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**EFFECT OF DIFFERENT SOWING DATES, NITROGEN FERTILIZERS, AND
PLANT DENSITIES ON YIELD OF SWEET CORN (*ZEA MAYS L.*
SACCHARATA)**

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SACCHARATA).**

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1. INTRODUCTION

Maize is considered the world's third most significant cereal, following wheat and rice. It contributes around 35% to human food requirements and supplies nearly 65% of feed for livestock, while also serving as a major raw material in numerous industrial sectors (Sanodiya, 2023). Among the six main maize types, sweet corn has gained substantial commercial significance both nationally and internationally. Commonly known as sugar corn or pole corn, sweet corn contains higher sugar levels than field maize due to a recessive mutation at the sugary locus. This genetic change leads to the accumulation of sugars in the endosperm, reaching 12–14%, which is two to four times greater than in conventional maize varieties. The sugars are highly water-soluble, making sweet corn distinct from other maize types (Singh, 2014).

Sweet corn (*Zea mays* L. convar. *Saccharata* Koern) is grown extensively worldwide, both for direct consumption as a fresh vegetable and for processing into diverse value-added food products. Sweet corn serves as an important source of dietary fiber, essential minerals, and key vitamins (Barátová, 2016). Unlike field corn and popcorn, it shows unique genetic regulation, particularly in genes involved in carbohydrate accumulation within the endosperm, along with other traits that influence plant growth and development (Qu, 2016). Maize, wheat, and rice serve as staple crops, contributing nearly 45% of global edible dry matter and supplying about 60% of total calorie intake in developing nations (Awika, 2011). Maize has long been a staple food for populations across the globe (Taylor, 2010). Within the maize group, sweet corn stands out due to its distinctive sweetness and flavour, which makes it highly sought after for both fresh consumption and processing. Advances in breeding have enhanced its sugar content, and the crop typically reaches maturity within 75–90 days after planting. The kernels generally contain about 5–6% sugars, 10–11% starch, 3% soluble polysaccharides, and roughly 70% moisture. Yellow-kernel sweet corn varieties are especially appreciated for their moderate protein levels, potassium content, and essential vitamins (Swapna, 2020). From a nutritional perspective, sweet corn is an important component of a healthy diet. It supplies energy through carbohydrates and natural sugars and provides essential vitamins such as A, B3 (important for metabolism and brain function), and C. It also contains folic acid, protein, dietary fiber, and vital minerals. According to Swapna (2020), some super sweet cultivars may contain up to 46% total sugar, 18% starch, 14.5% protein, and 17% oil, demonstrating the biochemical diversity and industrial potential of sweet corn. The

demand for sweet corn is especially strong in nations like the United States and Canada, and its popularity continues to rise across Asia, particularly in India.

The distinct sweetness of sweet corn results from a recessive mutation that disrupts the usual conversion of sugars into starch. During the milk stage, its kernels may hold more than 25% sugar, setting it apart from other maize varieties. It is believed that sweet corn arose from a natural mutation in maize and was initially domesticated by Native American tribes. In 1779, the Iroquois introduced the well-known “Papoon” variety to settlers, which led to its rapid spread across the central and southern United States. Unlike field corn, harvested at full maturity, sweet corn is collected during the milk stage and consumed as a vegetable. Although industrial processing extends shelf life, it may reduce nutritional value due to heat-induced nutrient loss (*Singh, 2014*).

In Hungary, sweet corn is the most widely cultivated vegetable crop. According to the Hungarian Fruit and Vegetable Interprofessional Organisation, its cultivation area was about 38,000 hectares in 2003, decreased to 24,000 hectares by 2005, and rose again to over 30,000 hectares in 2006. The significance of sowing date in sweet corn production has been recognised since the early 20th century. *Cserháti (1901)* observed that early sowing of high-quality seeds could accelerate crop maturity, a finding that has been recently confirmed by *Dadrasi (2024)*.

Grain yield is shaped by the interaction between genetic makeup and environmental conditions. Certain yield-associated traits exhibit stability across diverse environments, making them highly useful in breeding efforts (*Martínez-Peña, 2023*). Because yield is a complex, environmentally influenced characteristic, breeders often investigate how agronomic and morphological traits relate to yield to guide more efficient selection (*Ghallab, 2017*). Fertiliser efficiency is affected by developmental stage, genotype, and plant age (*Lazcano, 2011*). Genetic variation plays an essential role in nutrient uptake and internal assimilate allocation (*Sharma, 2021; Kumari, 2020*). To develop improved sweet corn hybrids, breeders need to work with genetically diverse populations that display significant variation in important agronomic traits. Appropriate selection criteria are critical for success. Yield components influence overall productivity directly and indirectly (*Seker, 2004*). Correlation coefficients quantify both the strength and direction of the association between variables, but they should not be interpreted as evidence of causality (*Schober, 2018*).

Although considerable research has been conducted on sweet corn production, there is still a need for studies that examine how nitrogen fertilisation, sowing date, and plant density interact to influence both yield and quality (Szalókiné Zima, 2023; Vad et al., 2023). Many previous experiments have addressed these factors separately or focused mainly on yield, with fewer assessing ear quality, sugar levels, or dry-matter accumulation under different agronomic practices. Recent findings show that adjusting plant density and nitrogen application can markedly increase maize productivity and improve water–nitrogen use efficiency (Lai et al., 2023), while the choice of sowing date plays a pivotal role in determining yield structure and production stability (Domokos et al., 2024). I propose that aligning nitrogen inputs with appropriate sowing dates and plant densities will improve yield stability and ear quality in modern sweet corn hybrids grown in Hungary. Moreover, I expect that hybrids will differ in their responses to these combined management practices, allowing for hybrid-specific recommendations that support climate-resilient and high-quality sweet corn production.

Objectives of the Study:

- 1-Identify optimal sowing dates for different sweet corn hybrids.
- 2-Determine the ideal plant density that enhances yield and morphological traits.
- 3-Evaluate how nitrogen fertilization influences plant growth patterns and the overall yield performance.
- 4-Examine how yield is influenced by its individual components using both correlation and path analysis techniques.
- 5-Estimate potential yield across various sweet corn hybrids.
- 6-Assess hybrids based on multiple agronomic and morphological parameters.
- 7-Perform statistical analyses, including regression, factor, and cluster analysis among hybrids.
8. Identify the highest-yielding hybrid with the best overall agronomic performance.

2. BIBLIOGRAPHY OVERVIEW

2.1 Justification

The development and yield of sweet corn are greatly influenced by key agronomic factors such as nitrogen fertilization, sowing date, and planting density. Nitrogen is a critical nutrient that supports vegetative growth by stimulating chlorophyll production, which in turn enhances photosynthesis. Proper nitrogen application improves kernel formation and yield outcomes. However, excessive nitrogen can cause overly vigorous vegetative growth that diverts energy away from ear development and may also lead to environmental issues like nutrient leaching and surface runoff.

Sowing date is crucial in determining the crop's exposure to climatic factors. Early planting allows the crop to mature under favorable weather conditions, while delayed sowing can shorten the growing period and increase susceptibility to hazards like late-season frost, potentially reducing yields. Correct timing is also important to align flowering and pollination stages, which directly influence kernel growth.

Plant population density is a key factor influencing the growth and yield performance of sweet corn. Overcrowded stands intensify competition for light, moisture, and nutrients, which can lead to smaller ears and diminished quality. Conversely, very low densities allow each plant to grow more vigorously but fail to make full use of the available field area, lowering overall yield per hectare. Thus, determining the optimal density for each hybrid under specific environmental conditions is essential for maximizing productivity and using resources efficiently. Such management decisions are crucial for maintaining both high-yielding potential and sustainable sweet corn production.

2.2 Morphology and Genetics of Sweet Maize

Despite the restricted diversity in present open-pollinated (OP) sweet corn varieties, useful alleles for improvement may still be present. Utilizing these resources in breeding requires thorough collection and analysis. Morphological assessment is critical to identify traits such as early maturation, disease resistance, and superior ear form. Organizing germplasm based on these features also helps minimize duplication in the collection. In the absence of known pedigrees or combining abilities, morphological grouping remains a viable method to discover lines with hybridization potential. Extensive studies over the last five decades have explored taxonomic and genetic links among maize varieties and races (*Wellhausen et al., 1957; Bird and Goodman, 1977; Camussi, 1979, 1980; Sanchez*

and Goodman, 1992; Llaurodo and Moreno-Gonzalez, 1993), yet detailed insights into sweet corn diversity are still lacking.

Although advanced molecular marker systems now support in-depth genetic exploration, morphological characterization remains a fundamental step for initial germplasm grouping (Smith and Smith, 1989). In a related study, Jarvis and Guthrie (1987) examined kernel damage on various maize types by exposing them to one to eight egg masses (each comprising 30 eggs). They excluded ear tips and assessed injury based on the number of kernels affected. Sweet corn cultivars such as Silver Queen and Tahitian Hi-Sugar showed notable vulnerability, with damage rising from 7.9 to 19.5 kernels per ear at low infestation, and up to 64.8 under severe exposure.

In our evaluation, only ears with damage confined to the tip and not exceeding 1%, roughly five kernels, were deemed acceptable. Any ear with insect damage beyond the tip region was rejected. Several breeding lines demonstrated moderate resilience against ear-feeding pests, and this trait was often passed on in hybrids. This level of resistance remained steady under narrower silks and increased pest pressure. Similar resistance levels have previously been linked to lower insecticide needs (Munkvold, 1997; Hutchison et al., 1992). However, due to the industry's zero-tolerance for European corn borer (ECB) damage and the need to avoid costly trimming during processing, the demand for stronger genetic resistance remains high.

Sweet corn's appealing traits originate from specific genetic mutations in the endosperm that increase sugar levels while reducing starch. The major genetic variants comprise *shrunk2* (*sh2*), *brittle1* (*bt1*), *sugary1* (*su1*), *sugary enhancer* (*se*), *brittle2* (*bt2*), *dull1* (*du1*), and *waxy1* (*wx1*) (Tracy, 2001). According to Pajic et al., (2004), these mutations disrupt key enzymes in the starch biosynthetic pathway, thereby altering carbohydrate distribution and significantly decreasing starch accumulation. Among these genes, *sh2*, *bt1*, *su1*, and *se* are of particular relevance because they raise sugar content while minimizing starch production (Lertrat and Pulam, 2007). Specifically, *sh2* and *bt1*, found on chromosomes 3 and 5, respectively, function to retain higher sugar levels by limiting starch formation. At this stage of development, genotypes carrying *sh2* and *bt1* demonstrate nearly a sixfold increase in sugar concentration. Sweet corn possesses higher concentrations of reducing sugars and sucrose compared with conventional maize, while its water-soluble polysaccharide (WSP) content remains largely unchanged (Feng et al., 2008). Genotypes with the *sh2sh2* mutation preserve their sweetness longer after harvest

than *su1su1* varieties (Lertrat and Pulam, 2007; Mehta et al., 2017). The *se1* gene influences carbohydrate accumulation, and when present alongside *su1*, it results in sugar concentrations comparable to *sh2* types, while preserving the water-soluble polysaccharide (WSP) composition typical of conventional *su1* lines (Tracy, 1997). Although breeding principles from field corn can be applied to sweet corn, their application must be adapted to meet its unique quality requirements and limited post-harvest longevity. Breeding efforts must therefore emphasise both yield improvement and sensory quality. Understanding the genetic architecture of inbred lines is essential for population management, pre-breeding activities, and germplasm conservation. Since morphological traits are often influenced by environmental factors, relying solely on phenotype can be misleading. A combined approach integrating morphological assessments with molecular markers provides a more accurate understanding of genetic diversity. Polymorphic DNA markers play a key role in uncovering genome structure and clarifying evolutionary relationships. Their value becomes particularly significant in marker-assisted selection when associated with quantitative trait loci (QTLs) that govern kernel quality and composition (Pandey et al., 2018). Utilising these markers enables breeders to efficiently identify and choose superior genotypes that align with market demands.

2.3 Types of sweet maize by sugar content

2.3.1 Conventional sweet maize

Sweet corn (*Zea mays* convar. *saccharata* var. *rugosa*), also called sugar corn or pole corn, is a special type of maize cultivated mainly for direct consumption because of its naturally high sugar levels. Its sweet flavour comes from a recessive gene mutation that stops the usual conversion of sugars into starch in the endosperm. In contrast to field corn, which is harvested at full maturity for animal feed or industrial applications, sweet corn is gathered at the milk stage and eaten as a vegetable. Since its kernel sugars slowly convert into starch after harvest, sweet corn has a very short shelf life and should be eaten fresh or preserved by freezing or canning to maintain kernel tenderness. Among the six main maize types, dent, flint, pod, popcorn, flour, and sweet maize originated from a natural mutation of field corn. Originally grown by Native American communities, sweet corn was introduced to European settlers by the Iroquois in 1779, who called it ‘Papoon’.

Its cultivation gradually expanded throughout the southern and central United States. During the 19th century, open-pollinated white varieties gained popularity, with enduring cultivars such as ‘Country Gentleman’, a Shoepeg type with unevenly spaced small kernels, and ‘Stowell’s Evergreen’ still cultivated today. A key development came in 1933 with the release of Golden Cross Bantam, the first widely adopted single-cross hybrid, specifically bred for improved resistance to diseases, particularly Stewart’s wilt. The genetic basis of sweetness in corn has since been identified, allowing breeders to develop cultivars with specific sweetness levels based on the following gene types:

- *su* (standard sugary)
- *se* (sugary enhanced)
- *sh2* (shrunken-2)

At present, numerous sweet corn varieties are available, with continuous improvements resulting from modern breeding programs. The edible portion is the kernel, a caryopsis-type fruit that forms along the cob and is enclosed by protective leaves called husks. Being a monocot species, sweet corn characteristically develops an even number of kernel rows. The silks, which function as the female flowers, emerge from the tips of the husks. Prior to cooking, most commonly before boiling, though sometimes left intact for roasting, the husks and silks are manually removed in a process known as husking or shucking. In modern farming, hybrid cultivars, usually sweeter and quicker to mature, have largely replaced open-pollinated varieties in commercial production. Standard *su* types should be consumed within 30 minutes of harvest because their sugar degrades rapidly. However, heirloom cultivars like Golden Bantam remain favored by home gardeners and niche markets for their nostalgic flavor and texture, despite being less sweet than hybrids. Varieties like Silver Queen carry the *su1* gene, which increases sugar content during ear development but also causes rapid starch formation after harvest (*Ishwar Singh, 2014*).

2.3.2 Sweet maize with increased sugar content

This gene plays a role in elevating sugar concentration and enhancing kernel tenderness, working in tandem with the sugary1 (*su1*) gene. In hybrids that are heterozygous for the sugary enhancer (*se*) gene, only one allele is present, resulting in about 25% of the kernels displaying the sugary-enhanced trait. The remaining 75% exhibit standard sweet corn characteristics. However, when hybrids are homozygous for *se*, possessing two copies,

all kernels express the trait fully. These genotypes are appreciated for their higher sugar content, which contributes to an extended shelf-life post-harvest (*Ishwar Singh, 2014*).

Sweetness in sweet corn is a function of the sugar-to-starch ratio in the endosperm. Efforts to genetically improve sweet corn have concentrated on selecting mutants that increase sugar retention in the endosperm. Extensive research has explored the biosynthesis of starch and the genetic mechanisms controlling carbohydrate distribution within the kernel.

Extensive research has focused on the key genetic factors that regulate sugar retention and starch reduction in sweet corn (*Creech, 1965; Boyer & Shannon, 1984; Tracy, 1997*). Among these, four major mutations, *shrunk2 (sh2)*, *brittle1 (bt1)*, *sugary1 (su1)*, and *sugary enhancer1 (se1)*, play critical roles. The *sh2* and *bt1* mutations, located on chromosomes 3 and 5, respectively, are classified as Class 1 mutations. These significantly reduce starch accumulation while markedly increasing sugar content, producing kernels that are typically shrunken, brittle, opaque, and angular when dried. In contrast, *su1* and *se1*, classified as Class 2 mutations on chromosomes 4 and 2, respectively, primarily influence starch biosynthesis during the later stages of kernel development. They alter both the quantity and composition of endosperm polysaccharides. Dried *su1* kernels appear wrinkled and translucent, whereas *se* kernels, expressed only in a *su1* background, are pale, slow drying, swollen, and exhibit color variations depending on genetic background. Notably, Class 1 mutations are epistatic over Class 2 mutations (*Boyer & Shannon, 1984; Tracy, 1997*). Although hybrids with *su1*, *se*, *sh2*, or *bt1* are available commercially, each type has distinct limitations. *Su1* varieties rapidly lose sweetness after harvest. *Sh2* and *bt1* maintain higher sugar levels longer but often have tougher seed coats and lack the creaminess of *su1* varieties. These types also suffer from poor germination. *Se* types retain sweetness longer than *su1* but degrade faster than *sh2*. Breeding efforts have led to hybrids that combine high sugar content with better seed Vigor and agronomic performance by stacking endosperm mutations, particularly those involving *su1*. These developments are protected by U.S. Patents 3,971,161 and 4,630,393.

Bonucci's patents describe two innovative sweet corn hybrids: Sweet Gene Hybrid and Sweetie. The first, also known as the sugary-shrunken hybrid (*su1su1Sh2sh2*), is created by crossing a sugary-shrunken line (*su1su1sh2sh2*) as the female parent with a sweet corn line (*su1su1Sh2Sh2*) as the male. The resulting F1 seeds appear phenotypically normal and yield F2 ears that segregate in a 3:1 ratio of *su1* to *sh2* kernels. This hybrid boasts

around 50% more sucrose and 33% more total sugars than standard varieties. The second hybrid, “Sweetie” or Improved Super Sweet (*Su1su1sh2sh2*), is formed by crossing *Su1Su1sh2sh2* (female) with *su1su1sh2sh2* (male).

Modern breeding continues to focus on combining beneficial endosperm mutations, giving rise to new sweet corn types defined by unique gene combinations. These types are generally grouped into super sweet and sugary categories (Mehta, 2020).

Newly released *sh2*-based hybrids such as Xtra-Tender Brand®, Gourmet Sweet Brand®, and Multi-Sweets® exemplify this innovation. These varieties blend the *sh2* mutation with *se* and modifier genes, resulting in much more tender kernels than conventional *sh2* types. They exhibit sugar concentrations above 30%, excellent flavor, longer shelf life, and enhanced field performance.

