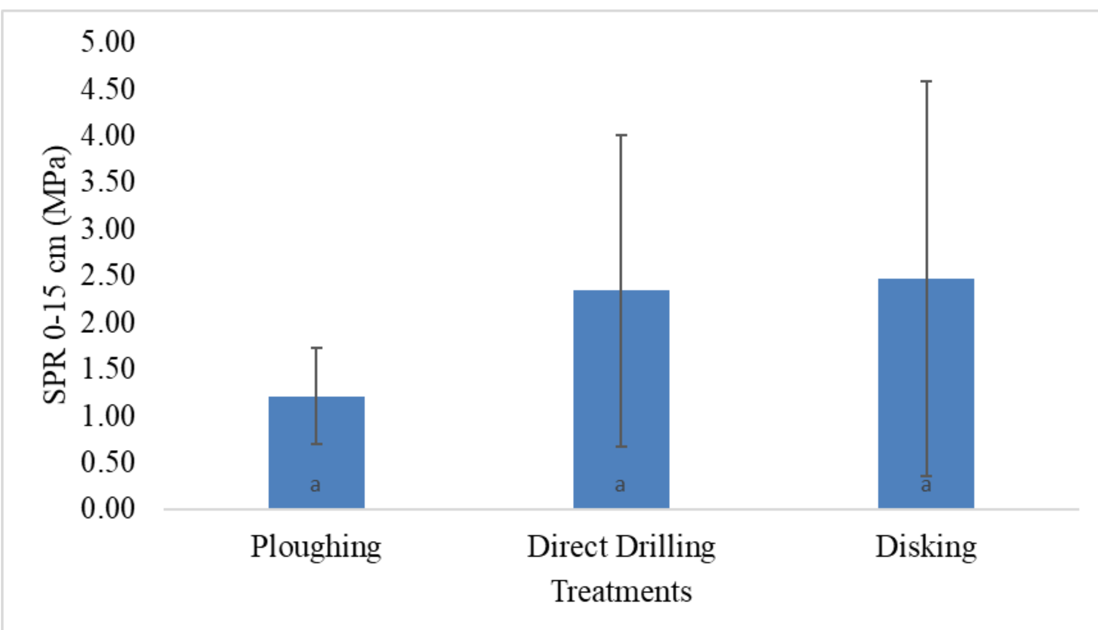

Figure 6: Graph of Soil Penetration Resistance 0-15 cm (MPa)

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between the mean score of both three treatment Disking tillage (2.47±2.115), Ploughing tillage (1.21±0.519) and Direct Drilling (2.34±1.666).

4.2. Soil Penetration Resistance 15-30 cm (MPa)

There was a significant effect of tillage in soil penetration resistance between 15-30 cm at the $p<0.05$ level for the three treatments [$F(2, 51) = 1.04$, $p = 0.362$].
Anova result of the soil penetration resistance at the depth of 15-30 cm as shown in the *table 7* below.

Table 7: Soil Penetration Resistance at 15-30 cm (MPa)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	12.040	2	6.020	1.036	0.362
Within Groups	296.254	51	5.809		
Total	308.294	53			

The graph below (*figure 7*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against soil penetration resistance at 15-30 cm depth.

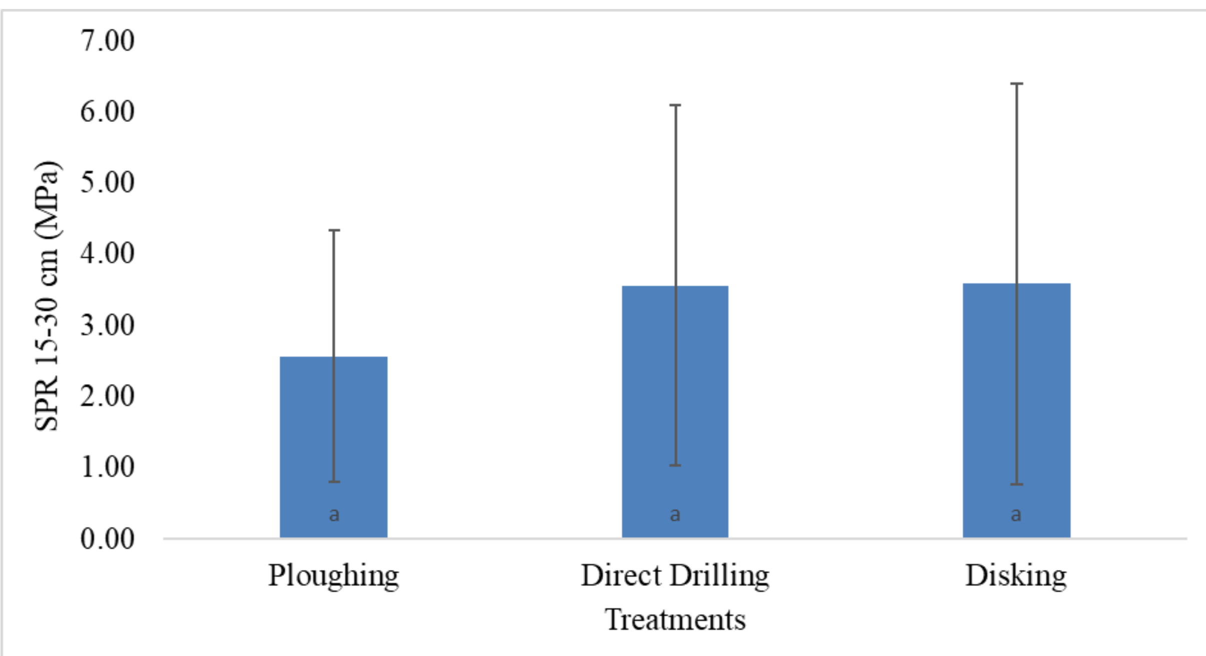

Figure 7: Graph of Soil Penetration Resistance 15-30 cm (MPa)

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between the mean score of the three treatments, Disking tillage (3.58±2.81), Ploughing tillage (2.57±1.76) and Direct Drilling (3.56±2,53).

4.3. Soil Penetration Resistance 30-50 cm (MPa)

There was a significant effect of tillage in soil penetration resistance between 30-50 cm at the $p<0.05$ level for the three treatments [$F (2, 51) = 2.68$, $p = 0.078$].

Anova result of the soil penetration resistance at the depth of 30-50 cm as shown in the *table 8* below.

Table 8: Soil Penetration Resistance at 30-50 cm (MPa)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	23.625	2	11.813	2.682	0.078
Within Groups	224.644	51	4.405		
Total	248.269	53			

The graph below (*figure 8*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against soil penetration resistance at 30-50 cm depth.

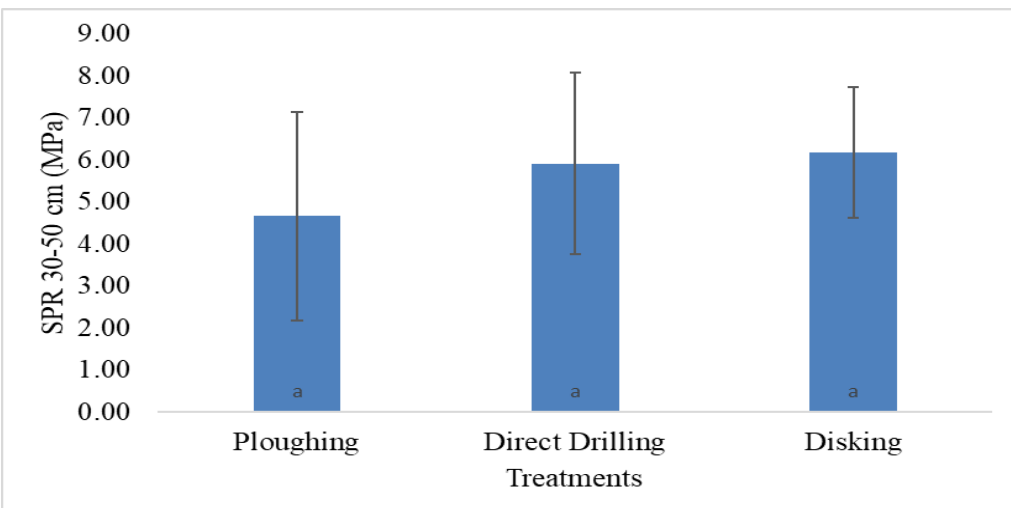

Figure 8: Graph of Soil Penetration Resistance 30-50 cm (MPa)

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between the mean score of both treatments Disking tillage (6.18±1.55), Ploughing tillage (4.66±2.48). and Direct Drilling (5.91±2.16).

The findings pertaining to soil penetration resistance (*figure 6, 7 and 8*) indicate that there is an association between depth and soil compaction. The reason for this can be attributed to the excessive workload pressure exerted by the overlying soil layer. The increasing soil density due to the overlying soil pressure results in higher penetration resistance with depth. Moreover, the cohesive forces, which are responsible for the attraction between soil particles, tend to be more pronounced in deeper layers of soil. Due to its high degree of cohesion, a greater amount of work and energy is required to penetrate the soil. My finding are supported by (Kiliç et al., 2004) , (Medina et al., 2012).

The results also indicated that ploughing tillage shows lower soil penetration resistance compared to direct drilling and disking tillage (*figure 6, 7 and 8*). This can be attributed to the more intensive nature of ploughing, which involves a complete twisting and inversion of the soil which results in the disruption of the soil structure. In contrast, direct drilling and disking methods result in reduced levels of soil disturbance. The soil structure retains greater integrity, leading to increased penetration resistance, due to reduced soil disturbance resulting from direct drilling and disking practices. The results are supported by (Schjonning and Rasmussen, 2000).

4.4. Soil Moisture Content 0-15 cm (m/m%)

There was a significant effect of tillage in soil moisture content between 0-15 cm at the $p<0.05$ level for the three treatments [$F(2, 51) = 2.82$, $p = 0.069$].

Anova results of the soil moisture content at the depth of 0-15 cm as shown in the *table 9* below.

Table 9: Soil Moisture Content at 0-15 cm (m/m%)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	71.669	2	35.835	2.820	0.069
Within Groups	648.088	51	12.708		
Total	719.757	53			

The graph below (*figure 9*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against soil moisture content at 0-15 cm depth.