Synergistic types such as Sweet Breed™ and Triple Sweet® have been bred by incorporating *su1*, *se*, and *sh2* genes. These hybrids are homozygous for *su1* but heterozygous for the others, leading to ears with mixed kernel types.

Sweet Breed™ hybrids, such as Sweet Chorus, Sweet Rhythm, and Sweet Ice developed by Harris Moran Seeds, feature a heterozygous *se* background, producing roughly 25% *se*, 25% *sh2*, and 50% *su1* kernels. These varieties balance high sugar content and improved seed quality, offering advantages over traditional *su1* types.

Sweet corn (*Zea mays* convar. *saccharata* var. *rugosa*), also referred to as sugar corn or pole corn, is mainly grown for its elevated sugar content. This characteristic sweetness arises from a naturally occurring recessive mutation that inhibits the transformation of sugars into starch in the endosperm. In contrast to field corn, which is harvested at full maturity primarily for livestock feed, sweet corn is collected at the milk stage and consumed fresh or preserved through canning or freezing due to the rapid decline of sugar content after harvest. Among the six primary types of maize, dent, flint, pod, popcorn, flour, and sweet corn are distinguished by their tender kernels and characteristic sweetness. Indigenous peoples of North America cultivated sweet corn long before its formal introduction to European settlers by the Iroquois in 1779, with the ‘Papoon’ variety marking the start of its widespread cultivation in the United States. Each kernel of sweet corn is a caryopsis that develops on ears arranged in even-numbered rows, reflecting the plant’s monocot structure, and is enclosed by protective husks. Silks emerge from the ear to enable pollination, and husks and silks are typically removed (through husking or

shucking) prior to cooking. In modern cultivation, open-pollinated sweet corn has largely been supplanted by hybrids that are sweeter, mature earlier, and retain flavor longer. While *su1* types require prompt consumption to ensure optimal taste, heirloom varieties such as ‘Golden Bantam’ remain favored in-home gardens and niche markets for their tender texture and rich flavor, despite their comparatively lower sugar content.

2.3.3 Super Sweet Maize

Super-sweet maize varieties are distinguished by their exceptionally high sugar content relative to conventional sweet corn types (*Oliveira Júnior et al., 2006*). In Brazil, where annual field corn production exceeds 58 million tons (*Colussi, 2023*), there lies a substantial opportunity to expand the cultivation of super-sweet corn. Nevertheless, its market presence remains modest due to the limited number of commercially available hybrids. This shortfall restricts access for key stakeholders, including growers, processors, and consumers, highlighting the pressing need for breeding programs aimed at developing and distributing improved cultivars (*Bordallo et al., 2005*).

Despite the desirable traits of the super-sweet phenotype, such as elevated sugar levels, it presents certain agronomic limitations, notably poor seed Vigor and increased susceptibility to pests and diseases (*Oliveira Júnior et al., 2006*). Therefore, advanced breeding approaches are vital to facilitate the successful development and widespread cultivation of these varieties. These efforts should focus on multi-environmental performance evaluations, the exploration of genetic variation within germplasm collections, and the selection of genotypes with strong agronomic and quality characteristics (*Nigussie and Saleh, 2007*). In Brazil, the sweet corn seed industry is currently dominated by Syngenta Seeds Inc., which markets Tropical Plus, a super-sweet hybrid. However, the diversity of cultivars remains minimal, and the genetic base for elite breeding materials is quite narrow. Globally, only around 300 open-pollinated sweet corn varieties have been identified (*Mahato, 2018*), and Brazil maintains a limited germplasm pool with only 20 accessions in its national gene bank, most of which are derived from foreign breeding programs (*Flavia, 2014*).

The *sh2* mutation is a key genetic trait responsible for the super-sweet phenotype, allowing sugar concentrations in the kernels to reach as high as 29.9% at the milk stage (20 days after pollination), which is significantly higher than the 10.2% found in *su1* types and 3.5% in conventional field corn (*Creech, 1965*). These *sh2*-based cultivars retain

sweetness for longer periods due to reduced starch accumulation, although they tend to lack the creamy texture typically associated with standard sweet corn, a result of decreased levels of water-soluble polysaccharides. In comparison, *bt* mutants demonstrate lower sugar levels than *sh2* types, recorded at 22.5% versus 19.3% sucrose content at 21 days post-pollination, yet they still significantly exceed the sugar concentration of field corn, which averages 2.9% (Nelson, 1980).

From a sensory perspective, super-sweet corn is known for its crisp texture and extended sweetness post-harvest, a result of the slow transformation of sugars into starch. However, one of the major cultivation challenges of super-sweet hybrids is their poor seed germination, especially under cool soil conditions. This is attributed to the shriveled and lightweight nature of their kernels. To address these limitations, Professor James Brewbaker at the University of Hawaii initiated targeted breeding efforts in the 1960s to adapt *sh2* and *bt* types for tropical environments. These efforts led to the development of 17 sweet (*su1*) and super-sweet (*bt*, *bt2*, and *sh2*) maize populations, with a focus on enhancing yield, kernel traits, and resistance to diseases like maize mosaic virus. Several of these lines were released early in their development and have seen international use. For instance, *sh2 COMP 1* was launched in Thailand in 1968. The genetic lineage of these varieties traces back to Hawaiian Sugar, a cross between Cuban and Golden Bantam corn, with contributions from diverse global germplasm sources (Brewbaker, 2015).

The Martonvásár Agricultural Research Institute has made enduring and modern contributions to maize and sweet-corn improvement, beginning with harvest-related grain moisture evaluations by Marton *et al.*, (2003). Advancements in genetic diversity and molecular characterization were strengthened through the work of Nagy *et al.*, (2003), while biotic stress resistance was significantly highlighted in the rootworm tolerance research of Marton *et al.*, (2009). More recent studies, including the physiological and stress-response investigations of Balassa *et al.*, (2021) and the cold-tolerance screening by Csepregi-Heilmann *et al.*, (2023), demonstrate the institute's continued scientific progress. Collectively, these modern and historical studies underline Martonvásár's central role in advancing Hungarian maize and sweet-corn research.

2.4 Chemical Composition

Besides their high sugar content, sweet corn kernels are appreciated for their nutritional value when consumed fresh. They typically contain 2.1–4.5% protein, 1.1–2.7% fat, 3–20% starch, and 0.9–1.9% cellulose. Sweet corn is also a source of essential micronutrients, providing about 9–12 mg of vitamin C per serving, along with smaller amounts of vitamins A, B1, and B2 (*Lee & McCoon, 1981*). Additionally, the kernels contribute several essential minerals, including sodium, potassium, magnesium, calcium, phosphorus, iron, selenium, copper, nickel, and chromium. Data from the United States Department of Agriculture (USDA) indicate that sweet corn's nutritional profile is largely shaped by its high moisture content, which makes up nearly 72.7% of the kernel weight. The remaining 27.3% represents total solids, consisting mainly of carbohydrates (81%), followed by protein (13%), lipids (3.5%), and trace constituents (2.5%) (*Hardenburg et al., 1986*).

2.5 Importance of Sweet Maize

Sweet corn is a warm-season annual crop with considerable economic importance, especially in the United States, and its cultivation is steadily expanding throughout Europe. In 2004, European production alone reached roughly 500,000 tons of grain. Due to its high land requirements and substantial nutrient demands, particularly for nitrogen, adopting sustainable agricultural practices is crucial for maintaining productivity while conserving the environment. The term “sweet corn” describes maize varieties carrying naturally occurring recessive mutations that alter carbohydrate deposition in the endosperm, distinguishing them from conventional field corn.

These mutations are classified into two main biochemical categories based on their effects on kernel carbohydrate content. Class 1 mutations, such as *shrunk2 (sh2)*, cause a large increase in sugar levels and a substantial decrease in starch, thereby reducing overall carbohydrate content in the kernel. In contrast, Class 2 mutations, including *sugary1 (su1)*, primarily modify the structure and composition of polysaccharides, causing only minor reductions in starch. These genetic variations are present across numerous hybrids with diverse origins. Consequently, differences in nutrient uptake and utilization among mutants can produce varied responses to fertilization, affecting both yield and nutritional quality. This genetic and physiological diversity indicates that certain sweet corn hybrids

may be particularly well-suited for sustainable or organic production systems (Boyer, 2011).

Sweet corn (*Zea mays L. var. rugosa Bonaf.*), harvested during the early, milky stage of development, is a widely consumed vegetable crop. It serves as a source of dietary fiber, essential vitamins, and vital minerals. The crop is primarily cultivated for three main market segments: fresh produce, canned products, and frozen goods, each operating within distinct supply chains. More recently, demand has expanded to include innovative processed items like sweet corn milk and soup. Breeding advancements have significantly improved characteristics such as taste, texture, and shelf life, thereby supporting its rising popularity and market share. The eating quality of sweet corn, regardless of its form, is primarily defined by its sweetness, which stems from high sucrose content in the kernels, as well as its appealing aroma and distinctive texture. Texture is influenced by factors like pericarp softness, water-soluble polysaccharides (especially phytoglycogen), and overall kernel moisture (Evensen and Boyer, 1986).

This concise review emphasizes sweet corn's economic relevance, highlights the key genetic mutations affecting kernel composition, and reviews breeding programs aimed at enhancing sweetness. The kernel's balance of sugar and starch plays a pivotal role in determining flavor. Breeders have focused on selecting and developing genotypes with mutations that boost sugar content by altering carbohydrate biosynthesis in the endosperm. Extensive research has been devoted to understanding starch synthesis mechanisms and manipulating carbohydrate pathways at the genetic level. A number of important genes responsible for elevating sugar concentrations while reducing starch have been pinpointed (Creech, 1965; Boyer and Shannon, 1984; Tracy, 1997).

Among the most influential mutations are *shrunk2* (*sh2*), *brittle1* (*bt*), *sugary1* (*su1*), and *sugary enhancer1* (*se*). The *sh2* and *bt* genes, located on chromosomes 3 and 5, respectively, belong to Class 1 and are known to significantly reduce starch accumulation, resulting in kernels that are angular, brittle, collapsed, and opaque at maturity. Conversely, *su1* and *se*, which are found on chromosomes 4 and 2, respectively, are considered Class 2 mutations. These mutations influence the later stages of starch biosynthesis, modifying the composition and proportions of polysaccharides in the endosperm. Kernels with the *su1* mutation typically appear glassy and wrinkled, whereas those carrying *se*, which is expressed only in *su1* backgrounds, show traits such as enlarged shapes, lighter

coloration, and slower moisture loss. The unique physical characteristics of *se* mutants, including kernel collapse and brittleness, can differ depending on the hybrid's genetic makeup. Notably, Class 1 mutations are epistatic over Class 2, meaning that when both types are present in the same plant, the effects of Class 1 mutations predominate (Boyer & Shannon, 1984; Tracy, 1997).

2.6 Cultivation of Sweet Maize

In Poland, sweet corn (*Zea mays* var. *saccharata*) has emerged as an increasingly significant crop within the agricultural landscape. Although it is a relatively recent addition to the country's farming portfolio, the crop has witnessed rapid growth in popularity, now occupying between 5,000 and 6,000 hectares across the nation.

Various international studies have examined different aspects of sweet corn cultivation to enhance productivity and sustainability. In Malaysia, Isaak *et al.*, (2020) assessed two strategies for evaluating mechanization in sweet corn farming. The first, the PCL-HRL-EGL Cartesian plotting method, incorporated parameters such as production capacity, human heart rate, and energy expenditure from labor. The second technique introduced a mechanization index that quantified energy contributions from machinery and manual labor. These approaches serve as valuable tools to optimize mechanized operations. In Thailand, Laosutsan *et al.*, (2019) examined the main factors affecting farmers' adoption of good agricultural practices (GAP) in sweet corn production. Their study found that income was the primary driver motivating farmers to implement GAP. Additionally, they highlighted the importance of government-led certification programs in promoting sustainable farming practices among growers. enhance overall production efficiency in sweet corn systems.

In Pakistan, the study by Khan *et al.*, (2018) explored the influence of different sowing dates on sweet corn microclimatic conditions and growth responses. Their findings indicated that July planting offered the most suitable conditions, resulting in superior biometric traits such as maximum leaf area index, absolute growth rate, and crop growth rate. Conversely, earlier planting dates resulted in taller plants and greater dry matter accumulation. The adoption of precision agriculture in sweet corn production is also expanding. In Australia, Layden and O'Halloran (2016) investigated spatial variability in crop performance as a means of boosting yields in vegetable crops, including sweet corn. Their study utilized Green Seeker biomass sensors and remote sensing tools in collaboration with local growers. These technologies enabled the early detection of stress

factors, whether biotic or abiotic, allowing for site-specific agrochemical interventions that improved marketable yield. *Owen and LeBlanc (2016)* investigated novel approaches for growing sweet corn within Canadian organic farming systems. Their methods included transplanting seedlings instead of direct seeding, sowing into zone-tilled red clover used as a living mulch, and utilizing narrow biodegradable mini-mulches. The study also incorporated drip irrigation, organic compost, fertigation, and thorough pest management strategies. *Moteva et al. ,(2016)* determined optimal irrigation schedules for sweet corn using both drip and sprinkler systems to enhance yield and its components. Drip irrigation was shown to create favorable conditions for vegetative biomass growth, whereas sprinkler irrigation was more effective in promoting overall productivity.

2.7 Yield of Sweet Corn

Chemical fertilizers have generally been found to outperform organic fertilizers in promoting sweet corn growth. Nevertheless, persistent use of organic farming practices contributes to enhanced soil nutrient storage and supports a soil ecosystem rich in beneficial microorganisms. These microbes can later aid sweet corn in coping with environmental stresses such as climate fluctuations (*Ping, 2020*).

From a breeding perspective, genotypic stability across a range of environmental conditions is more valuable for processing applications than mere high yields in a single location. An ideal genotype should not only provide high yields on average but also show minimal variability under changing environmental conditions (*Martin, 2017*).

In Pekanbaru, sweet corn is a favored crop due to its taste; however, production volumes remain modest relative to international levels. This limitation is mostly due to suboptimal environmental conditions, particularly the acidic and nutrient-deficient Red Yellow Podsolik (PMK) soils. Repeated cultivation on these soils has caused considerable nutrient loss. Nonetheless, combining organic and inorganic fertilization practices has shown promise in rejuvenating soil fertility. Despite research efforts to refine corn fertilization strategies, current findings have yet to fully address the yield challenges (*Surtinah, 2020*).

Various biotic factors continue to threaten sweet corn yield. Among these, Western Corn Rootworm (WCR) larvae are especially destructive, as they damage root systems, thereby impairing water and nutrient absorption. This often leads to plant lodging and reduced harvest efficiency (*Chiang, 1973; Spike and Tollefson, 1989*). Additionally, adult WCRs damage silks, interfering with pollination and resulting in reduced kernel formation and

economic losses (*Culy et al., 1992*). Effective pollination, fertilization, and silk emergence are crucial to maize productivity. Maize is monoecious, with tassels (male) and ears (female) on the same plant. Pollen is usually released several days before silks emerge and continues over a two-week period, influenced by both genetic and environmental factors. A single tassel can release between 2 and 5 million pollen grains (*Madison, 2014*), while each silk can collect approximately 2,000 to 5,000 grains.

Genetic stability in maize is measured by how consistently a genotype performs under varying environmental conditions, which enables researchers to predict yield responses. A stable genotype maintains a uniform performance across diverse environments, reflecting low sensitivity to change (*Becker and Leon, 1988*). Conversely, genotypes with fluctuating performance demonstrate higher sensitivity. The goal is to identify cultivars that yield well and stably under different conditions (*Dia et al., 2016; Lu'quez et al., 2002; Mohammed et al., 2016*).

In sweet corn, yield stability is still an emerging concept, though commercial hybrids display varying degrees of resistance to stresses like diseases (*Pataky et al., 2011*), herbicide injury (*Nordby et al., 2008*), and weed competition (*So et al., 2009*). New research on processing varieties has shown that some genotypes perform well across multiple planting densities (*Williams, 2012*). Field surveys further indicate that many hybrids with high-density tolerance are currently underused. Increasing plant populations of such genotypes could lead to significant yield improvements. However, tolerance to crowding still varies among sweet corn hybrids. In field trials involving 26 hybrids grown at high plant densities, substantial yield differences were observed. Hybrids that thrived under these conditions also exhibited greater stability. Decoding the genetic foundations of such tolerance could help develop more productive sweet corn varieties. (*Williams, 2012; Williams, 2015*).

The synergy of enhanced genetics and optimized cultivation practices has led to the development of resilient maize hybrids (*Duvick, 1997; Duvick, 2005*). Modern cultivars show notable tolerance to biotic and abiotic pressures (*Tollenaar, 2002*), and the introduction of density-tolerant hybrids has made high-density planting practical, significantly boosting productivity.

Grain yield evaluated at physiological maturity is a fundamental criterion for optimizing cropping systems and steering plant breeding initiatives (*Adee, 2016*). Contemporary re-

search methodologies have broadened the concept of yield assessment, considering parameters that extend beyond the measurement of final harvested biomass. In contrast to field corn, sweet corn is collected at the R3 (milk) growth stage, as endosperm mutations result in elevated sugar concentrations and kernel moisture levels, typically ranging between 72% and 76% (*Abendroth et al., 2011*). Regardless of whether it is intended for fresh market use or industrial processing, sweet corn production necessitates specialized agronomic management and precise scheduling to ensure quality and yield outcomes (*Tracy, 1993*).

Access to clean, genetically pure, and viable hybrid seeds is vital for achieving optimal yield and product quality. However, seed contamination can occur during both field production and post-harvest handling, particularly in hybrid systems. Additionally, the short harvest window for sweet corn leads to rapid post-harvest quality degradation (*Szymanek, 2015*). Research has also shown that applying biofertilizers at the dough stage can significantly improve cob weight, leaf number, and stover dry mass (*Wangiyana, 2021*).

Sweet corn breeding programs frequently focus on traits such as biomass accumulation, sugar concentration, and desirable genetic markers. Hybrid sweet corn also presents opportunities in the bioenergy sector without compromising food security or sustainability (*Jaime, 2015*). Due to its high sugar and low starch content, sweet corn is particularly valuable but requires higher nitrogen inputs than other maize types. Consequently, breeding efforts have emphasized ear development over overall grain yield (*Canatoy, 2018*).

Research has shown that applying 120 kg ha⁻¹ of nitrogen at the V6 growth stage significantly increased seed yield and phosphorus uptake in the R400 cultivar, while grain protein content remained unchanged (*Claudemircc, 2018*). Neither seed vigor nor germination rate was affected by the nitrogen dosage or the timing of its application. Although slight decreases in phosphorus and slight increases in zinc levels were detected, these variations did not have a significant impact on physiological performance. The marked variability observed in key traits such as yield and sugar content emphasizes the necessity of incorporating these attributes into future breeding strategies (*Jaime, 2015*).

Nagy, (2012) found that maize yield is highly responsive to rainfall during the growing season, with a strong positive correlation ($r = 0.710$; $p < 0.01$) between precipitation and

yield. Seventeen years of data revealed that wet conditions consistently resulted in markedly higher yields compared to dry years. Fertilization also played a significant role, as applying 60 or 120 kg N ha⁻¹ increased yield relative to the unfertilized control. However, the step from 60 to 120 kg ha⁻¹ did not always produce an additional statistically significant yield gain. The interaction analysis showed that fertilization explained nearly twice as much of the yield variation as precipitation. In dry seasons, notable differences occurred primarily between fertilized and unfertilized plots, while in wet years, higher nitrogen levels produced substantially greater yields and enhanced nutrient-use efficiency. Overall, the findings indicate that the effectiveness of nitrogen fertilization depends strongly on moisture availability: lower N rates are adequate in dry years, whereas higher doses optimize yield and nutrient uptake when water supply is abundant.

Demeter and Bakos (2022) studied the Messenger sweet corn hybrid and observed that favorable environmental conditions increased fresh-ear yield from 15.16 t/ha to 19.86 t/ha, while mineral concentrations per kilogram (K, P, Mg) decreased, although total per-hectare mineral yield remained stable.

2.8 Fertilizer

Fertilization plays a vital role in enhancing agricultural productivity. However, achieving target yields and maintaining long-term soil fertility relies heavily on the adoption of effective fertilization practices (*Stamatakis, 1999; Manan, 2005; Zhang, 2009*). The residual impact of fertilizer applications extends beyond immediate crop cycles; for example, the use of NPK fertilizers has been demonstrated not only to boost crop yields but also to improve soil quality over multiple seasons, thereby benefiting subsequent crops grown in the same fields (*Kong, 2005*). Supporting research highlights these sustained advantages of NPK fertilizer residues and recognizes that synthetic fertilizers have been a major factor in yield increases since their widespread introduction in the 1950s (*Roberts, 2009*).

Among the nutrients, phosphorus (P) has been identified as particularly effective in raising sweet corn yields when compared to combinations of NPK with magnesium. Phosphorus application enhances the uptake of critical nutrients, including nitrogen, potassium, calcium, magnesium, and iron, relative to untreated soils. In peat-rich soils, optimal phosphorus application rates range from 670 to 890 kg ha⁻¹, producing yields around 13.2 to 13.9 t ha⁻¹ (*Purnomo, 2021*).

Potassium (K) is also an essential nutrient alongside nitrogen and phosphorus, contributing not only to yield but also to improving produce quality (Zörb and Sen Bayram, 2014). It is involved in vital plant functions such as enzyme activation, photosynthesis, and kernel formation (Mengel and Kirkby, 2001), while also enhancing plants' tolerance to various stresses (Zörb and Senbayram, 2014). Although potassium's effects on corn growth and quality are well-documented (Mallarino and Bergmann, 2011; Qiu et al., 2014), its specific influence on sweet corn under tropical soil conditions remains less explored.

Nitrogen (N) is fundamental to plant growth, significantly contributing to biomass accumulation throughout the growth cycle. Side-dressing with nitrogen fertilizers during crop development is a common practice to support yield improvement (Okumura et al., 2014). Increased nitrogen availability correlates with elevated leaf sugar content, greater dry mass, enhanced photosynthesis, and improved carbon assimilation, thereby promoting stronger physiological activity (Jin et al., 2015). High nitrogen applications during key growth stages such as silking have also been linked to higher grain protein and better nutritional profiles in maize (Silva et al., 2005; Sharif and Namvar, 2016). Nevertheless, excessive nitrogen use may result in environmental concerns such as nutrient runoff and greenhouse gas emissions (Lei Gao, 2020).

Nitrogen is frequently the primary nutrient limiting crop productivity and plays a crucial role in determining yield (Ferguson, 2002).

Its accumulation during growth stages in sweet corn follows a pattern comparable to field maize. Interestingly, sweet corn tends to have a higher nitrogen concentration per leaf area than field corn, though this does not always translate into greater photosynthetic efficiency or radiation use efficiency (RUE) (Jafarikouhin, 2020). Over-application of nitrogen can degrade soil health, pollute groundwater, and disrupt ecosystems (Kumar, 2019). Furthermore, excessive nitrogen may lower nitrogen use efficiency, increase lodging risk, and heighten pest and disease susceptibility. Silicon supplementation can mitigate these effects by enhancing nitrogen and water use efficiency, strengthening plant structural support, improving pest resistance, and stabilizing soil (Rajmani, 2012).

Although organic farming is often favored for its environmental and food safety benefits, it usually yields less than conventional systems (Ping, 2020). Under organic management, sweet corn has exhibited increased leaf phosphorus levels, higher shoot biomass, heavier

ears (both husked and unhusked), and overall better yields. Additionally, phosphorus uptake in organic systems can accelerate crop maturity and shorten harvest time (*Fahrurrozi, 2019*). Organic farming promotes ecological balance, biodiversity, and soil microbial activity through closed nutrient cycles (*Gamage, 2023*). For optimum sweet corn growth in organic systems, a mix of solid and liquid organic fertilizers is recommended, since nutrients from solid inputs may take up to 12 weeks to become available (*Foereid, 2018*).

The source of organic fertilizer also affects crop responses. Chicken manure has been shown to significantly enhance vegetative growth, boosting leaf number, plant height, and stem diameter, more effectively than cattle or horse manure (*Arshad et al., 2015*). These observations align with prior studies (*Ojeniyi et al., 2007; Safiullah et al., 2016*). While both solid and liquid organic fertilizers contribute positively to yield and nutrient uptake, relying solely on solid forms is often inadequate. Therefore, integrating both types is essential for maximizing productivity in organic systems (*Muktamar, 2017*). Nonetheless, some findings suggest that combining solid and liquid organic fertilizers does not always increase yields, though residual fertilizer effects still enrich rhizosphere nutrients, particularly phosphorus (*Canatoy, 2018*).

The surge in organic agriculture is driven mainly by its ecological advantages, enhanced food safety, and soil health improvements (*Hamzaoui, 2012*). However, a significant challenge in organic sweet corn production is the dependency on high-input cultivars requiring substantial amounts of nitrogen, phosphorus, and potassium (*Akintoye, 2012*). While conventional systems meet these demands easily with synthetic fertilizers, organic alternatives sourced from animal and plant residues generally contain lower nutrient levels (*Zublena, 1991*).

Innovations in organic cultivation, applicable both in fields and controlled environments, include biological agents and organic inputs to manage pests and diseases (*Litterick et al., 2004; Termorshuizen et al., 2006*). Among all essential nutrients, nitrogen remains the most limiting factor for maximizing yield (*Ferguson, 2002*). Although higher nitrogen inputs typically correlate with increased yields (*Tilman, 2011; Fan, 2011*), their overuse poses significant environmental risks (*Cui, 2010; Hirel, 2011*). Consequently, balanced fertilization is critical to enhancing nitrogen use efficiency and ensuring long-term sustainability (*Torres, 2014*).

Nitrogen continues to be the most demanded nutrient for healthy crop growth, but sweet corn cultivation often involves its overapplication, which may cause soil degradation. Urea, containing 46% nitrogen, is commonly used to correct nitrogen deficiencies, a key limiting factor in sweet corn production, but its use requires careful management to avoid negative impacts (Hayati, 2006). Enhanced phosphorus uptake in organic systems also supports improved yield traits and shortens the growing cycle (Fahrurrozi, 2019). Additionally, chicken manure applications can reduce potassium chloride (KCl) needs by up to 25% while improving soil health indicators like microbial respiration and activity (Darwin, 2020).

Organic farming has rapidly expanded over recent decades due to its contributions to environmental sustainability, soil health preservation, and yield improvements (Ghosh, 2020). Sweet corn (*Zea mays L.*) requires several essential nutrients, such as nitrogen, magnesium, zinc, iron, and potassium, all vital not only for crop performance but also for the nutritional quality of the resulting food.

In 2014, Péter Pepó demonstrated that maize hybrid performance is strongly influenced by both genotype and nutrient management. While unfertilized chernozem soils still supported substantial yields, the application of NPK fertilizers increased productivity by 3.2–6.5 t/ha. The highest yields were generally achieved with the N₁₂₀ + PK treatment, highlighting the importance of balanced nitrogen, phosphorus, and potassium supply. Additionally, proper fertilization improved water-use efficiency, showing that optimized nutrient management enhances both yield and resource efficiency in maize cultivation.

Széles (2019) demonstrated that maize hybrids respond differently to nutrient supply and that hybrid-specific fertilization strategies can help minimize yield losses under environmental stress. Treatments combining increased nitrogen with proportionally higher phosphorus and potassium (N + proportional PK) led to smaller yield reductions during drought compared to applications of higher nitrogen with constant PK. Among the hybrids studied, Renfor, Fornad, and Sushi showed the least yield decline under the T10 treatment in unfavourable conditions, whereas Armagnac performed best with T7 and Loupiac with T9. Fertilization generally enhanced grain protein content, with Armagnac reaching its maximum protein level under T5 regardless of the year, Loupiac under T4, and Fornad, Renfor, and Sushi achieving peak protein content under higher treatments in the favorable year (2016), while lower treatments sufficed in the dry year (2017). Protein accumulation was also influenced by water availability, with higher values in years with

better moisture conditions. Overall, the findings underscore that optimizing fertilizer management according to hybrid type can improve both yield and grain quality, making maize production more efficient and environmentally sustainable.

2.9 Plant Density

Sweet corn plant density varies widely, from about 9,900 to 79,000 plants per hectare. While higher densities can cause crowding stress among plants, the total marketable ear weight typically rises by around 0.8 tons per hectare at the highest densities. Interestingly, the overall plant yield (kg ha^{-1}) often remains relatively stable despite changes in density, although crate yield, which is critical for fresh market quality, has improved in newer hybrids (*Daljeet, 2021*).

Transplanting methods can increase plant populations by approximately 34% compared to direct seeding, which is often negatively impacted by abiotic factors such as soil crusting and low temperatures that reduce germination and establishment. This increase in plant numbers influences ear yield, with transplanted sweet corn achieving up to 4.1 tons per hectare more than direct-sown crops. Additionally, transplanting is associated with longer and heavier ears (*Teofil, 2021*).

Obtaining high-quality ear yield in sweet corn generally requires about 200 kg of nitrogen per hectare, which differs from nitrogen recommendations for field corn (*Rosen, 2017*). Historically, higher plant densities have been a significant driver of yield increases in field corn, mainly due to breeding hybrids that tolerate dense planting better (*Duvick, 2005; Tollenaar, 2002*). Research in the U.S. indicates that many density-tolerant hybrids are underused, and optimizing density for these can enhance profitability for both growers and processors (*Dhaliwal, 2019*).

High plant densities encourage faster canopy closure, limiting light penetration to the soil and thereby reducing weed growth. This strategy has been effectively applied in field corn breeding for decades. Studies of Era hybrids in Iowa (1930s–2001) showed consistent yield increases, with modern hybrids outperforming older ones due to better ability to develop ears under high-density stress (*Duvick, 1992; Shelton, 2013*). Older hybrids frequently showed barren plants or poorly filled ears at high densities. While weed suppression wasn't a primary breeding goal, enhanced density tolerance contributed indirectly by promoting earlier canopy closure (*McLachlan et al., 1993*).

Plant density affects grain yield, canopy photosynthesis, and biomass accumulation by improving light interception and optimizing radiation use throughout the growth cycle. However, too high density causes intense competition, reducing carbon and nitrogen uptake and thus kernel number. Some hybrids maintain yield stability across density ranges by producing tillers that compensate for stress (*Jiang, 2018*). Lower density often results in higher stomatal conductance and CO₂ assimilation. Sustainable yields require optimizing density alongside effective nutrient management (*Jiao, 2016*). Yield response to density is stronger when the crop's potential is high (*Du, 2021; Shi, 2016*). The 4R nutrient stewardship approach, focusing on the right source, rate, timing, and placement, can enhance nutrient use efficiency when incorporated into crop management practices (*Zhao, 2022*). High densities help close the canopy early, suppressing weeds. Early hybrid studies also documented linear yield gains per ear, with modern hybrids outperforming older types by maintaining ear development at high densities (*Duvick, 1992; Hammer, 2009*).

In both fresh market and processing systems, plant density strongly influences sweet corn yield (*Morris, 2000; Rangarajan, 2002*). Hybrid responses to density vary, as some hybrids possess heritable traits for density tolerance (*Williams, 2015*). Despite their potential, many of these tolerant hybrids remain underplanted in the Midwest (*Shelton, 2013*). The industry is thus shifting toward greater adoption of such hybrids to optimize performance and sustainability (*Dhaliwal, 2019*).

Over the past six decades, increases in field corn grain yield have been driven by both genetic advancements and improved crop management. Genetic gains are estimated to contribute about 50–70% of the overall yield improvement, with the remainder attributed to enhanced agronomic practices (*Quinn, 2019; Tollenaar, 1994; Duvick, 2001*). Modern hybrids exhibit greater tolerance to higher planting densities, allowing densities to increase by roughly 700 plants ha⁻¹ annually between 1987 and 2016 (*Assefa, 2018; Dhaliwal, 2021*). A crop's yield potential is primarily determined by its ability to intercept available environmental resources and efficiently transform atmospheric CO₂ into biomass (*Grzebisz, 2013*). In cereal crops, grain yield also depends on the proportion of biomass allocated to reproductive organs (*Grzebisz, 2013; Long, 2006*). *Zea mays L. var. saccharata* Bailey, commonly known as sweet corn, is widely cultivated, especially the

super sweet (*sh2*) and sugar-enhanced (*se*) varieties. This warm-season crop favors temperate climates but often faces challenges due to low seed vigor and poor emergence (Zhao, 2007).

2.10 Irrigation

Small discrepancies between predicted and actual sweet corn yields may occur when SPAD readings during the tasselling phase fall between 46 and 49. Under dry, rainfed conditions, using SPAD as a yield predictor is often unreliable; however, both SPAD and NDVI values measured at tasselling significantly influence kernel sugar content (Eszter, 2019).

Having irrigation infrastructure enables the application of fertilizers during the growing season, allowing for real-time, site-specific adjustments of nutrient supply. This practice better matches crop nitrogen demands and reduces nitrogen losses through leaching. Successful implementation depends on combining validated protocols and mechanistic models that consider both crop nitrogen uptake and soil nitrogen cycling. The AMAZE N model, tailored for sweet corn, has shown precision in estimating nitrate (NO₃-N) leaching into groundwater in sandy soils, indicating its potential to support adaptive nitrogen management strategies during the growing season (Mingwei, 2017). Boosting crop yields in arid and semi-arid zones, where natural rainfall cannot satisfy water requirements, is increasingly crucial due to the intensifying challenge of water scarcity (Geerts & Raes, 2009). In drip irrigation setups, a single-row layout with 225 cm lateral spacing has been shown to be less than optimal for sweet corn production. Even with a sufficient water supply, wider lateral spacing may lower both cob yield and water use efficiency. In contrast, employing a triple-row configuration at the same lateral spacing has demonstrated marked improvements in yield and water use efficiency (Mubarak, 2020).

Csajbók (2014) found that nutrient supply enhanced maize water use efficiency (WUE). During the drought year of 2007, a negative correlation was observed between WUE and soil moisture, indicating that higher soil moisture was associated with lower efficiency. Increasing light intensity also improved WUE, up to a photosynthetically active radiation (PAR) level of 1000 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$. Under dry conditions, maize used water more efficiently, whereas under well-watered conditions reduced efficiency. In fact, in wet years, maize transpired approximately 200–300% more water to assimilate 1 g of CO₂

compared to dry or water-stressed conditions. Irrigation had a significant effect on maize WUE, with the greatest impact observed in monoculture systems.

Szalókiné Zima (2023) carried out a lysimeter experiment at the Szarvas Experimental Station to investigate how irrigation and fertilization together affect sweet corn growth, nutrient uptake, and yield. The study showed that water availability is crucial for optimizing fertilizer efficiency. In irrigated plots, enhanced root activity and greater nutrient mobility led to significantly higher nutrient uptake, whereas under rainfed conditions, much of the applied fertilizer remained unused. An optimal fertilizer rate of approximately 300 kg NPK ha⁻¹ was found to maximize yield, with no substantial gains beyond this level. Under Hungarian climatic conditions, sweet corn required 400–450 mm of water per season for peak productivity. Fully irrigated plots produced 20–24 t ha⁻¹, while rainfed plots yielded only 10–14 t ha⁻¹, depending on rainfall patterns. Irrigation also improved water-use efficiency by about 25–30% compared to non-irrigated treatments. The study further highlighted that excessive fertilization under limited water conditions leads to nutrient losses and reduced environmental sustainability. Overall, the findings underscore that achieving high and stable sweet corn yields requires not only proper fertilization but also adequate water supply to ensure effective nutrient utilization.

Nemeskéri et al., (2019) highlighted the close relationship between water availability and nutrient management by examining how sweet corn hybrids respond physiologically and spectrally to different irrigation regimes. Their experiment compared fully irrigated, deficit-irrigated, and rainfed treatments, assessing parameters such as chlorophyll concentration, leaf area index (LAI), and spectral indicators like NDVI and SPAD. The results demonstrated that limited water supply markedly reduced photosynthetic capacity, chlorophyll content, and canopy growth, which led to yield reductions of 30–50% relative to optimal irrigation. Water shortages also diminished kernel quality, particularly ear mass and sugar levels, traits essential for high-quality sweet corn. Considerable hybrid variation was observed, with one genotype sustaining higher NDVI and LAI under drought stress, indicating improved tolerance. Correlation analysis showed strong links between spectral measurements and yield traits, supporting the use of remote sensing as an effective tool for monitoring crop condition and forecasting productivity. The authors concluded that maintaining adequate moisture during critical growth phases, especially tasselling and silking, is vital for proper ear development and sugar accumulation, and that

NDVI and SPAD can serve as dependable indicators for targeted irrigation and nutrient management.