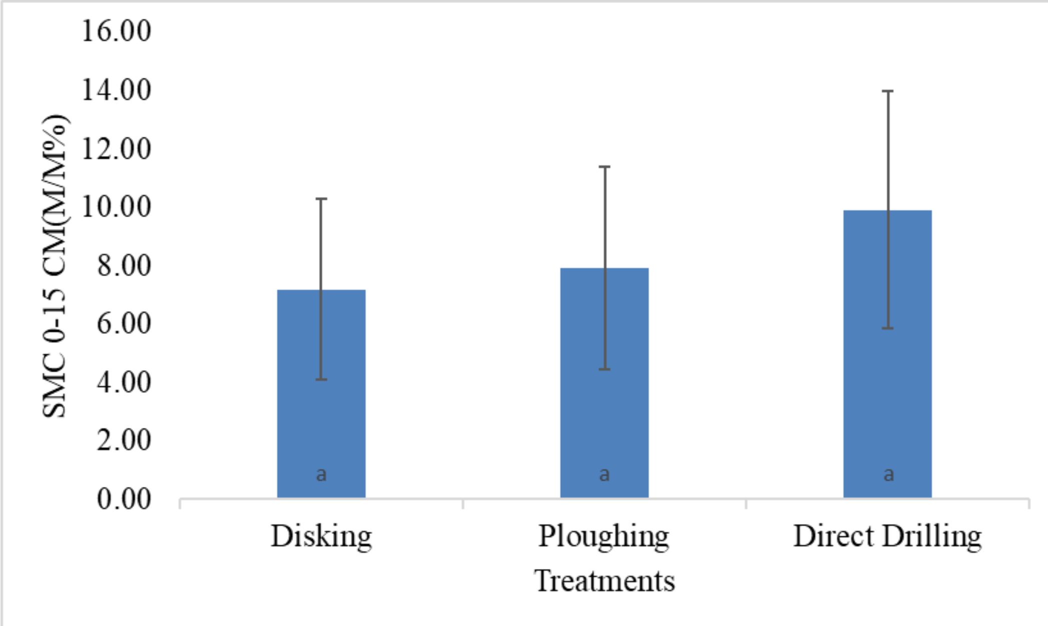

Figure 9: Graph of Soil Moisture Content 0-15 cm (m/m%)

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between mean score of both treatments Direct Drilling (9.91±4.05), Ploughing tillage (7.90±3.47) and Disking tillage (7.19±3.11).

4.5. Soil Moisture Content 15-30 cm (m/m%)

There was a significant effect of tillage in soil moisture content between 15-30 cm at the $p<0.05$ level for the three treatments [$F (2, 51) = 3.35$, $p = 0.043$].

Anova results of the soil moisture content at the depth of 15-30 cm as shown in *table 10* below.

Table 10: Soil Moisture Content at 15-30 cm (m/m%)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	71.669	2	38.258	3.347	0.043
Within Groups	648.088	51	11.429		
Total	719.757	53			

The graph below (*figure 10*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against soil moisture content at 15-30 cm depth.

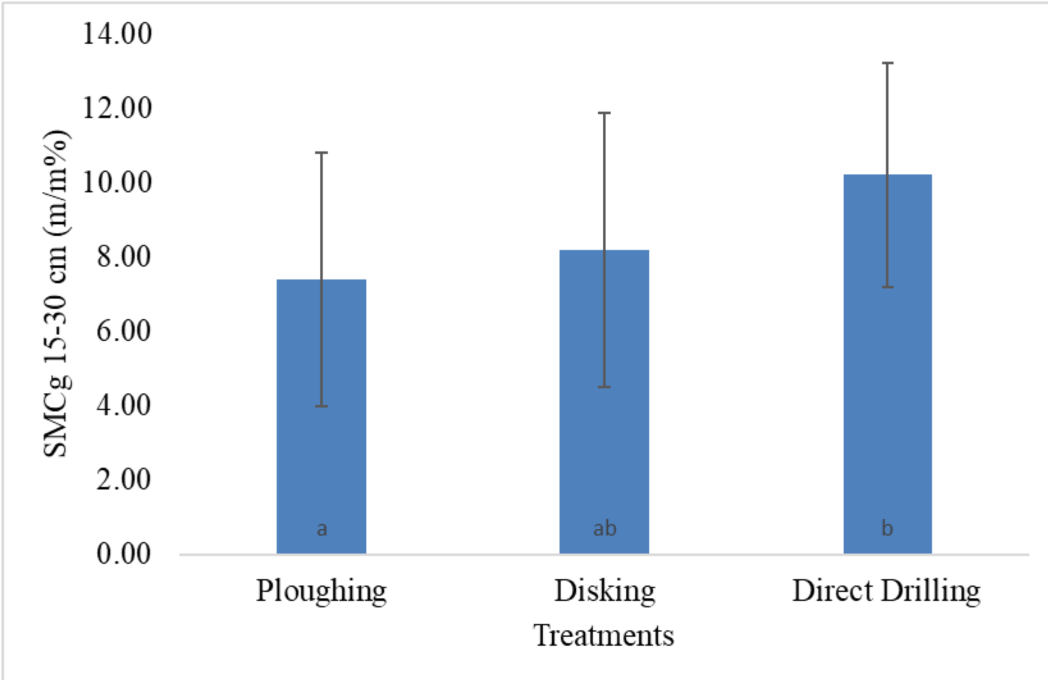

Figure 10: Graph of Soil Moisture Content 15-30 cm (m/m%)

Post hoc comparisons using the Tukey HSD test indicated that the mean score for the Direct Drilling (10.21±3.01) was significantly different than Disking tillage (8.19±3.68). However, there was no significant difference from Ploughing tillage (7.38±3.41) and both Disking tillage and Direct Drilling.

4.6. Soil Moisture Content 30-50 cm (m/m%)

There was a significant effect of tillage in soil moisture content between 30-50 cm at the $p<0.05$ level for the three treatments [$F(2, 51) = 0.52$, $p = 0.599$].
Anova results of the soil moisture content at the depth of 15-30 cm as shown in *table 11* below.

Table 11: Soil Moisture Content at 30-50 cm (m/m%)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	11.571	2	5.786	0.517	0.599
Within Groups	570.535	51	11.187		
Total	582.106	53			

The graph below (*figure 11*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against soil moisture content at 30-50 cm depth.