2.11 Sowing Date

The timing of transplanting significantly impacts crop growth and development (*Hay, 1986*). Adjusting sowing dates can effectively minimize risks related to insect pests, disease outbreaks, and adverse weather conditions, thereby enhancing overall yield (*Maity, 2023*). *Herbek (1986)* reported that delaying corn planting, particularly in drought-affected regions, often results in reduced yields due to disrupted pollination and grain filling processes. Conversely, *Oktem et al., (2004)* found that the highest fresh ear yield occurred with crops sown on July 25, while the lowest yield was recorded for those sown on April 25.

Because soluble sugars in sweet corn quickly convert to starch post-harvest, the crop must be consumed fresh, canned, or frozen promptly. To maintain a continuous supply for processing and marketing, sweet corn is typically cultivated over a three-month period in northern and central parts of the United States (*Williams, 2008*).

Heat stress negatively affects ear development and kernel formation in maize, causing significant yield reductions (*Liu, 2023*). Sweet corn grows best when planted in soils with temperatures between 15 and 20 °C and thrives under ambient temperatures ranging from 20 to 30 °C (*Bird et al., 1977*). In field conditions, the combination of high temperature and water stress can severely constrain productivity. Planting date plays a crucial role in determining sweet corn's growth patterns and yield potential. For instance, in central Illinois, sweet corn planted in early May exhibited slower development and formed a denser canopy than crops sown in late June (*Williams and Lindquist, 2007*). Across different sowing dates in the Midwest, delayed planting corresponded with slower leaf emergence rates and a reduced final leaf count (*Williams, 2008*).

Martin (2008) observed that sweet corn hybrids planted at various dates were 13% to 23% taller than widely used cultivars in the north-central United States, highlighting a gap in research on how planting time influences growth and yield. The study emphasized that understanding consistent responses to sowing dates could improve and refine crop management practices.

Sweet corn also holds an important agronomic role. When grown with modern techniques, it helps suppress weeds and serves as a beneficial preceding crop, especially for wheat (*Shibzukhov, 2021*).

Grasping how sweet corn hybrids respond to diverse environmental and agronomic conditions is essential for evaluating their adaptability. This knowledge supports breeding programs and informs management decisions. Typically, new varieties must be tested across multiple sowing dates, locations, and seasons to confirm their appropriateness for targeted production zones.

2.12 Interaction Between Hybrids and Environmental Factors in Sweet Corn Production

The productivity and quality of sweet corn are heavily influenced by the interplay between hybrid genetics and environmental conditions. Studies show that hybrids respond differently to variables such as temperature, soil type, and water availability. For instance, drought-tolerant sweet corn hybrids have shown better yields in regions facing water shortages (*Khaledi, 2025*). Stressors like high temperatures during pollination can impair kernel development, underscoring the importance of selecting hybrids adapted to specific environmental situations (*Wang, 2020*).

Hybrids with improved tolerance to heat stress maintain higher yields under elevated temperatures than those that are less tolerant (*Djalovic, 2023*). The interaction between hybrid genotype and soil conditions is also critical; some hybrids perform best in well-drained soils, whereas others are better suited to heavier or nutrient-deficient soils (*Tejada, 2003*). Furthermore, factors such as light intensity and photoperiod affect hybrid performance, with certain varieties excelling in areas with longer daylight hours (*Edreira, 2012*).

Precipitation patterns also influence hybrid responses, especially during vulnerable phases like tasseling and silk emergence. In regions with abundant rainfall, hybrids with increased resistance to diseases such as rust and blight generally achieve higher yields (*Kim, 2023*). Therefore, choosing hybrids well-matched to the local environment can significantly enhance sweet corn yield and quality.

The study *Agronomic Benefits of Long-Term Trials* by *Márton Jolánkai et al., (2018)* underscores the importance of long-term agricultural experiments in revealing the intricate interactions between crops, soil properties, and environmental factors over extended

periods. The authors describe these trials as living scientific instruments that sustain controlled conditions across many growing seasons, making it possible to monitor gradual shifts in soil fertility, nutrient cycling, and crop performance. Their results show that long-term trials are crucial for assessing the sustainability of various fertilization regimes, demonstrating how continuous or altered nutrient inputs influence soil nutrient status, organic matter levels, and long-term yield consistency.

The research also stresses that long-term trials are vital for determining how crop varieties adapt and maintain performance stability under fluctuating climatic and soil conditions. Multi-year data enable researchers to analyze crop behavior across different weather scenarios, supporting the identification of resilient, high-yielding varieties suited to specific environments. Furthermore, the authors point out the scientific and educational significance of these trials, which function as open-field laboratories for training and research, validating agronomic models, and refining nutrient management strategies.

3. MATERIALS AND METHODS

3.1 Experiment of the Effect of Different Levels of Nitrogen Fertilizer and Different Plant Densities on the Yield of Four Sweet Corn Hybrids in the 2022 Season

3.1.1 Field experiment

The field experiment was initiated on April 27, 2022, at the Látókép Plant Cultivation Research Centre of the University of Debrecen, situated in Hungary's Hajdúság region (N 47°33', E 21°27'). The experimental site is characterized by calcareous chernozem soil with a near-neutral reaction (pH 6.46, KCl), which provides highly favorable conditions for sweet corn production. A factorial arrangement was applied within a randomized complete block design (RCBD) comprising four replications per hybrid. Each experimental plot contained four rows, with data collection restricted to the two central rows to minimize border effects and enhance accuracy. The primary objective was to investigate how different nitrogen fertilization levels affect yield-associated traits across four sweet corn hybrids. Analysis of variance (ANOVA) was used to determine the significance of treatment effects, while Pearson's correlation coefficient was employed to explore associations among measured traits and identify the main factors influencing hybrid performance.

3.1.2 Materials

The experiment evaluated four sweet corn hybrids, SF1379, Tyson, GSS6924, and Messenger, within a factorial design that incorporated three nitrogen application rates (100, 150, and 200 kg N ha⁻¹) and three planting densities of 60,000, 70,000, and 80,000 plants per hectare.

3.1.3 Soil preparations

Green peas were cultivated as the preceding crop. The land was initially plowed, followed by further preparation through disk harrowing, levelling, and ridging. The plots were sectioned, and seedbeds were finalized approximately one month before planting at the end of April 2022. Manual hoeing was performed one month after sowing. The crop received six irrigation sessions throughout the season, with around 25 mm of water each time, except for the second irrigation, which applied approximately 30 mm. In 2021, all experimental plots received a uniform application of 300 kg/ha of NPK fertilizer (8:24:24). Nitrogen was applied in the form of Pétisó at 500 kg/ha, providing 27% N. The experimental plots each contained four rows, with data and measurements taken

exclusively from the two central rows to avoid border interference. Soil insect Crop management included the application of Force 1.5 G at 12 kg ha⁻¹. Throughout the growing season, plant protection was maintained using a combination of herbicidal and insecticidal treatments, including selective post-emergence herbicides and insecticides such as Laudis, Coragen 20 SC, Karate Zeon 5 CS, and Ampligo at the recommended rates.

3.1.4 Measurements

From each treatment plot, ten plants were randomly selected and tagged to record growth and yield-related characteristics. Observations included days to emergence and emergence percentage, plant height (cm), phenological stage at the sixth leaf, and the number of lodged or broken plants. Yield-related measurements comprised total yield (kg ha⁻¹), silking and tasselling dates, ear length (cm) and diameter (mm), number of kernel rows per ear, kernels per row, total number/cob, Number of plants in the second and third rows before harvest, yield from these rows (kg), yield both with and without husks, grain weight (g), percentage yield, and final moisture content (%).

3.1.5 Methods for Assessing Crop Development and Yield Metrics

The time from sowing to the emergence of seedlings above the soil surface was recorded as the emergence period. Emergence percentage was determined by dividing the number of seedlings that emerged by the total seeds sown. Plant height was measured from the soil surface to the tip of the tallest leaf, while the sixth-leaf stage was recorded when the collar of the sixth leaf became visible. The number of lodged plants was noted, and total yield (kg ha⁻¹) was estimated by weighing harvested plants and extrapolating to a per-hectare basis. Silking and tasseling dates were recorded when approximately half of the plants displayed visible silks and tassels. Ear length was measured using a ruler, and ear diameter was determined with calipers. Kernel rows per ear and kernels per row were counted manually. All measurements were taken from the two central rows to reduce edge effects. Harvested weights were recorded both with and without husks to determine respective yields. Grain yield was calculated after drying, and grain moisture content was measured using a moisture meter.

3.1.6 Harvesting

The SF1379 and Messenger hybrids were harvested at the end of July, whereas GSS6924 and Tyson reached maturity and were collected in early August.

3.2 Assessment of the Impact of Various Sowing Dates on the Yield Performance of Four Sweet Corn Hybrids in 2022

Four sweet corn hybrids were evaluated across three sowing dates, April 27, May 31, and June 29, with four replications per treatment. Each plot consisted of four rows, while yield-related data were collected from the two central rows at harvest to reduce border effects and ensure precise measurements.

Hybrids Evaluated:

1. SF 1379
2. Braveheart
3. Tyson
4. Messenger

3.2.1 Parameters Recorded

From each plot, ten plants were randomly chosen and tagged for evaluating vegetative growth, yield, and related traits. The measured parameters included: days to emergence, emergence percentage, plant height (cm), phenological stage at the sixth leaf, number of lodged plants, yield per hectare (kg), dates of silking and tasseling, ear length (cm), number of broken plants, yield from the central rows (kg), ear diameter (mm), number of rows per ear, kernels per row, total ears, number of plants in the second and third rows before harvest, yield with husks, yield without husks, grain weight (g), percentage yield, and grain moisture content (%).

3.3 Agronomic Techniques

3.3.1 Sowing Date 1 Trial (2022.04.27)

Soil preparation for the experiment began on 11 October 2021, following the harvest of green peas. The seedbed was prepared twice, first on 2 March and again on 26 April 2022. Sowing was performed on 27 April 2022, followed by field cultivation on 31 May 2022. Fertilization involved a basal application of 300 kg ha⁻¹ of NPK (8:24:24) on 2 October 2021, supplemented with 500 kg ha⁻¹ of Pétisó (27% N) on 26 April 2022 to provide additional nitrogen. For soil pest and weed management, Force 1.5 G was applied at 12 kg ha⁻¹ on 27 April 2022. Throughout the growing season, crop protection involved applying Laudis at 2 L ha⁻¹ on 22 May 2022, Coragen 20 SC at 0.15 L ha⁻¹ and Karate Zeon 5 CS at 0.25 L ha⁻¹ on 6 July 2022, and Ampligo at 0.25 L ha⁻¹ on 18 July 2022.

Irrigation was performed multiple times, with 25 mm applied on 1 July, 30 mm on 3 July, and 25 mm daily from 13 to 16 July. Harvesting was conducted based on hybrid maturity: SF1379 on 28 July, Tyson and GSS6924 on 1 August, and Messenger on 4 August 2022.

3.3.2 Sowing Date 2 Trial (2022.05.31)

The seedbed was prepared on 30 May 2022, with sowing carried out on 31 May, and field cultivation completed on 29 June 2022. Fertilization included a basal application of 300 kg ha⁻¹ NPK (8:24:24) on 2 October 2021, followed by an additional nitrogen supply of 500 kg ha⁻¹ Pétisó (27% N) on 26 April 2022. Soil pest control was carried out using Force 1.5 G at 12 kg ha⁻¹ on 31 May 2022. Herbicide and insecticide applications were performed as follows: Laudis at 2 L ha⁻¹ on 19 June, Coragen 20 SC at 0.15 L ha⁻¹ and Karate Zeon 5 CS at 0.25 L ha⁻¹ on 24 July, and Ampligo at 0.25 L ha⁻¹ on 10 August. Irrigation was applied on 1 July (25 mm), 3 July (30 mm), daily from 13 to 16 July (25 mm per day), and again on 24 August (25 mm). Harvesting was conducted according to hybrid maturity, with Tyson and GSS6924 harvested on 25 August, and SF1379 and Messenger on 2 September 2022.

3.3.3 Sowing Date 3 Trial (2022.06.29)

The seedbed was prepared twice, on 30 May and 28 June 2022, with sowing carried out on 29 June 2022. The first mechanical cultivation took place on 20 July. Fertilization began with a basal application of 300 kg ha⁻¹ NPK (8:24:24) on 2 October 2021, followed by 500 kg ha⁻¹ of Pétisó (27% N) on 26 April 2022. Soil pest management was conducted using Force 1.5 G at 12 kg ha⁻¹ on 29 June, while herbicide treatment with Laudis (2 L ha⁻¹) was applied on 12 July. Insecticide applications included Coragen 20 SC (0.15 L ha⁻¹) and Karate Zeon 5 CS (0.25 L ha⁻¹) on 27 August, followed by Ampligo (0.25 L ha⁻¹) on 10 September. Irrigation was performed on 1 July (25 mm), 3 July (30 mm), daily from 13 to 16 July (25 mm per day), and again on 24 August (25 mm). Harvesting was carried out according to the maturity of each hybrid: Tyson on 27 September, GSS6924 on 30 September, and SF1379 and Messenger on 10 October 2022.

3.4 Evaluation of the Effect of Sowing Date on the Yield of Various Sweet Corn Hybrids in 2023

In the 2023 season, four sweet corn hybrids were examined across four sowing periods, April 30, May 30, June 30, and July 15, under full irrigation. Each treatment was replicated four times. Plots contained four rows, and post-harvest observations were

conducted on the second and third rows. The specific agro-technical activities for each sowing variant (V1 through V4) are detailed below.

3.4.1 Sowing Date 1 (V1)

Hybrids Tested:

1. Azlan
2. HMX825 (Kamet)
3. Braveheart
4. GSS3071

3.4.2 Data Collection

In each plot, ten plants were randomly selected, tagged, and assessed for various growth and yield traits. The measured parameters included: date and percentage of emergence, phenological stage, dates when 50% and 100% of plants produced silks, dates when 50% and 100% of plants tasselled, number of rows per cob (from 10 cobs per plot), kernels per row (from 10 cobs), Number of broken and lodged plants, plant numbers before harvest (from the two central rows), plant height (cm), plot yield (number of cobs), yield per hectare (kg), fresh and dry weights, total cob weight (kg), cob weight without husks (kg), grain yield (g), efficiency percentage, and cob dry matter content (kg).

3.4.3 Soil Preparation for Sweet Corn Trials

The experimental field had previously been sown with winter wheat. Primary tillage was performed on 11 October 2022 using a Rabewerk Super Albatros plow. Secondary soil preparation was carried out with a Väderstad NZ Aggressive combinator on 2 March and 26 April 2023. Inter-row cultivation was performed on 5 June 2023 using a Monosem SGC. Sowing was completed on 28 April 2023 with a Gaspardo MTE 3000 seeder.

3.4.4 Fertilization and Crop Protection

On 26 April 2023, calcium ammonium nitrate (CAN, 27% N) was applied at a rate of 500 kg/ha. Soil disinfection was carried out on 28 April 2023 using Force 1.5 G at 12 kg/ha. During the crop growth period, protection measures included spraying Laudis at 2 L/ha on 30 May 2023 and Coragen 20 SC at 0.15 L/ha on 7 July 2023.

3.4.5 Irrigation and Harvesting

Irrigation was applied on 3, 11, 19, and 25 July 2023, with each event delivering 25 mm of water. Harvesting was carried out on 31 July and 1 August for the first and second hybrids, and on 3 August for the third and fourth hybrids.

3.4.6 Sowing Date 2 (V2)

In the second sowing trial, the field was prepared using a Väderstad NZ Aggressive combinator on 26 April 2023, followed by inter-row cultivation with a Mono-sem SGC on 29 June 2023. Sowing was carried out on 29 May with a Gaspardo MTE 3000 seeder. Fertilization consisted of a single application of calcium ammonium nitrate (CAN, 27% N) at 500 kg/ha on 26 April. Soil pest management was performed on 29 May using Force 1.5 G at 12 kg/ha. Crop protection included spraying Laudis at 2 L/ha on 19 June and Coragen 20 SC at 0.15 L/ha on 7 July. Irrigation was applied on 3, 11, 19, and 25 July, with 25 mm of water applied per event. Harvesting occurred on 23 August for the first two hybrids and on 24 August for the third and fourth hybrids.

3.4.7 Sowing Date 3 (V3)

For this trial, field preparation was conducted using a Väderstad NZ Aggressive combinator on 26 June 2023, followed by inter-row cultivation with a Monosem SGC on 22 July. Sowing was carried out on 27 June using a Gaspardo MTE 3000 seeder. Fertilization involved applying calcium ammonium nitrate (CAN, 27% N) at 500 kg/ha on 26 April. Soil disinfection was performed on 27 June using Force 1.5 G at 12 kg/ha. Crop protection included spraying Laudis at 2 L/ha on 12 July. Irrigation events occurred on 3, 11, 19, 25 July, and 29 August, with 25 mm of water applied each time. Harvesting was done on 15 September for the first two hybrids and on 18 September for the third and fourth hybrids.

3.4.8 Sowing Date 4 (V4)

This experiment began with a combinator use (Väderstad NZ Aggressive) on June 26, 2023, and interrow cultivation (Monosem SGC) on July 31. Seeds were sown on July 10 using the Gaspardo MTE 3000. Fertilizer (CAN 27% N) was applied on April 26 at 500 kg/ha. Soil disinfection was carried out on July 10 using Force 1.5 G (12 kg/ha). Laudis was sprayed on July 28 (2 L/ha). Irrigation dates included July 3, 11, 19, 25, and August

29, with 25 mm each time. Harvests occurred on September 28 for the first two hybrids, October 3 for the third, and October 9 for the fourth.

3.5 Assessment of Yield Potential in Five Sweet Corn Hybrids for the 2023 Growing Season

Five sweet corn hybrids were tested under fully irrigated conditions, with each treatment replicated four times. Plots contained five rows, and assessments were based on the second and third rows.

Hybrids Evaluated:

1. Spirit
2. Azlan
3. GSS6924
4. Impress
5. Dessert78

3.5.1 Measurements

In each plot, ten plants were randomly chosen, tagged, and assessed for various growth and yield characteristics. The parameters measured included: date of emergence, emergence percentage, phenological stage at the sixth leaf, dates when 50% and 100% of plants silked, dates when 50% and 100% of plants tasselled, number of rows per cob (from 10 cobs per plot), kernels per row (from 10 cobs), Number of broken and lodged plants, plant numbers before harvest in the second and third rows, plant height (cm), plot yield (number of cobs and kg), yield per hectare (kg), fresh and dry weights, total cob weight (kg), cob weight without husks (kg), grain yield (g), harvest efficiency (%), and cob dry matter content (kg). Soil preparation followed the harvest of a winter wheat crop. Plowing was carried out on October 11, 2022, using a Rübwerk Super Albatros. Further tillage was conducted with a Väderstad NZ Aggressive on March 2 and April 26, 2023. Monosem SGC was used for row crop cultivation on June 15 and interrow operations on June 21.

Sowing was carried out on 16 May 2023 using a Gaspardo MTE 3000 seeder. Fertilization consisted of applying calcium ammonium nitrate (CAN, 27% N) at 500 kg/ha on 26 April, followed by a 13-20-10 compound fertilizer at 100 kg/ha on 15 May and 21 June. For crop protection, soil disinfection was done on 16 May with Force 1.5 G at 12 kg/ha. Spray

applications included Laudis at 2 L/ha on 22 May, Yara Vita Zinc at 2 L/ha on 30 May, Coragen 20 SC at 0.15 L/ha on 7 July, and Ampligo at 0.25 L/ha on 18 July. Irrigation was applied on 3, 11, 19, and 25 July, each time delivering 25 mm of water. Harvesting dates were 14 August for Hybrid 1, 17 August for Hybrid 2, 18 August for Hybrids 3 and 5, and 21 August for Hybrid 4.

3.6 Experiment Influence of Different Nitrogen Fertilizer Levels on the Yield of Various Sweet Corn Hybrids in the 2023 Season

Five sweet corn hybrids were evaluated under three nitrogen regimes, each totalling 100 kg N/ha. The treatments differed in application timing: a single full dose, two split doses of 50+50 kg/ha, and three split doses of 33.3+33.3+33.3 kg/ha. All plots were irrigated and arranged in four replications. Each experimental unit consisted of four rows, with the second and third rows used for yield measurements. The following section details the agronomic practices employed, which conformed to contemporary standards for sweet corn cultivation and precision nutrient management.

Hybrids Studied:

1. GSS6924
2. Royalty
3. Spirit
4. Azlan
5. GSS5649

3.6.1 Measurements

Each plot had ten randomly marked plants selected for measuring growth and productivity traits. Collected data included: day of emergence, emergence percentage, sixth-leaf stage, 50% and 100% silking, 50% and 100% tasseling, number of rows per cob (10 cobs/plot), kernels per row (10 cobs/plot), broken and lodged plants, pre-harvest plants Number (2nd and 3rd rows), plant height (cm), yield (pieces and kg), yield per hectare (kg), fresh and dry biomass, cob weight (kg) with and without husk, grain weight (g), harvest efficiency (%), and cob dry matter content.

The field preparation for the sweet maize trial began with winter wheat as the preceding crop. Plowing was executed on October 11, 2022, using a Råbework Super Albatros. Subsequent tillage was carried out with a Väderstad NZ Aggressive combinator on March

2 and April 26, 2023. Interrow cultivation operations were performed on June 5, 15, and 21 using a Monosem SGC machine. Sowing was carried out on 28 April 2023 using a Gaspardo MTE 3000 planter. Fertilization consisted of three applications of CAN (27% N) at 100 kg/ha each, applied on 26 April and 15 June, in accordance with the experimental design. Soil pest management was initiated with Force 1.5 G at 12 kg/ha on 28 April. Foliar treatments were applied as follows: Laudis (2 L/ha) on 30 May, Coragen 20 SC (0.15 L/ha) on 7 July, and Ampligo (0.25 L/ha) on 18 July. Irrigation events took place on 3, 11, 19, and 25 July, with 25 mm of water applied during each session. Harvesting was conducted according to hybrid maturity, with Hybrid 1 collected on 3 August, Hybrid 2 on 21 July, Hybrid 3 on 2 August, Hybrid 4 on 31 July, and Hybrid 5 on 1 August 2023.

3.7 Comparative Evaluation of Yield in Various Sweet Corn Hybrids for the 2023 Season

The study assessed 32 sweet corn hybrids, each cultivated in a single replicate under full irrigation conditions. Each plot comprised two rows, each measuring 10 meters in length, and the experiment followed standard modern sweet corn cultivation practices.

The hybrids were planted in two distinct sowings:

First sowing: Spirit, Starshine, 1218, ZUY1355IA, SF1770, SF2169, SF1379, Noa, 1231, 1446, ZHY5022OD, Willinger, HMC302, HMC305, KIARA; Second sowing: GH6055, ZUY1357IA, HMX820, Camden, Royalty, Impress, ZHY5233OD, FORERUNNER, HMC305, HMC312, HMX832, GSS6924, Townsend, SVSK2949, SVSK4540, SVSK5701, Messenger.

3.7.1 Measurements

In each plot, ten plants were randomly selected, tagged, and evaluated for morphological and yield-related traits. The recorded parameters included: date and percentage of emergence, phenological stage at the sixth leaf, dates when 50% and 100% of plants silked, dates when 50% and 100% of plants tasselled, number of rows per cob (from 10 cobs per plot), kernels per row (from 10 cobs per plot), counts of broken and lodged plants, plant numbers before harvest in the second and third rows, plant height (cm), yield per plot in number of pieces and kilograms, yield per hectare, fresh and dry cob weights (kg), cob weight without husks (kg), grain yield (g), harvest efficiency (%), cob dry matter content (kg), cob length (cm), and cob diameter (mm). Soil preparation for the hybrid

comparison began with the previous crop, winter wheat. Plowing was completed on October 11, 2022, using the Rábewerk Super Albatros. Tillage using the Väderstad NZ Aggressive was performed on March 2 and again on April 26, 2023. Interrow cultivation using the Monosem SGC took place on June 5 and 15, 2023.

Sowing was conducted in two rounds, on 28 April and 29 May, using a Gaspardo MTE 3000 planter. Fertilization involved a single application of calcium ammonium nitrate (CAN, 27% N) at a rate of 500 kg/ha on 26 April 2023. Soil pest control was carried out on 28 April with Force 1.5 G at 12 kg/ha, followed by foliar treatments of Laudis (2 L/ha) on 30 May and Coragen 20 SC (0.15 L/ha) on 7 July. Irrigation was administered on 3, 11, 19, and 25 July, applying 25 mm of water at each event.

Harvest Dates:

First sowing: Spirit and Starshine – 21 July; SF1770 and SF2169 – 24 July; 1218, ZUY1355IA, ZHY5022OD, HMC302 – 3 August; SF1379, Noa, 1231, 1446, Willinger, HMC305, KIARA – 2 August. Second sowing: GH6055, Royalty, ZHY5233OD, HMC305, HMX832, Messenger – 23 August; HMX820, GSS6924, SVSK5701 – 24 August; Impress, FORERUNNER, HMC312, Townsend, SVSK2949 – 25 August; ZUY1357IA, Camden, SVSK4540, Messenger – 29 August.

3.8 Weather Characteristics of the 2022 Growing Season (Debrecen–Látókép)

Following the severely dry season of 2021, the winter of 2022 continued to receive minimal rainfall. Total precipitation over six months was recorded at just 144 mm, about 70 mm below the historical average. Though slightly cooler than average, the period was characterized by elevated sunshine duration. Detailed statistics are available in Table 1.

The lower soil layers did not receive enough moisture recharge. During the period from January to March, only 32 mm of precipitation was recorded. Along with sunny and windy weather, this resulted in rapid topsoil drying, which heightened the risk of significant drought stress throughout the crop's growing season.

Table 1 Monthly and Semi-annual Patterns of Temperature, Precipitation, and Sunshine Duration in 2022

Period	Mean Temperature (°C)	Precipitation (mm)	Sunshine Duration (hours)
Winter period (Oct–Mar)	–	144 (–70)	891 (+217)
Summer period (Apr–Sep)	18.5 (+1.0)	268 (–78)	1566 (+50)
April	9.0 (–2.2)	53 (–3)	177 (–37)
May	17.6 (+1.0)	10 (–54)	275 (+25)
June	22.2 (+2.9)	17 (–49)	358 (+89)
July	23.4 (+2.1)	22 (–44)	312 (+26)
August	23.5 (+2.7)	17 (–32)	303 (+14)
September	15.3 (–0.9)	152 (+104)	141 (–67)

Owing to the prevailing drought conditions, soil preparation activities during spring were feasible across all regions as early as March. April brought slightly cooler temperatures accompanied by moderate rainfall. This month registered the most pronounced negative temperature deviation of the growing season, with an average of 9.0°C—2.2°C below the long-term mean, though still milder than April 2021.

In contrast, the weather in May was warm and notably dry from the outset. Despite the variations, the overall spring of 2022 was conducive for sweet corn sowing and early development. From April 12 onward, the average soil temperature consistently surpassed the critical 10°C threshold required for sweet corn germination, reaching approximately 15°C by the end of the month (Figure 1). On most days, air temperatures lagged several degrees behind soil temperatures, resulting in a sustained surplus in soil warmth.

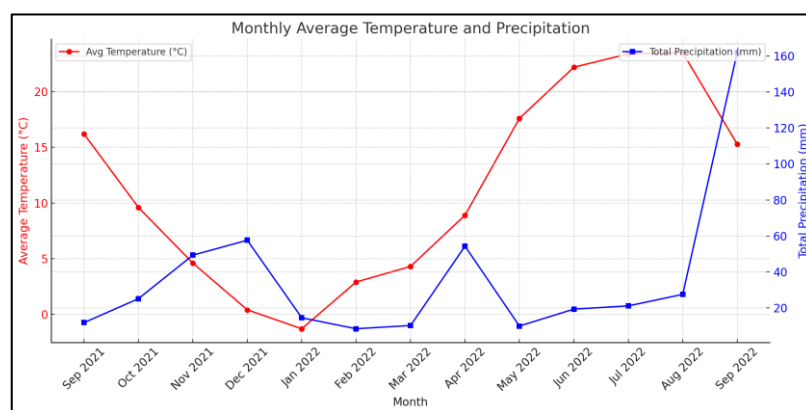


Figure 1 Monthly Average Temperature and precipitation 2021-2022. The chart illustrates the monthly variations in average temperature and total precipitation from September 2021 to September 2022. Temperature peaks during summer (June–August 2022), while precipitation shows a sharp rise in September 2022.

The summer of 2022 was characterized by extreme heat and a prolonged lack of rainfall. As shown by ten-day interval data (Figure 2), dry conditions began in early May and persisted until the end of August. From early June through mid-September, temperatures

consistently exceeded seasonal norms, with only a minor decrease around mid-July, yet still remaining above average. The mean monthly temperatures in June, July, and August were 2–3°C higher than historical averages.

This period also saw a notable increase in sunshine duration, accompanied by predominantly clear skies and minimal cloud cover. Total rainfall during the summer reached only 56 mm, even lower than the 72 mm recorded in 2021. Since 1951, only one summer, 1962, has recorded less precipitation, with 55 mm. Merely two days experienced rainfall exceeding 10 mm: 11.5 mm on June 4 and 12 mm on July 31. However, these brief showers offered little relief due to excessive evaporation driven by high air temperatures.

Throughout the three summer months, sunshine hours exceeded the long-term average, with June recording the highest solar radiation intensity. The dominance of a persistent high-pressure system resulted in clear skies, dry air masses, and pronounced diurnal temperature fluctuations. Despite nighttime temperatures often dropping below 20 °C, the frequency of heat days (daily maximum temperatures ≥ 30 °C) was exceptionally high, totalling 44 over the summer period. A severe drought took hold throughout the Debrecen region and much of Hungary. Since the widespread adoption of maize cultivation, no previous growing season had experienced yield losses of such severity. Even in the region's fertile and well-draining chernozem soils, maize crops failed across extensive areas.

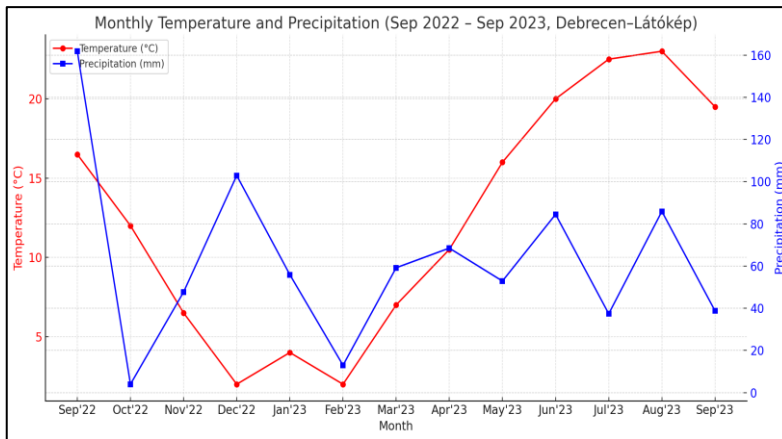


Figure 2 Monthly Temperature and precipitation (September 2022-2023). The figure illustrates a typical seasonal Template in Debrecen-Látókép, with low winter temperatures, summer heat peaks, and irregular rainfall distribution throughout the year.

At the onset of September, there was a dramatic shift in weather patterns marked by significant rainfall. The total precipitation for the month reached 152 mm, more than three times the long-term average and surpassing the cumulative total recorded between January and August 2022. While early September experienced warm temperatures, the remainder of the month was predominantly cool. The prolonged periods of wet and mild conditions contributed to a delayed moisture release in maize crops, influencing the final yield.

3.9 Statistical Analysis

3.9.1 Analysis of Variance

Analysis of variance (ANOVA) is a statistical technique used to evaluate the extent of variation in a continuous dependent variable attributable to one or more categorical factors. These factors, typically nominal, define the treatment groups under investigation. ANOVA is widely applied to determine whether significant differences exist among group means by comparing the variance between treatment groups with the random variance observed within groups (*Martin, 2008*).

In sweet corn research, ANOVA serves as a crucial tool for assessing the effects of treatments such as fertilizer application rates, irrigation regimes, and hybrid types on yield and associated agronomic traits. This statistical approach enables researchers to quantify treatment impacts and make reliable comparisons across experimental conditions, supporting informed decisions in agronomy and crop production management. In this study,

all collected data were analyzed using analysis of variance (ANOVA) following the method described by *Miller (1958)*, with calculations performed in GenStat software. The analysis focused on the 2022 growing season, and treatment means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of $P \leq 0.05$. Additionally, Pearson correlation coefficients were calculated in SPSS to evaluate the relationships among the measured traits. This correlation analysis provided insights into the associations between yield and its contributing factors. Correlation coefficients for fresh ear yield and related traits were obtained from combined datasets across both years, following the procedure outlined by *Miller (1958)*.

3.10 Duncan Multiple Range Analysis

To compare more than two group means, researchers use procedures collectively referred to as multiple-range tests. These methods rely on multiple critical values, providing greater statistical power than simpler tests such as the Least Significant Difference (LSD) test, which relies on a single threshold.

One of the most influential multiple-range tests was introduced by *Duncan (1955)*. His method allows for comprehensive pairwise comparisons between all treatment means. The technique is both straightforward and powerful, gaining widespread acceptance in fields like plant science for post-ANOVA comparisons.

Key Features of Duncan's Multiple Range Test (DMRT):

1. **Comprehensive Pairwise Testing:** The test performs comparisons between all possible pairs of means in the dataset.
2. **Sequential Methodology:** It starts with comparing the means that are farthest apart and then gradually moves to those closer in value.
3. **Variable Significance Thresholds:** Unlike tests such as Tukey's, which use a constant threshold, DMRT applies an adaptive significance level, tightening the criteria as the means being compared become more similar.
4. **Greater Sensitivity:** DMRT is known for its ability to detect smaller differences between treatment means. However, this increased sensitivity comes with a higher probability of Type I errors (false positives).

Despite its susceptibility to false positives, Duncan’s test remains an important tool for researchers across disciplines, including agriculture, biology, and psychology, where distinguishing treatment effects is vital (*Duncan, 1955*).

3.11 Correlation Analysis

Correlation analysis is a statistical technique used to determine both the direction and strength of the relationship between two quantitative variables. A monotonic relationship occurs when changes in one variable consistently correspond to changes in another, either in the same or opposite direction. A positive correlation indicates that both variables tend to increase or decrease together, while a negative correlation implies that an increase in one variable is associated with a decrease in the other. For datasets that meet parametric assumptions, such as normal or t-distributions, the Pearson correlation coefficient is typically used to evaluate the linear association between variables. According to *Patrick (2018)*, correlation analysis is an effective method for uncovering patterns and dependencies, providing a foundation for further investigation in agronomy and related scientific fields.

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

N indicates the total number of observation pairs. $\sum xy$ is the sum of the products for each pair of values, $\sum x$ represents the sum of all x-values, and $\sum y$ represents the sum of all y-values. $\sum x^2$ is the total of the squared x-values, while $\sum y^2$ is the total of the squared y-values.

A Spearman Rank-Order Correlation Coefficient

When the relationship between two variables does not follow a specific distribution (i.e., non-parametric data), the Spearman correlation coefficient is applied. This statistic is used to assess the strength and direction of a monotonic relationship between the variables, providing a reliable measure of association when the assumptions of parametric correlation are not met.

$$r_{xy} = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n \sum x_i^2 - (\sum x_i)^2} \sqrt{n \sum y_i^2 - (\sum y_i)^2}}$$

The Pearson correlation coefficient (R) quantifies both the strength and direction of the relationship between two variables, x and y. In this formula, n denotes the total number of observations, x_i represents the value of x for the i th observation, and y_i corresponds to the value of y for that same observation.

3.12 Regression Analysis

Regression analysis is a widely used statistical approach in agricultural research, including sweet corn studies, for evaluating the relationships between dependent and independent variables. This method helps determine how factors such as fertilization levels, irrigation regimes, and environmental conditions impact crop yield and growth.

Key Applications:

1. Yield Estimation

Regression models enable the prediction of sweet corn yield based on variables such as nitrogen input, planting density, and soil moisture content (*Patrick, 2018*).