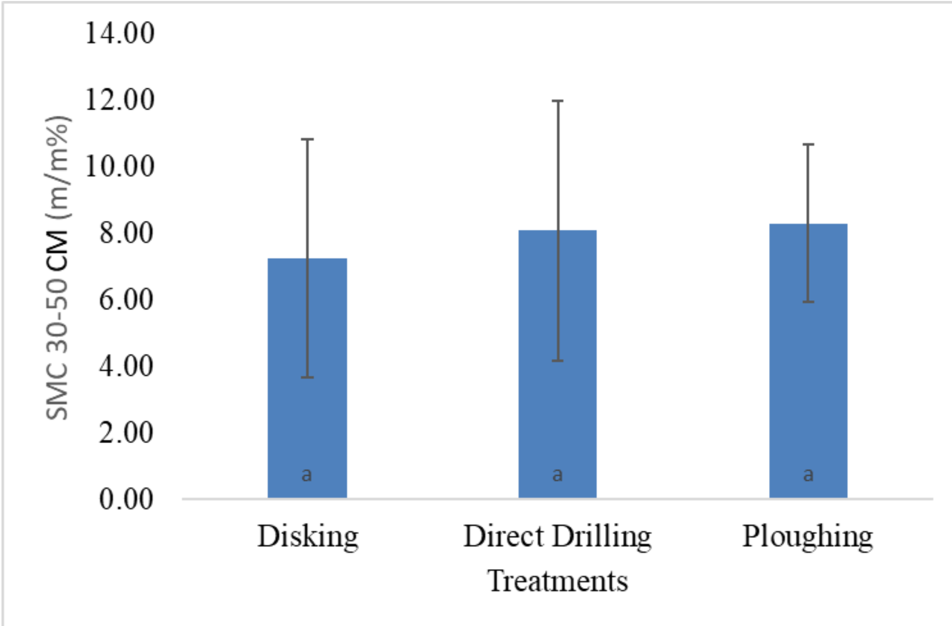

Figure 11: Graph of Soil Moisture Content 30-50 cm (m/m%)

Post hoc comparisons using the Tukey HSD test indicated that there is not significantly different between the mean score of the three treatments, Disking tillage (7.22±3.57), Ploughing tillage (8.30±2.38) and Direct Drilling (8.07±3.89).

Based on the findings, it was observed that the moisture content at a depth of 15-30 cm was greater (*figure 10*) compared to both the 0-15 cm and 30-50 cm depths (*figures 9 and 11* respectively). The increase in moisture content in the 15-30 cm depth is a result of water saturation in the topsoil layers (0-15 cm) caused by rain or irrigation, leading to percolation downwards. If there is sufficient irrigation or rainfall, it is possible for moisture to penetrate deeper layers of soil, typically between 30 and 50 centimeters, albeit to a reduced extent. Furthermore, due to its proximity to the surface, the uppermost layer (0-15 cm) experiences a higher rate of water evaporation. When comparing the 15–30 cm layer, it is possible that the moisture content of the top layer may be lower. This findings agree with finding of (Heathman *et al.*, 2003) , (Li et al., 2020).

In relation to treatment methods, direct drilling exhibits a notable increase in moisture content compared to ploughing tillage and disking tillage (*figure 9, 10, and 11*). This distinction arises from the fact that direct drilling, unlike conventional tillage techniques, entails a reduced duration of plowing and soil disking. The process of plowing and disking can expedite the evaporation of moisture by subjecting the soil to the elements of air and sunlight. In contrast, direct drilling minimizes soil disturbance, thereby enabling the soil to retain its moisture content. Moreover, residual crop residues resulting from the practice of direct drilling often persist on the surface of the soil and serve as a form of mulch. The residue cover has a crucial role in reducing moisture loss through evaporation by shading the soil and acting as a barrier between the soil and the atmosphere. This findings have support of (Jemai *et al.*, 2013) , (Roper *et al.*, 2013)

4.7. Carbon Dioxide L (g/m^2/h)

There was a significant effect of tillage in carbon dioxide (L) at the $p<0.05$ level for the three treatments [$F(2, 51) = 1.97$, $p = 0.149$].

Anova results of the Carbon Dioxide L (g/m^2/h) as shown in *table 12* below.

Table 12: Carbon Dioxide L (g/m^2/h)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	0.084	2	0.042	1.974	0.149
Within Groups	1.086	51	0.021		
Total	1.178	53			

The graph below (*figure 12*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against Carbon Dioxide L (g/m^2/h).

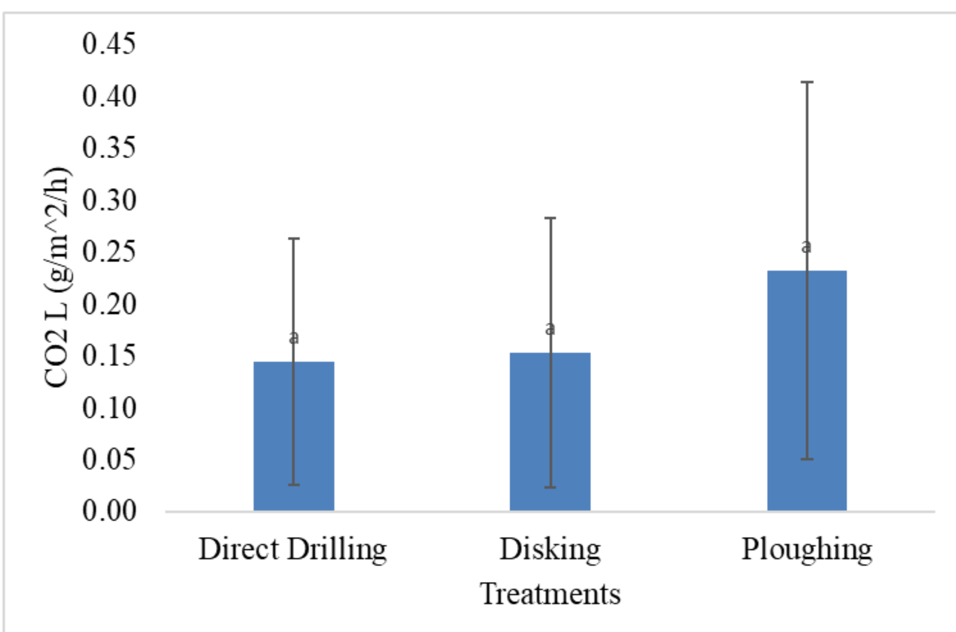

Figure 12: Graph of Carbon Dioxide L (g/m^2/h)

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between the mean score of the three treatments, Disking tillage (0.15±0.13), Ploughing tillage (0.23±0.18) and Direct Drilling (0.14±0.12).