2. Growth Dynamics

By analysing the association between plant development indicators (e.g., height, leaf area) and environmental conditions, regression analysis assists in optimizing cultivation strategies (*Patrick, 2018*).

3. Economic Evaluation

Regression analysis can also be applied to link production costs with yield and market performance, thereby facilitating the economic evaluation of different agricultural practices. It is used to explain the variability of a response variable based on one or more predictor variables (*Martin, 2008*).

Steps in Conducting Regression Analysis:

1. Define the model's objective and determine the appropriate dependent variable.

2. Identify relevant independent (explanatory) variables.
3. Estimate the parameters of the regression model.
4. Interpret the coefficients, evaluate model fit, and assess variable significance.
5. Validate assumptions underlying the model.
6. If necessary, revise the model to address any assumption violations.
7. Confirm the model's accuracy through validation tests.

A simple linear regression model is expressed by the equation:

$$y = a + b \times x + E$$

- a denotes the intercept.
- b is the slope.
- E denotes the error term.

Regression analysis employs observed data to estimate unbiased values of the slope and intercept, facilitating accurate modelling of the relationships between variables (*Patrick, 2018*).

3.13 Data Clustering Analysis

Cluster analysis is a statistical approach used to group data with shared features, which is particularly helpful in sweet corn research for uncovering patterns in genetics, crop performance, and adaptation to environmental factors.

Primary Applications:

- 1. Evaluating Genetic Diversity**

Cluster analysis helps group sweet corn genotypes based on morphological or genetic attributes, aiding breeding programs and conservation efforts (*Kaur, 2018*).

- 2. Agronomic Performance Categorization**

This method classifies cultivars by performance traits like yield and disease resistance, guiding cultivar selection tailored to specific field conditions (*Kaur, 2018*).

- 3. Environmental Adaptation**

Cluster analysis is used to evaluate cultivar responses to different environmental factors such as irrigation, soil types, and climatic variations (*Zaman, 2020*).

Overall, cluster analysis belongs to the broader field of unsupervised learning, where data with unknown groupings is structured based on inherent patterns. Various algorithms are available for revealing such hidden structures and organizing the data into meaningful groups.

In this study, sweet corn varieties were clustered based on their yield responses and agronomic performance, offering valuable insights into varietal selection for diverse growing conditions (*Kaur, 2018; Zaman, 2020*).

Density-Based Clustering:

One advanced method for clustering is based on identifying areas of high point density within the data, with remaining points considered noise. Two notable techniques include:

- DBSCAN (*Ester et al., 1996*): Detects core, border, and noise points by counting neighbors in a defined radius, then groups core points into clusters.
- OPTICS (*Ankerst et al., 1999*): An extension that handles clusters with varying densities.

Advantages of Density-Based Methods:

It is not necessary to specify the number of clusters beforehand. This approach is capable of identifying clusters with complex, non-linear, or non-convex shapes. The clustering procedure concludes when the data density falls below a predetermined threshold (*Ester et al., 1996; Ankerst et al., 1999*).

3.14 Factor Analysis

Factor analysis refers to a group of statistical methods used to condense a large set of observed variables into a smaller number of hidden, underlying factors. These unobservable factors are believed to explain the correlations between measured variables and capture the common variance that links them together. For example, in psychological studies, observed behaviors or questionnaire responses (known as manifest variables) can be influenced by abstract characteristics such as dominance or broader personality traits, a phenomenon observed in both humans and non-human primates (*Weiss, 2010*). In agricultural research, particularly sweet corn studies, factor analysis is used to identify and rank the most influential agronomic traits, environmental variables, and management strategies affecting yield and crop quality.

- *Khomphet (2024)* applied factor analysis to determine the primary agronomic factors influencing sweet corn productivity.
- *Chaudhary (2024)* evaluated environmental influences on sweet corn growth, isolating critical variables for effective field management.
- *Revilla (2021)* used this method to identify combinations of practices that maximized both yield and quality in sweet corn cultivation.

Factor analysis is thus a powerful statistical tool for extracting meaningful insights from complex datasets, allowing researchers to focus on the most significant variables that shape sweet corn performance under varied growing conditions.

4. RESULTS

4.1 Impact of Varying Nitrogen Fertilizer Levels on the Yield of Four Sweet Corn Hybrids – 2022 Season

4.1.1 Statistical Analysis

The ANOVA findings revealed a highly significant interaction ($p < 0.01$) between nitrogen fertilizer rates and sweet corn hybrids for emergence percentage. Additionally, traits including the number of cobs per plant, grain moisture content, total plant population, kernel rows per ear, and yield percentage displayed significant differences at the 5% probability level. Other measured traits, however, were not significantly influenced by the treatments. The analysis also showed highly significant variation ($p < 0.01$) among the four sweet corn hybrids for key characteristics such as emergence percentage, plant population, yield percentage, plant height, number of kernels per ear, ear length, grain moisture content, kernel row number, and ear diameter. Considerable differences were observed in the number of cobs and ears, both with and without husks, while the remaining traits exhibited no statistically significant variation. When analyzed separately, nitrogen application had a significant effect on plant height, cob Number, yield percentage, and the number of dehusked ears (Tables 2 and 3). The highest yield was achieved with 100 kg N ha^{-1} , whereas further increases to 150 kg N ha^{-1} and 200 kg N ha^{-1} caused yield declines of 461 kg ha^{-1} and $1,405 \text{ kg ha}^{-1}$, respectively. These findings are consistent with the observations made by *Lei Gao (2020)*, who highlighted that combining straw return with optimized nitrogen application can sustainably improve sweet corn productivity and minimize nitrogen losses (*Ping-Fu, 2020*). Given the growing challenges of climate change in agriculture, improving nitrogen use efficiency is crucial for stabilizing yields. These outcomes also support the findings of *Okti Herliana (2020)*, who demonstrated that nitrogen levels at 25% and 50% of the recommended rate were most effective in enhancing sweet corn yield.

The current results are also in agreement with *Tinghui Dang (2017)*, who noted that maize grain yield and nitrogen uptake were not significantly different when using three optimized nitrogen fertilizer regimes compared to conventional methods. Grain yield changes were reported to vary between 100 and 300 kg/ha. Additionally, compared to traditional practices, there were marked increases in agronomic nitrogen use efficiency and nitrogen partial factor productivity, rising by approximately 20.2%–23.2% and

21.9%–23.7%, respectively. These results align with those of *Juan Zhai (2022)*, who found that under nitrogen application rates of N250 and N350, omitting basal nitrogen significantly reduced the kernel count per ear, thereby negatively affecting yield.

In integrated nutrient-water management systems utilizing drip irrigation and staged nitrogen application, higher nitrogen levels promoted stronger crop stands. This practice enhanced stalk lodging resistance during early growth, delayed stalk senescence, improved structural strength, and positively influenced key physiological attributes during the reproductive phase.

The overall evidence supports the effectiveness of applying 100 kg N/ha as an ideal rate in sweet corn production, a conclusion echoed in multiple studies. For instance, *Drulis et al., (2022)* demonstrated that using this rate in combination with urease inhibitors significantly improved both yield and nitrogen use efficiency compared to lower nitrogen inputs. Likewise, *Palomares and Arbizu (2024)*, in their study under arid conditions using *Azospirillum sp.* inoculation, confirmed that 100 kg N/ha increased yield and enhanced plant vigor. Furthermore, *Todosijević Ljubica (2018)* emphasized that moderate nitrogen levels, particularly the 100 kg N/ha rate, consistently promoted optimal maize growth and productivity across various climatic regions. Altogether, these studies validate the 100 kg N/ha application as a practical and efficient approach for enhancing sweet corn yield.

4.1.2 LS D% Analysis

Based on the LSD% results, the hybrid Messenger exhibited the highest emergence rate at 80.22%, whereas SF1379 recorded the lowest at 57.42%. In terms of yield (kg/ha), Messenger again ranked highest with an average of 17,494 kg/ha, while SF1379 produced the lowest yield of 14,172 kg/ha. Regarding plant height, GSS6924 had the tallest plants, averaging 185.6 cm, compared to SF1379, which was the shortest at 130.3 cm. For ear length, SF1379 achieved the maximum value of 21.05 cm, whereas Tyson recorded the shortest ears at 18.63 cm. The number of kernel rows per ear was highest in Tyson (19.93) and lowest in SF1379 (17.52). For the number of cobs per plot, Messenger achieved the highest value at 74.75, whereas SF1379 recorded the lowest at 59.25. Regarding the number of kernels per row, SF1379 had the highest average of 42.92, while Tyson had the lowest at 36.84.

For ear diameter, the Tyson hybrid produced the widest ears, averaging 52.98 mm, while Messenger exhibited the narrowest ears at 48.60 mm. In terms of moisture content, Tyson

again recorded the highest value at 75.48%, with Messenger showing the lowest at 62.72%. The overall mean values for these traits across all tested hybrids are summarized in Table 4 and illustrated in Figures 3, 4, and 5,8.

Table 2 ANOVA of Sweet Corn Hybrid Traits – 2022 Growing Season

parameters	Source	d.f	F-value	P-value
Emergence%	Hybrids	3	101.92	0.001
	N	2	2.18	0.129
	Hybrids. N	6	12.61	0.001
Broken plants	Hybrids	3	0.86	0.471
	N	2	0.49	0.614
	Hybrids. N	6	1.36	0.261
Number cobs	Hybrids	3	4.37	0.011
	N	2	4.17	0.024
	Hybrids. N	6	2.31	0.057
Lodged plants	Hybrids	3	0.94	0.434
	N	2	2.19	0.127
	Hybrids. N	6	1.38	0.254
Moisture%	Hybrids	3	421.93	0.001
	N	2	1.88	0.168
	Hybrids. N	6	2.92	0.022
Number/plants	Hybrids	3	11.41	0.001
	N	2	1.55	0.227
	Hybrids. N	6	2.24	0.064
Plant height(cm)	Hybrids	3	47.63	.001
	N	2	4.91	0.014
	Hybrids. N	6	1.66	0.161
Amount%	Hybrids	3	4.54	0.009
	N	2	3.48	0.042
	Hybrids. N	6	2.05	0.086

Table 3 Analysis of Variance for Sweet Corn Hybrid Traits – 2022 Season

parameters	Source	d.f	F-value	P-value
Ear with husk	Hybrids	3	2.44	0.082
	N	2	2.28	0.118
	Hybrids. N	6	1.52	0.204
Ear without husk	Hybrids	3	2.57	0.071
	N	2	3.93	0.030
	Hybrids. N	6	1.35	0.264
Grain yield(g)	Hybrids	3	1.36	0.271
	N	2	0.32	0.727
	Hybrids. N	6	1.13	0.369
Length/ear(cm)	Hybrids	3	14.58	0.001
	N	2	0.53	0.592
	Hybrids. N	6	0.45	0.838
Diameter/ear(mm)	Hybrids	3	47.56	0.001
	N	2	2.14	0.133
	Hybrids. N	6	1.55	0.192
Number/kernels	Hybrids	3	23.70	0.001
	N	2	1.15	0.330
	Hybrids. N	6	1.23	0.314
Number rows/ear	Hybrids	3	32.03	0.001
	N	2	1.13	0.336
	Hybrids. N	6	2.85	0.624
Yield kg/ha	Hybrids	3	1.96	0.139
	N	2	0.55	0.581
	Hybrids. N	6	0.89	0.512

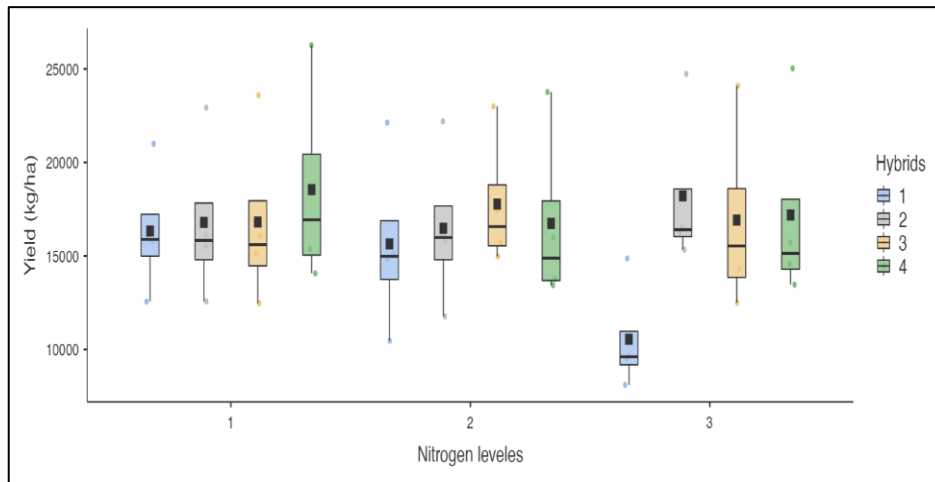


Figure 3 Impact of Varying Nitrogen Fertilizer Levels on Sweet Corn Hybrid Yield (kg/ha) – 2022

Table 4 LSD% analysis of sweet corn hybrid traits under different nitrogen fertilizer levels

Hybrids	Number/rows	Group	Amount%	Group	Emergence%	Group
SF1379	17.52	a	37.166	b	57.42	a
Tyson	19.93	c	35.70	a	62.81	b
GSS6924	18.85	b	36.31	ab	72.55	c
Messenger	17.85	a	36.53	ab	80.22	d
Hybrids	Number/cobs	Group	Yield kg/ha	Group	Grain yield(g)	Group
SF1379	59.25	a	14172	a	1.524	a
Tyson	64.25	a	17163	a	1.518	a
GSS6924	67.25	ab	17169	a	1.445	a
Messenger	74.75	b	17494	a	1.4889	a
Hybrids	Diameter/ear(mm)	Group	Ear with husk	Group	Ear without husk	Group
SF1379	49.56	b	4.100	ab	3.137	ab
Tyson	52.98	c	4.258	b	3.312	b
GSS6924	49.15	ab	3.979	a	3.058	a
Messenger	48.60	a	4.075	ab	3.13	ab
Hybrids	Length/ear(cm)	Group	Number kernels	Group	Yield kg (2-3 rows)	Group
SF1379	21.05	c	42.92	c	21.26	a
Tyson	18.63	a	36.84	a	25.75	a
GSS6924	20.01	b	36.85	a	25.75	a
Messenger	19.77	b	40.53	b	26.24	a
Hybrids	Moisture%	Group	Number/plants	Group	Plant height(cm)	Group
SF1379	73.10	b	63.089	a	130.3	a
Tyson	75.48	c	59.67	a	174.3	b
GSS6924	75.28	c	63.58	a	185.6	b
Messenger	62.72	a	77.58	b	174.3	b

Based on Duncan's multiple range test, treatments labelled with the same letter do not differ significantly at the 0.05 probability level.

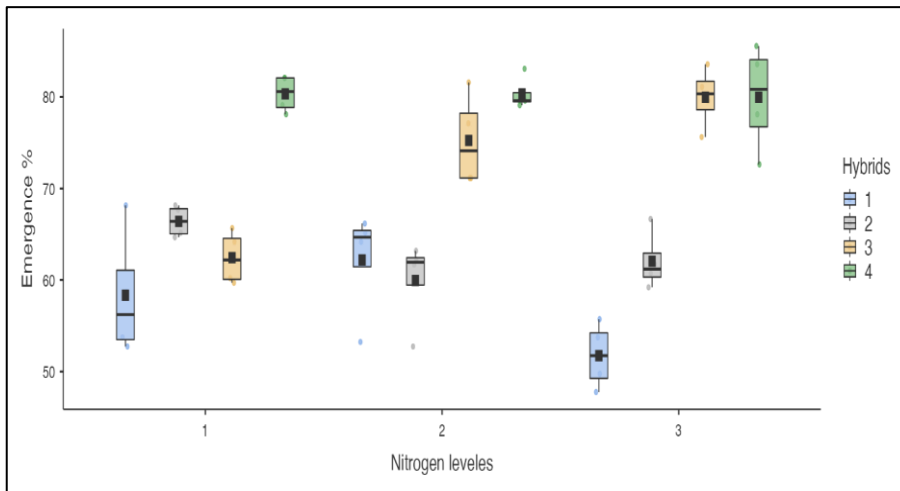


Figure 4 Effect of Different Nitrogen Fertilizer Levels on Emergence (%) of Sweet Corn Hybrids, 2022

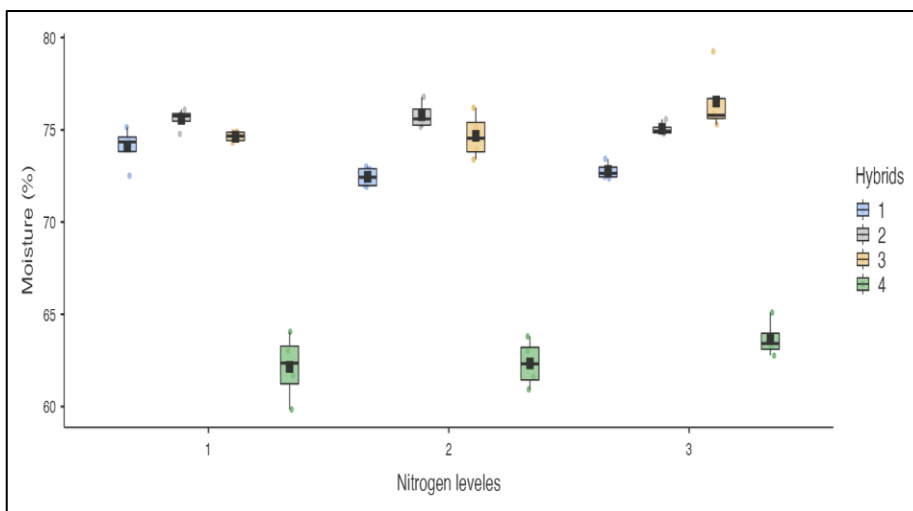


Figure 5 Impact of Varying Nitrogen Fertilizer Rates on Moisture Content (%) of Sweet Corn Hybrids – 2022

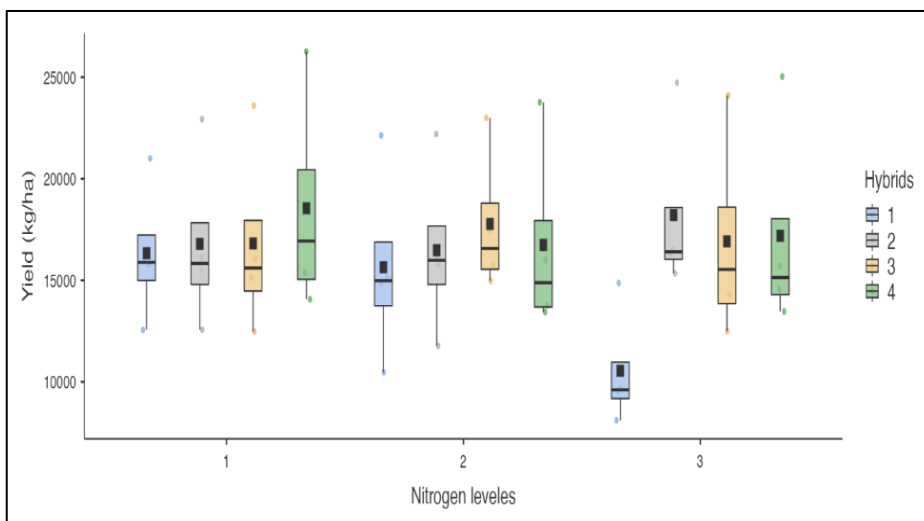


Figure 6 Descriptives between plant height(cm) and yield kg/ha of different sweet corn hybrids 2022

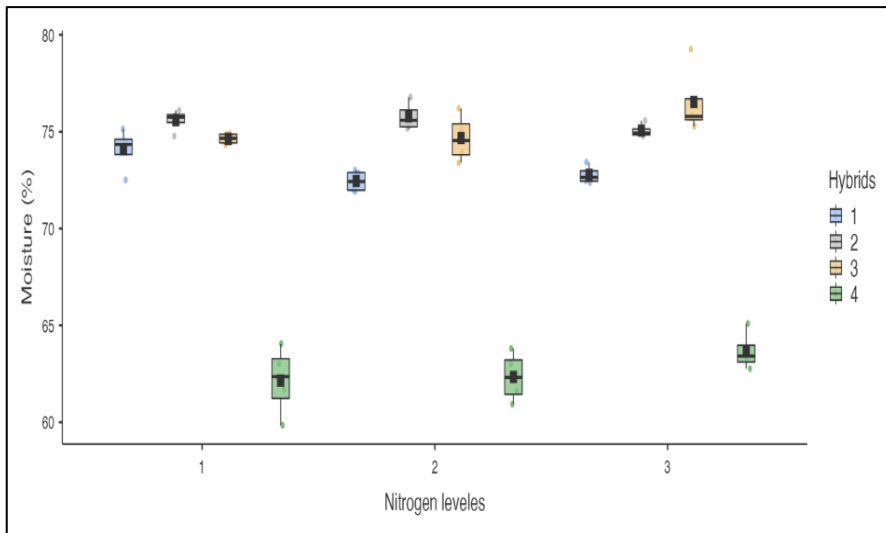


Figure 7 Scatter plot line between yield/kg and moisture% of different sweet corn hybrids

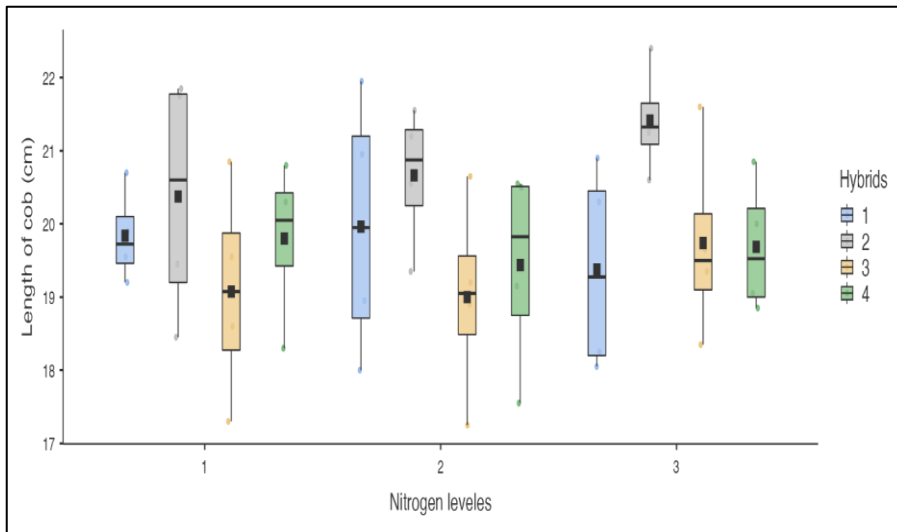


Figure 8 Effect of different levels of Nitrogen fertilizer on the length/ear(cm) of sweet corn hybrids, 2022 season

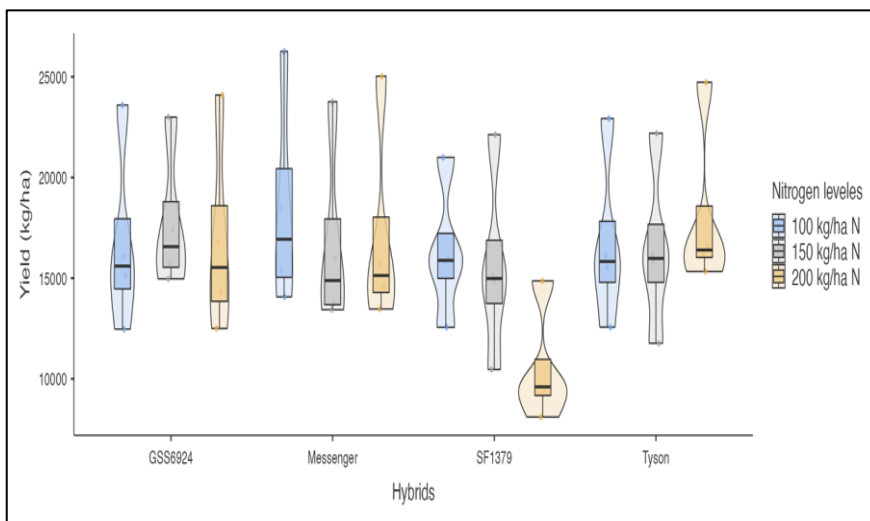


Figure 9 Descriptives between yield/kg with moisture% of different sweet corn hybrids

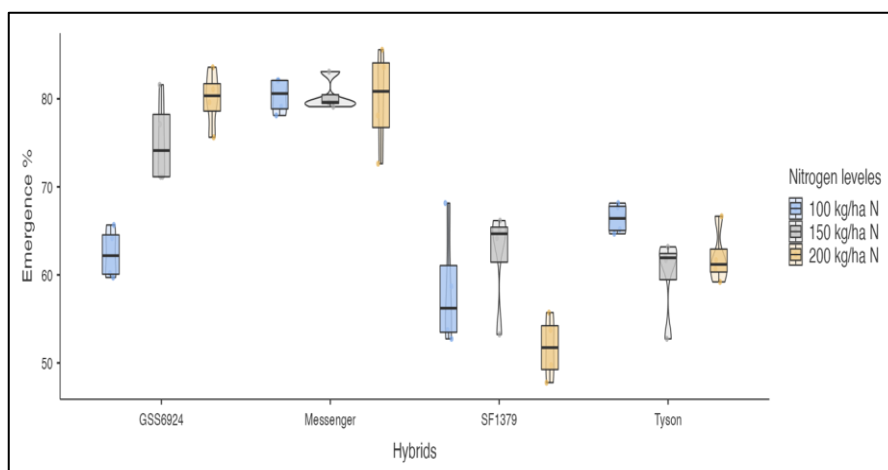


Figure 10 Descriptives of Emergence% with plant height(cm) of different sweet corn hybrids

4.1.3 Correlation Analysis

The correlation study revealed a strong, positive, and statistically significant association between emergence percentage and the 6-leaf stage ($r = 0.772^{**}$). Moreover, time to emergence exhibited a meaningful positive correlation with silking ($r = 0.573^{**}$) and tasseling ($r = 0.679^{**}$). An exceptionally high correlation was found between silking and tasseling stages ($r = 0.955^{**}$), suggesting their close developmental linkage.

Plant height was significantly and positively correlated with silking ($r = 0.500^{**}$), suggesting a coordinated pattern of growth.

The number of plants was positively associated with both emergence percentage ($r = 0.481^{**}$) and the six-leaf stage ($r = 0.465^{**}$), emphasizing the importance of early vegetative growth for successful stand establishment. Emergence percentage also correlated positively with yield ($r = 0.344^*$), reflecting its influence on final productivity. Additionally, the number of cobs per plot was positively related to emergence percentage ($r = 0.486^{**}$) and the six-leaf stage ($r = 0.422^{**}$), highlighting the role of early vigor in promoting cob development. Moisture content demonstrated strong and highly significant correlations with days to emergence ($r = 0.961^{**}$), silking ($r = 0.692^{**}$), and tasseling ($r = 0.776^{**}$), underlining its association with key growth stages. Emergence percentage was positively correlated with plant height ($r = 0.374^{**}$), indicating that early growth may influence overall biomass accumulation. Likewise, the sixth-leaf stage was significantly and positively correlated with both the number of plants ($r = 0.465^{**}$) and the number of cobs ($r = 0.422^{**}$). Additionally, plant height exhibited a significant positive relationship with the tasseling stage ($r = 0.429^{**}$). A positive relationship was observed between

yield and both plant height ($r = 0.356^*$) and the number of cobs per plant ($r = 0.345^*$), with cob number showing the strongest association with yield ($r = 0.911^{**}$), highlighting its major influence on overall productivity. Silking was significantly associated with ear diameter ($r = 0.312^*$), while plant height demonstrated strong correlations with kernel row number per ear ($r = 0.487^{**}$) and ear diameter ($r = 0.521^{**}$). Yield also displayed a positive connection with kernel row count ($r = 0.328^*$), and ear diameter was linked to moisture content ($r = 0.331^*$). Ear length correlated strongly with kernels per row ($r = 0.817^{**}$). Both emergence percentage and the sixth-leaf stage were significantly correlated with cob number ($r = 0.486^{**}$ and $r = 0.422^{**}$, respectively).

Plant height was additionally correlated with cob number ($r = 0.345^*$), whereas ear diameter was significantly associated with both plant height ($r = 0.521^{**}$) and silking time ($r = 0.312^*$). Kernel row number showed the strongest relationship with plant height ($r = 0.487^{**}$), and yield was most strongly linked to the number of cobs ($r = 0.911^{**}$). Kernel row count was also positively correlated with yield ($r = 0.328^*$) and cob number ($r = 0.290^*$). Furthermore, ear diameter had a positive association with moisture content ($r = 0.331^*$), and ear length maintained a strong correlation with kernels per row ($r = 0.817^{**}$). The strongest correlation observed among the traits was between ear diameter and the number of kernel rows ($r = 0.591^{**}$), which also showed a positive association with grain moisture content ($r = 0.331^*$). Correlation coefficients for all evaluated traits are presented in Tables 5–12. Additionally, kernel row number per ear exhibited a highly significant relationship with both total grains per ear and ear diameter, supporting findings by *Devi (2001)*, *Kramer (1995)*, and *Mohsan (2002)*. Similarly, the number of grains per row showed strong correlations with total grains per ear, ear length, and ear diameter, in agreement with previous findings reported by *Parth (1988)*, *Viola (2003)*, and *Muhammad (2001)*.

The data further highlighted that plant height was positively correlated with kernel row number and grain count, both of which influenced yield, supporting the conclusions of *Suhaisini (2016)*, *Niji (2018)*, and *Chinthiya (2019)*. A highly significant relationship between the number of cobs and yield was also observed, consistent with the findings of *Olawamide (2020)* and *Suhaisin (2020)*.

The total number of grains per ear was significantly and positively associated with both ear length and ear diameter, suggesting that larger ears tend to produce more grains. Furthermore, the number of kernel rows and total grain count per ear showed significant

correlations with yield (kg/ha), highlighting their importance as selection criteria in sweet corn breeding programs. These observations agree with the studies of *Oktem (2008)* and *Hefny (2011)*. The relationships among these traits are illustrated in Figures 6,7,9,10.

Table 5 Impact of Varying Nitrogen Fertilizer Rates on Correlation Among Sweet Corn Hybrid Traits

Characters	Emergences%	Time/Emergence	6 th leaves the stage	Time/Silking	Time/Tasseling
Emergence%	1	-.655**	.772**	-.095	-.114
Time/Emergence	-.655**	1	-.816**	.573**	.679**
6 th leaves/stage	.772**	-.816**	1	-.351*	-.451**
Time/Silking	-.095	.573**	-.351*	1	.955**
Time/Tasseling	-.114	.679**	-.451**	.955**	1

*, ** indicate that the differences between traits are statistically significant at $P < 0.05$ and $P < 0.01$, respectively.

Table 6 Different nitrogen fertilizer levels influence the correlation coefficients among the various traits of sweet corn hybrids.

Characters	Emergence%	Time/Emergence	6/Leaves/stage	Time Silking	Time Tasseling
Plant height	.374**	-.095	.161	.500**	.429**
Number/plants	.481**	-.601**	.465**	-.403**	-.430**
Lodged plants	-.058	.187	.029	.000	.032
Yield kg/ha	.344*	-.131	.238	.151	.112
Number/cobs	.486**	-.332*	.422**	-.052	-.084
Moisture%	-.549**	.961**	-.743**	.692**	.776**
Length/ear	-.071	.099	-.024	.191	.081

Statistical significance between traits is indicated by * for $P < 0.05$ and ** for $P < 0.01$.

Table 7 The correlation coefficients among the traits of sweet corn hybrids are affected by varying levels of nitrogen fertilizer.

Characters	plant height	Number of plants	lodged plants	yield/kg/ha	Number/cobs
Emergence%	.374**	.481**	-.058	.344*	.486**
Time/Emergence	-.095	-.601**	.187	-.131	-.332*
6/leaves	.161	.465**	.029	.238	.422**
Silking	.500**	-.403**	.000	.151	-.052
Tasseling	.429**	-.430**	.032	.112	-.084

Statistical significance among traits is indicated by a single (*) and double (**) asterisk, corresponding to $P < 0.05$ and $P < 0.01$, respectively.

Table 8 Varying nitrogen fertilizer levels impact the correlation coefficients among the traits of sweet corn hybrids.

Characters	Plant height	Number/plants	Lodged plants	Yield kg/ha	Number/cobs
Plant height	1	.197	-.168	.356*	.345*
Number/plants	.197	1	-.058	.008	.130
Lodged plants	-.168	-.058	1	.037	.086
Yield kg/ha	.356*	.008	.037	1	.911**
Number/cobs	.345*	.130	.086	.911**	1
Moisture%	.044	-.612**	.155	-.051	-.283
Length/ear	-.195	-.011	.224	-.175	-.172

A single (*) and double (**) asterisk indicate statistically significant differences among traits at $P < 0.05$ and $P < 0.01$, respectively.

Table 9 Different levels of nitrogen fertilizers affect the correlation coefficient between different characteristics of sweet corn hybrids.

Characters	Moisture%	length /cob	diameter/ear	Number/rows	Number/kernels
Emergence%	-.549**	-.071	-.098	.060	-.222
Time/Emergence	.961**	.099	.260	.005	.188
Th 6/leave stage	-.743**	-.024	-.195	-.012	-.122
Time/Silking	.692**	.11	.312*	.071	.144
Time/Tasseling	.776**	.081	.243	.074	.059
Plant height	.044	-.195	.521**	.487**	-.220

The symbols * and ** represent statistically significant differences between the characters at $P < 0.05$ and $P < 0.01$, respectively.

Table 10 Varying nitrogen fertilizer levels influence the correlation coefficients among different traits of sweet corn hybrids.

Characters	Moisture%	Length/ear	Diameter/ear	Number/rows	Number/kernels
Number/plants	-.612**	-.011	-.060	.116	.009
Lodged plants	.155	.224	-.082	.032	.090
Yield kg/ha	-.051	-.175	.209	.328*	-.308*
Number/cobs	-.283	-.172	.076	.290*	-.323*
Moisture%	1	.086	.331*	.048	.153
Length/ear	.086	1	-.106	-.496**	.817**

*, ** indicate statistically significant differences between the characters at $P < 0.05$ and $P < 0.01$, respectively.

Table 11 Different levels of nitrogen fertilizers affect the correlation coefficient between different characteristics of sweet corn hybrids

Characters	Emergence%	Time/ Emergence	6/leaves/ stage	Time/Silking	Time/Tasseling	Plant height	Number/ plants	Lodged plants
Yield kg/ha	.344*	-0.131	0.238	0.151	0.112	.356*	0.008	0.037
Number/cobs	.486**	-.332*	.422**	-0.052	-0.084	.345*	0.13	0.086
Moisture%	-.549**	.961**	-.743**	.692**	.776**	0.044	-.612**	0.155
Length/ear	-0.071	0.099	-0.024	0.191	0.081	-0.195	-0.011	0.224
Diameter/ear	-0.098	0.26	-0.195	.312*	0.243	.521**	-0.06	-0.082
Number/rows	0.06	0.005	-0.012	0.071	0.074	.487**	0.116	0.032
Number/kernels	-0.222	0.188	-0.122	0.144	0.059	-0.22	0.009	0.09

The symbols * and ** denote statistically significant differences between the characters at $P < 0.05$ and $P < 0.01$, respectively.

Table 12 Varying nitrogen fertilizer levels influence the correlation coefficients among different traits of sweet maize hybrids.

Characters	Yield kg/ha	Number/cobs	Moisture%	Length/ear	Diameter/ear	Number/rows	Number/kernels
Yield kg/ha	1	.911**	-0.051	-0.175	0.209	.328*	-.308*
Number/cobs	.911**	1	-0.283	-0.172	0.076	.290*	-.323*
Moisture%	-0.051	-0.283	1	0.086	.331*	0.048	0.153
Length/ear	-0.175	-0.172	0.086	1	-0.106	-.496**	.817**
Diameter/ear	0.209	0.076	.331*	-0.106	1	.591**	-0.044
Number/rows	.328*	.290*	0.048	-.496**	.591**	1	-.542**
Number/kernels	-.308*	-.323*	0.153	.817**	-0.044	-.542**	1

The symbols * and ** indicate statistically significant differences between the characters at significance levels of $P < 0.05$ and $P < 0.01$, respectively.