4.8. Carbon Dioxide Q (g/m^2/h)

There was a significant effect of tillage in carbon dioxide (Q) at the $p<0.05$ level for the three treatments [$F (2, 51) = 0.28$, $p = 0.755$].

Anova results of the Carbon Dioxide Q (g/m^2/h) as shown in *table 13* below.

Table 13: Carbon Dioxide emission Q (g/m^2/h)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	0.009	2	0.004	0.283	0.755
Within Groups	0.774	51	0.015		
Total	0.783	53			

The graph below (*figure 13*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against Carbon Dioxide Q (g/m^2/h).

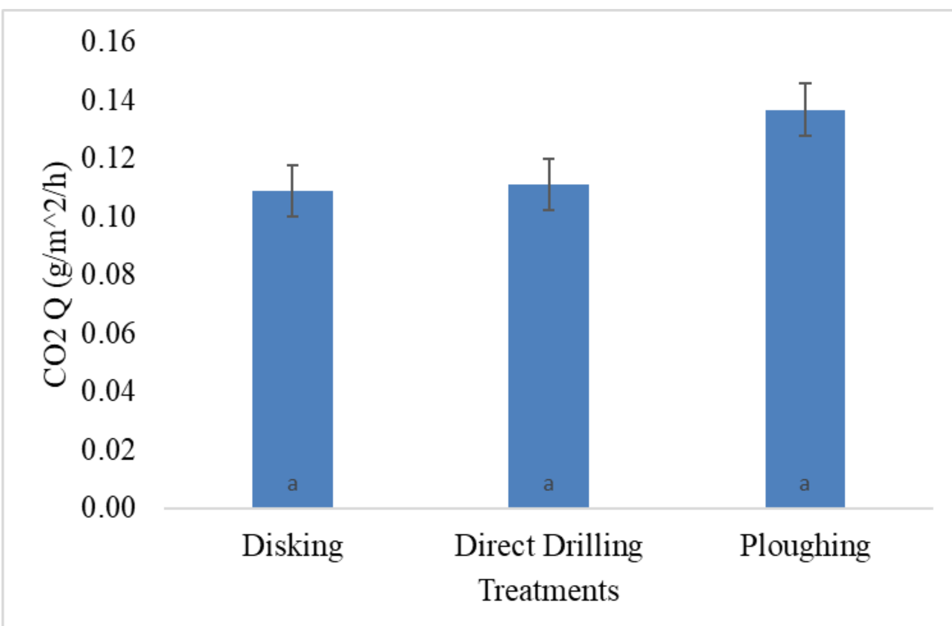

Figure 13: Graph of Carbon Dioxide Q (g/m^2/h)

Post hoc comparisons using the Tukey HSD test indicated that there is not a significant difference between the mean score of the three treatments, Disking tillage (0.11±0.12), Ploughing tillage (0.14±0.13) and Direct Drilling (0.11±0.12).

From the finding, we observed that carbon dioxide is more released in ploughing tillage than in direct drilling and disking tillage (*figure 12, and 13*). This is because the act of ploughing has the potential to disturb the structure of soil and cause the disintegration of soil aggregates, which play a crucial role in the retention and stabilization of organic matter. This disturbance facilitates the decomposition of carbon inside organic matter, leading to the subsequent release of carbon dioxide (CO_2). The findings are similar to the findings of (Krištof *et al.*, 2014) , (Alvarez et al., 2001).

4.9. Clod percentage

There was a significant effect of tillage in clod percentage at the $p<0.05$ level for the three treatments [$F (2, 51) = 1.33$, $p = 0.274$].

Anova results of the Clod percentage as shown in *table 14* below.

Table 14: Clod percentage

	Sum of Square	df	Mean Square	F	Sig
Between Groups	322.586	2	161.293	1.328	0.274
Within Groups	6195.359	51	121.478		
Total	6517.945	53			

The graph below (*figure 14*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against Clod percentage.

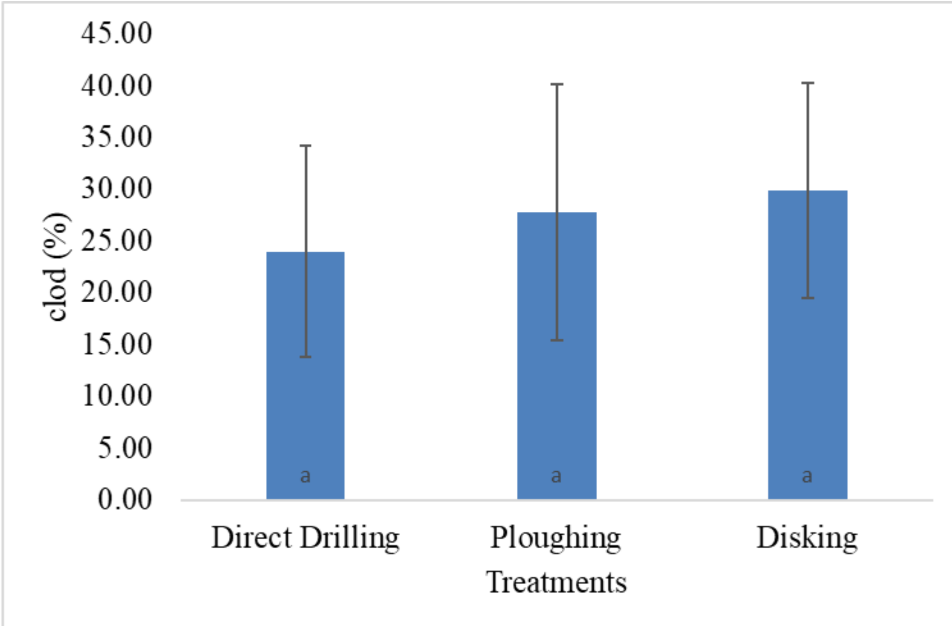

Figure 14: Graph of Clod percentage

Post hoc comparisons using the Tukey HSD test indicated that there is not significant difference between the mean score of the three treatments, Disking tillage (29.91±10.40), Ploughing tillage (27.78±12.36) and Direct Drilling (24.00±1.17).

Based on the obtained results, it can be observed that both disking tillage and ploughing tillage methods generate a higher percentage of clods in comparison to the direct drilling method (*figure 14*). This phenomenon can be attributed to the fact that. Direct drilling is a cultivation technique that minimizes soil disturbance, hence preserving the integrity of the soil structure to a significant extent. On the other hand, the act of plowing and disking induces significant soil disturbance, leading to the disintegration and rearrangement of soil particles, ultimately giving rise to the development of clods. The findings is supported by (Lyles and Woodruff, 1962).

4.10. The crumb percentage

There was a significant effect of tillage in crumb percentage at the $p<0.05$ level for the three treatments [$F(2, 51) = 0.02$, p = 0,984].

Anova results of the Clod percentage as shown in *table 15* below.

Table 15: Crumb percentage

	Sum of Square	df	Mean Square	F	Sig
Between Groups	1.780	2	0.890	0.016	0.984
Within Groups	2876.208	51	56.396		
Total	2877.988	53			

The graph below (*figure 15*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against Crumb percentage.

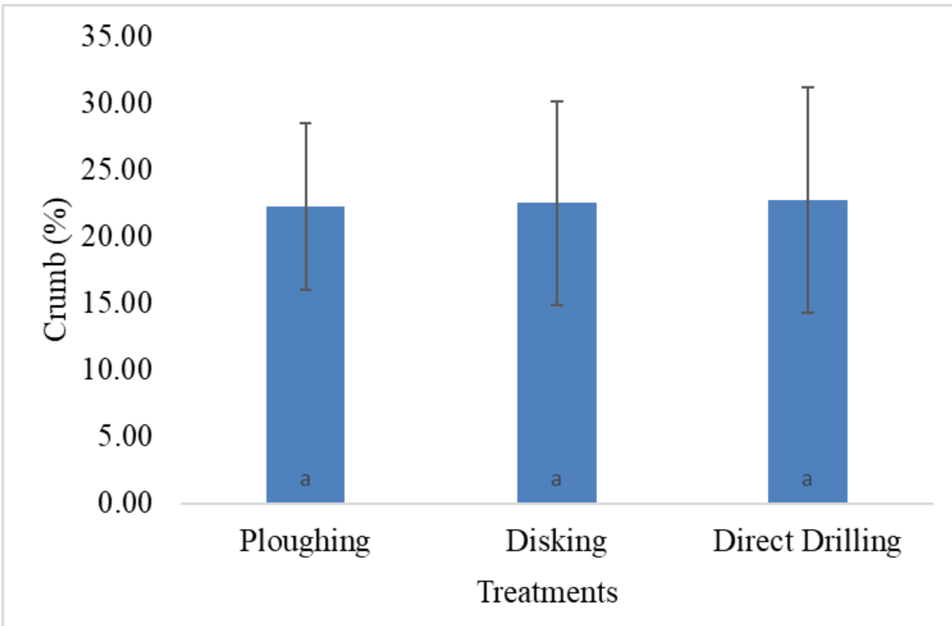

Figure 15: Graph of Crumb percentage

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between the mean score of the three treatments, Disking tillage (22.54±7.63), Ploughing tillage (22.28±6.29) and Direct Drilling (22.72±8.45).

Based on the findings, it can be observed that both treatments exhibit comparable effects on the crumb percentage (*figure 15*). The influence of initial soil conditions on the effectiveness of various tillage methods in altering crumb percentages is a factor to consider. Given that these tillage procedures do not significantly alter the fundamental soil structure, they have the potential to generate comparable crumb percentages in soils that are already quite uniform and well-organized. The results are supported by (Dekemati *et al.*, 2020) , (Bogunović *et al.*, 2019)

4.11. Dust percentage

There was a significant effect of tillage in dust percentage at the $p<0.05$ level for the three treatments [F (2, 51) = 1.25, p = 0,297].

Anova results of the Clod percentage as shown in *table 16* below.

Table 16: Dust percentage

	Sum of Square	df	Mean Square	F	Sig
Between Groups	26.452	2	13.226	1.245	0.297
Within Groups	541.916	51	10.626		
Total	568.368	53			

The graph below (*figure 16*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against Dust percentage.

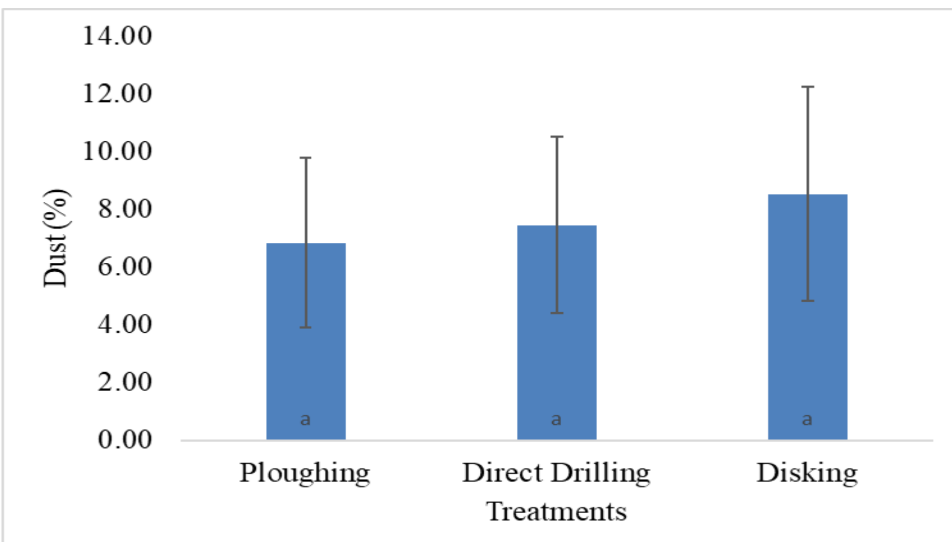

Figure 16: Graph of Dust percentage

Post hoc comparisons using the Tukey HSD test indicated that there is no significant difference between the mean score of the three treatments, Disking tillage (8.54±3.71), Ploughing tillage (6.85±2.95) and Direct Drilling (7.47±2.95).

Based on the findings, it can be observed that Disking tillage exhibits a higher percentage compared to both Direct drilling and Ploughing tillage methods (*figure 16*). The reason for this is that disking is commonly linked to a relatively shallow disruption of the soil, in contrast to plowing, which typically involves deeper penetration into the soil. The reduction of dust production can be achieved through the burial of agricultural remnants and the implementation of deeper soil disturbance to minimize the exposure of fine soil particles. The finding is supported by (Birkás *et al.*, 2002)

4.12. The results of the yield (kg/h)

There was a significant effect of tillage in yield at the $p<0.05$ level for the three treatments [F (2, 51) = 1.25, p = 0,297].

Anova results of the Yield (kg/h) as shown in *table 17* below.

Table 17: Yield (kg/h)

	Sum of Square	df	Mean Square	F	Sig
Between Groups	423308.338	2	211654.169	4.793	0.012
Within Groups	2252203.446	51	44160.852		
Total	2675511.783	53			

The graph below (*figure 17*) shows the relationship between treatments (ploughing tillage, disking tillage and direct drilling) against Yield (kg/h).

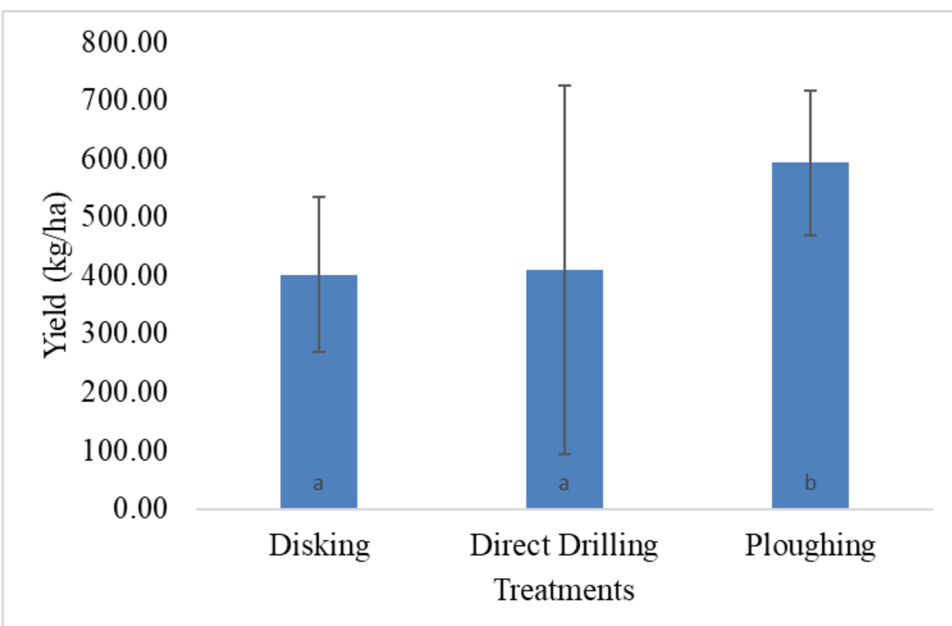

Figure 17: Graph of Yield (kg/h)

Post hoc comparisons using the Tukey HSD test indicated that the mean score for the Ploughing tillage (593.24±124.29) was significantly different than both Direct Drilling (409.62±315.49) and Disking tillage (401.49±132.28). However, there was not significantly different from Direct Drilling and Disking tillage.

Based on the obtained results, it can be observed that ploughing tillage exhibits a larger yield in comparison to both disking tillage and direct drilling (*figure 17*). The reason behind the preference for ploughing lies in its comprehensive approach to soil preparation, involving the overturning of topsoil to effectively bury both weed seeds and remnants of previous crops. By implementing this approach, it is possible that the newly cultivated crops might potentially enhance their chances of successful establishment through the mitigation of resource rivalry, particularly in terms of nutrients and light availability. In contrast, it is worth noting that direct drilling and disking techniques result in reduced soil disturbance, perhaps leading to decreased efficacy in the burial of weed seeds and residual plant material.

Moreover, the act of plowing can contribute to the improvement of soil aeration by loosening compacted soil layers and increasing the availability of oxygen to plant roots. This may have a positive impact on both root growth and nutrient absorption. Potential disparities in soil aeration levels could arise when comparing the techniques of straight drilling and disking. The findings are supported by (Sharma and Abrol, 2012)

5. CONCLUSION

This research is based on the study of the effect of tillage on soil physical parameters (soil penetration resistance, soil moisture content, carbon dioxide, clod%, crumb%, and dust%) on soybean production (yield).

In the soil penetration resistance, the finding indicates that for both treatment groups (direct drilling, ploughing tillage and disking tillage) as the soil depth increases, the soil penetrations resistance as well. The results obtained at a depth of 0-15 cm were 2.47 MPa, 1.21 MPa and 2.34 for disking tillage, ploughing tillage, and direct drilling respectively. At depths of 15-30 cm, the results of disking tillage were 3.58 MPa, ploughing tillage was 2.57 MPa, and direct drilling was 3.56 MPa. Finally, at the depth of 30-50 results were disking tillage 6.18 MPa, ploughing tillage 4.66 MPa and direct drilling 5.91 MPa.

The analysis of soil moisture content revealed that within the 15-30 cm depth range, moisture levels were slightly higher for direct drilling (10.21 m/m%), ploughing tillage (7.38 m/m%), and disking tillage (8.19 m/m%) compared to both the 0-15 cm depth range (direct drilling 9.91 m/m%, ploughing tillage 7.90 m/m%, and disking tillage 7.19 m/m%) and the 30-50 cm depth range (direct drilling 8.07 m/m%, ploughing tillage 8.30 m/m%, and disking tillage 7.22 m/m%).

The study reveals that ploughing tillage practices result in increased emissions of carbon dioxide (0.23 g/m^2/h L and by 0.14 g/m^2/h Q.) when comparing the carbon dioxide emissions of disking tillage (0.15 g/m^2/h CO2 L and 0.11 g/m^2/h CO2 Q) and direct drilling (0.14 g/m^2/h CO2 L and 0.11 g/m^2/h CO2 Q).

The findings of the study indicate that direct drilling resulted in a higher percentage of clods, by 29.9%, than ploughing tillage by 27.7%, and direct drilling by 24%.

The analysis on crumb % revealed that both treatments have slightly the same results, direct drilling 22.72%, ploughing tillage 22.28% and disking tillage 22.54%.

The analysis results demonstrate that disking tillage produces a higher amount of dust by 8.54%. Direct drilling follows by 7.47% increase, and ploughing tillage by 6.85%.

The results of the study suggest that ploughing tillage contributes to a significantly higher production of 593.24 g/h, compared to direct drilling which yields 409.62 g/h, and disking tillage which yields 401.49 g/h.

6.SUMMARY

Thesis title: Assessing the Impact of Tillage Methods on Soybean Production.

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Soybeans (*Glycine max* L. Merr.) are a highly adaptable and nutritionally significant agricultural commodity that assumes a pivotal function in supplying protein and other vital elements for the sustenance of both human and animal populations. The significant role of their versatility and diverse range of applications renders them a crucial element inside the global food supply chain.

The primary objective of this study was to evaluate the impact of methods of tillage on various soil physical parameters, including soil penetration resistance, soil moisture content, carbon dioxide levels, clod percentage, crumb percentage, and dust percentage. The focus of the investigation was to determine the effects of these parameters on soybean production, specifically in terms of yield. The field experiment was carried out in Szárítópuszta, a locality inside the town of Gödöllő in Hungary. The Experimental and Training Farm associated with the Hungarian University of Agriculture and Life Sciences is situated approximately 2 kilometers to the east of the university. The data was collected from the end of spring, summer, and autumn (May, June, July, August, September, and October).

The study employed a randomized strip design with three replications and three treatments. The experiment consisted of two tillage treatments (ploughing tillage and disking tillage) and direct drilling, each reproduced three times. This resulted in a total of nine field plots, each measuring 50 meters in length and 6 meters in width. All the plots were parallel in terms of their lengths. The statistical software SPSS was utilized to conduct one-way ANOVA and LSD tests in order to examine the significant variations in soil parameters across different treatment conditions.

The findings of the study indicate a statistically significant difference ($p<0.05$) in yield across the three treatments. Ploughing tillage resulted in a higher mean yield of 593.24 g/h, compared to the mean yields of 409.62 g/h and 401.49 g/h for straight drilling and disking tillage, respectively.

The results of the study on soil penetration resistance reveal a progressive increase in soil compaction from the upper layer (0-15 cm) to the deeper layer (30-50 cm), with the maximum resistance recorded at 6.16 MPa through direct drilling in the 30-50 cm layer.

The findings from the analysis of soil moisture indicate a slightly elevated moisture content within the depth range of 15-30 cm. The highest recorded moisture level, reaching 10.21 m/m%, was seen in the direct drilling method at this specific depth.

Regarding carbon dioxide, the findings indicate that ploughing tillage practices result in the release of a substantial quantity of carbon dioxide, specifically 0.23 g/m^2/h.

In terms of clod percentage outcomes, it has been observed that disking tillage exhibits a comparatively higher percentage of 29.9%. The percentage of crumb structure was found to be nearly identical across all treatments, including disking tillage (22.54%), direct drilling (22.72%), and ploughing tillage (22.28%). Disking tillage resulted in a notably high percentage of 8.54% for dust content.

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DECLARATION

Signed below, Athumani Adam Shemahonge student of the Szent István Campus of the Hungarian University of Agriculture and Life Science, at the BSc Agricultural Engineering declare that the present Thesis is my own work and I have used the cited and quoted literature in accordance with the relevant legal and ethical rules. I understand that the one-page-summary of my thesis will be uploaded on the website of the Campus/Institute/Course and my Thesis will be available at the Host Department/Institute and in the repository of the University in accordance with the relevant legal and ethical rules.
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As primary supervisor of the author of this thesis, I hereby declare that review of the thesis was done thoroughly; student was informed and guided on the method of citing literature sources in the dissertation, attention was drawn on the importance of using literature data in accordance with the relevant legal and ethical rules.

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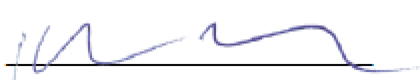

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