4.2 Analysis of variance on traits of Different Sowing dates of Four Hybrids of Sweet Corn, Season 2022

The combined ANOVA for the study year indicated that sowing date had a highly significant effect on numerous traits, including emergence percentage, ear diameter (mm), grain yield (g), ear weight (with and without husk), number of cobs per plot, number of kernel rows, total kernel number, plant height (cm), and moisture content (%). Additionally, traits such as ear length, number of plants before harvest, and yield (kg/ha) also showed significant variation due to sowing date (Table 13).

The interaction between genotype and sowing date showed significant effects on almost all evaluated traits, with the exception of kernel number, ear weight without husk, ear diameter, and percentage amount. In contrast, the genotype effect was significant for most variables, though not for ear diameter, kernel number, kernel row number, or amount (%).

Based on the results obtained from the sowing date experiments with sweet maize, it was concluded that the crop stand had a more favourable course of development and outstanding yield in the case of the first sowing date. Averaged over the four examined hybrids, the obtained yield was 17,138 kg/ha. These outcomes are consistent with those of *Mitch (2020)*, who emphasized the importance of tailoring planting dates and hybrid selection to specific locations and climatic conditions to counter rising variability due to climate change.

Contrarily, the findings did not align with *Abdullah ÖKTEM (2004)*, who observed the highest fresh ear yields during late June to early August (second crop cycle) under semi-arid conditions in Southeastern Anatolia. In that region, early planting in April or May is constrained due to extreme temperatures (often exceeding 40 °C), low humidity (35%), and dry, hot winds, all of which negatively impact pollination success and kernel development.

However, the present findings corroborate those of *Burhan KARA (2013)*, who reported that the lowest emergence rate and yield components were observed from the earliest sowing date (April 1) under straw mulch conditions. Conversely, a higher kernel number per ear (562.1 grains in 2010; 552.3 grains in 2011) was obtained under delayed planting. Furthermore, *Burhan KARA (2011)* recorded the highest fresh ear yield (14,952.6 kg/ha in 2010; 14,805.2 kg/ha in 2011) and ear count per hectare (65,781.8 in 2010; 65,789.6 in 2011) from sowing dates between May 1 and May 15 under semi-arid conditions in

Southwestern Anatolia. His study also emphasized that sowing time substantially influences fresh ear yield and associated traits.

In the Hungarian context, sowing date also plays a pivotal role in sweet corn performance. Research has consistently demonstrated that late April sowing provides superior growing conditions and results in enhanced yields compared to later planting in May. For instance, trials by *Öktem and Öktem (2004)* affirmed that early sowing, particularly in late April, maximized yield potential by utilizing spring soil moisture and avoiding high-temperature stress during flowering. Similarly, *Williams (2008)* highlighted that late April sowing ensures favorable thermal conditions aligned with the crop's growing degree day requirements, which supports optimal development.

Nevertheless, in specific regions of Hungary, early May sowing has also proven productive, particularly when adequate soil moisture is present. *Wyseure (2023)* found that shifting planting to early May in certain years aligned well with temperature trends, offering yields comparable to those from late April sowing. Although late April remains the preferred sowing window, annual decisions must consider interannual weather variability, including potential risks from early frost or heatwaves during early vegetative stages.

4.2.1 LSD (%) Analysis

The LSD% results demonstrated that among the four hybrids, GSS6924 recorded the highest emergence rate at 92.66%, while SF1379 had the lowest at 68.32%. With respect to moisture content, the hybrid Tyson showed the highest value (78.19%), whereas SF1379 and GSS6924 both exhibited the lowest moisture content (74.43%).

For the cob number per plot, Messenger achieved the highest mean value at 76.25, while SF1379 again recorded the lowest at 61.17. Similarly, GSS6924 exhibited the highest number of plants before harvest (72.42), whereas SF1379 recorded the lowest (59.25).

When evaluating plant height, GSS6924 produced the tallest plants (206.6 cm), while SF1379 remained the shortest (147.7 cm). Regarding yield performance, Messenger produced the highest yield (28.76 kg/ha), significantly outperforming SF1379, which yielded the lowest at 19.03 kg/ha. All detailed results are presented in Table 14, Table 15, and Figures 11–13.

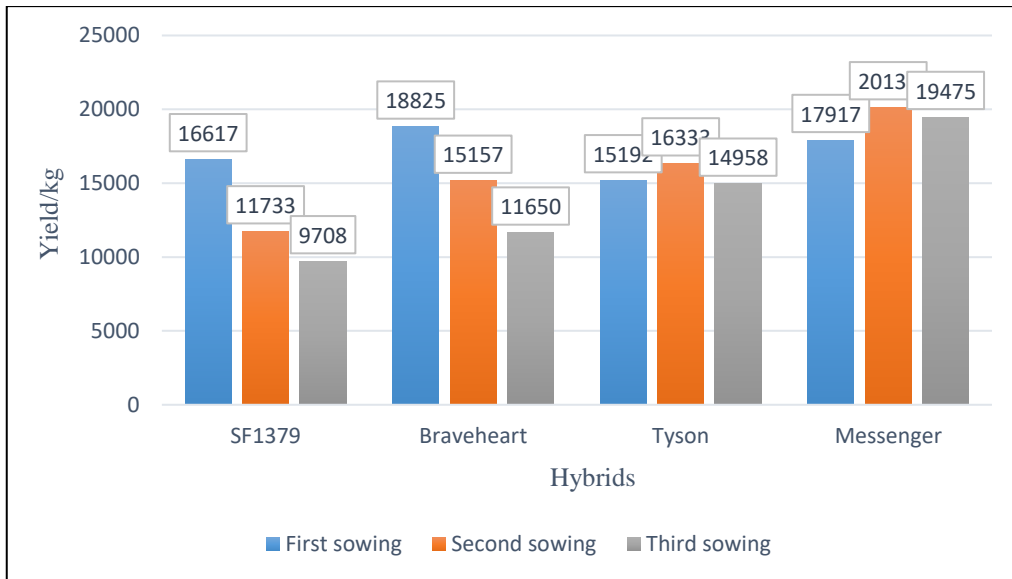


Figure 11 This bar chart illustrates the yield (kg/ha) of four sweet corn hybrids across three sowing dates. The first sowing (blue bars) generally produced the highest yield, except for Messenger, which performed best in the second sowing (20133 kg/ha). The third sowing (gray bars) resulted in the lowest yields for all hybrids except Messenger, which maintained a relatively high yield (19475 kg/ha).

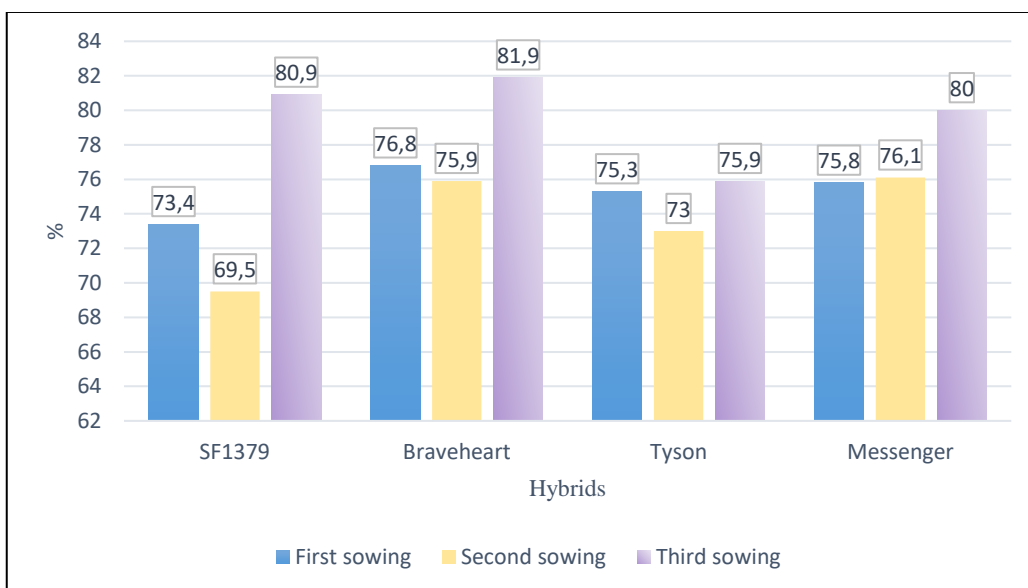


Figure 12 This bar chart illustrates the moisture percentage of four sweet corn hybrids (SF1379, Braveheart, Tyson, and Messenger) across three sowing dates. The third sowing consistently recorded the highest moisture content, whereas the second sowing showed the lowest values for all hybrids. These variations indicate that sowing time plays a significant role in influencing kernel moisture retention.

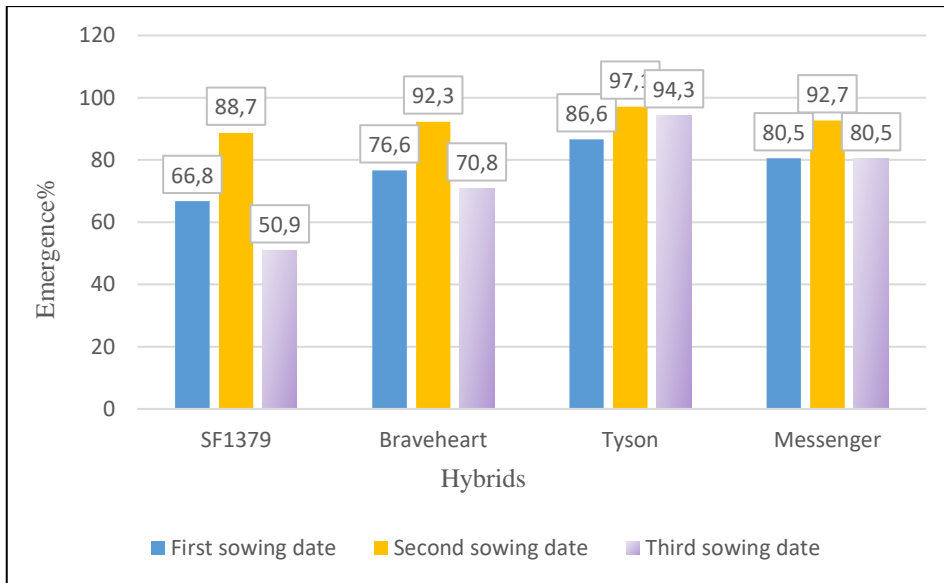


Figure 13 This bar chart illustrates the emergence percentage of four sweet corn hybrids (SF1379, Braveheart, Tyson, and Messenger) across three sowing dates. The second sowing date consistently recorded the highest emergence rates, while the third sowing date generally exhibited the lowest values for most hybrids. This trend indicates that the environmental conditions during the second sowing were more conducive to seed emergence.

Table 13 Analysis of Variance of Sweet Corn Hybrid Traits Across Different Sowing Dates

Characters	Cv %	L.s.d%	Source	Se	F-value	P-value
Amount%	3.1	0.921	Hybrids Sowing date Hybrid. Sowing	1.109	0.08 23.20 0.28	0.969 .001 0.942
Diameter/ear(mm)	4.4	1.778	Hybrids Sowing date Hybrid. Sowing	2.141	0.09 14.32 0.47	0.964 .001 0.827
Ear without husk	8.1	0.2602	Hybrids Sowing date Hybrid. Sowing	0.3132	1.11 19.58 0.73	0.359 .001 0.632
Ear with husk	11.8	0.2825	Hybrids Sowing date Hybrid. Sowing	0.3401	1.68 18.19 0.96	0.191 .001 0.470
Grain/yield(g)	8.0	0.0921	Hybrids Sowing date Hybrid. Sowing	0.1109	1.51 33.24 1.19	0.230 .001 0.335
Length/ear(cm)	106.5	19.77	Hybrids Sowing date Hybrid. Sowing	23.81	0.98 0.93 0.96	0.415 0.404 0.469
Number /kernels	9.0	2.777	Hybrids Sowing date Hybrid. Sowing	3.344	0.55 6.01 0.31	0.650 0.006 0.926
Number /rows	4.3	0.620	Hybrids Sowing date Hybrid. Sowing	0.746	0.56 17.69 0.97	0.644 .001 0.459
Emergence%	10.1	6.81	Hybrids Sowing date Hybrid. Sowing	8.19	18.54 22.22 3.21	.001 .001 0.014
Moisture%	10.1	6.81	Hybrids Sowing date Hybrid. Sowing	8.19	28.12 107.35 10.31	.001 .001 .001
Number/cobs	16.6	9.44	Hybrids Sowing date Hybrid. Sowing	11.37	4.67 6.37 1.88	0.008 0.005 0.114
Number/plants(before harvest)(2-3 rows)	15.9	8.70	Hybrids Sowing date Hybrid. Sowing	10.48	4.40 4.15 2.61	0.010 0.025 0.035
Plant height(cm)	8.7	13.12	Hybrids Sowing date Hybrid. Sowing	15.80	29.32 11.31 1.57	.001 .001 0.186
Yield kg/ha	19.2	2499.0	Hybrids Sowing date Hybrid. Sowing	3008.7	9.47 4.55 2.51	.001 0.018 0.041

Table 14 Mean Values of Selected Traits of Sweet Corn Across Different Sowing Dates

Hybrids	Amount%	Diameter/ear	Ear with husk	Ear without husk	Grain/yard(g)	Length/ear(cm)	Number /grains
SF1379	35.83 a	48.60 a	3.954 a	2.946 a	1.421a	18.93 a	37.36 a
Braveheart	35.97 a	48.62 a	3.933 a	2.975 a	1.415a	19.12 a	37.88 a
Tyson	35.97 a	48.69 a	3.804 a	2.796 a	1.371a	18.81 a	37.47 a
Messenger	36.05 a	48.27 a	3.704 a	2.771 a	1.338a	32.55 a	36.21 a

*Means sharing the same letters within each column do not differ significantly, as determined by DMRT at the 5% significance level.

Table 15 Mean Values of Sweet Corn Traits Across Different Sowing Dates

Hybrids	Number/rows	Emergence%	Moisture%	Number/cobs	Number/plants	Plant height(cm)	Yield/kg
SF1379	17.68 a	68.32 a	74.43 a	61.17 a	59.25 a	147.7a	19.03 a
Braveheart	17.4 a	79.89 b	78.19 b	63.92 ab	61.50 ab	188.0b	22.82 b
Tyson	17.52 a	92.66 c	74.43 a	72.50 bc	72.42 c	206.6c	23.24 b
Messenger	17.28 a	84.74 b	77.32 b	76.25 c	69.75 bc	185.9 b	28.76 c

*Means followed by the same letter within each column are not significantly different based on DMRT at the 5% significance level.

4.3 Analysis of variance for different nitrogen fertilizer levels on the traits of sweet corn hybrids during the 2023 season.

The analysis of variance revealed that varying levels of nitrogen fertilizer exerted a highly significant influence on several flowering-related characteristics. These included tasselling percentage, the onset of silking at both 100% and 50%, as well as the phenological development at the six-leaf stage. Notably, nitrogen treatments also significantly affected cob weight without husk and the emergence date. However, several traits, such as grain yield, harvest density, dry matter content, dry and fresh biomass weight, nitrogen use efficiency, emergence percentage, emergence count per unit area, number of kernels per ear, number of rows, plant height, and overall yield per hectare, did not exhibit statistically significant responses to nitrogen levels.

The interaction between genotype and nitrogen fertilizer application demonstrated highly significant effects for the majority of traits, except for grain yield, harvest density, dry weight, fresh weight, dry matter, efficiency, emergence percentage, number of kernels, yield per hectare, and cob weight without husk. A notable exception was the emergence

count, which did show a significant interactive response. Genotypic effects alone were significant for a limited number of traits, specifically emergence date, dry weight, dry matter content, efficiency, and yield per hectare, while other observed characteristics remained statistically unaffected by genotype variation.

Among the nitrogen application strategies tested, a single-dose application proved to be the most productive, achieving a maximum yield of 25,200 kg/ha. This result highlights the potential efficiency of a single nitrogen dose over other fertilization methods in enhancing yield output.

These outcomes correspond closely with the findings of *Amanullah (2009)*, who reported that elevated nitrogen levels improved synchronization and timing of tasseling and silking in maize, corroborating the present study's findings on flowering traits. Similarly, *Seyed Sharifi (2016)* noted that nitrogen application enhanced cob weight, although its effect on grain yield and harvest density was minimal or non-significant under some conditions, aligning with current observations.

The genotype-by-nitrogen interaction pattern observed here is also consistent with the findings of *Khatri (2023)*, who noted that while some maize genotypes displayed improved nitrogen use efficiency, others remained largely unresponsive in terms of grain yield. Furthermore, *Meseka (2006)* emphasized that genotypic differences notably influenced early growth characteristics like emergence timing, though yield traits often remained stable unless nitrogen management was specifically optimized.

These results underline the importance of integrating genotype selection with appropriate nitrogen management to optimize early developmental traits and potentially improve resource-use efficiency. The comprehensive outcomes are detailed in Table 16 and illustrated in Figures 14–15.

Table 16 Analysis of Variance of Sweet Corn Hybrid Traits at Different Nitrogen Levels, 2023 Season

Parameters	Source	d.f	F-value	P-value
100% Tasselling	Hybrids	4	0.70	0.596
	Nitrogen	2	0.00	1.000
	hybrids. Nitrogen	8	0.00	1.000
100%silking	Hybrids	4	0.70	0.596
	Nitrogen	2	0.00	1.000
	Hybrids Nitrogen	8	0.00	1.000
50%Tasseling	Hybrids	4	0.70	0.596
	Nitrogen	2	0.00	1.000
	Hybrids Nitrogen	8	0.00	1.000
50%silking	Hybrids	4	0.70	0.596
	Nitrogen	2	0.00	1.000
	Hybrids Nitrogen	8	0.00	1.000
6/leaves stage	Hybrids	4	0.65	0.629
	Nitrogen	2	8.25	.001
	Hybrids Nitrogen	8	0.02	1.000
Grain/yield	Hybrids	4	0.66	0.624
	Nitrogen	2	0.19	0.829
	Hybrids Nitrogen	8	0.37	0.929
Date Emergence	Hybrids	4	1.00	0.418
	Nitrogen	2	1.00	0.376
	Hybrids Nitrogen	8	1.00	0.450
Density harvest (Number of plants before harvest)	Hybrids	4	0.76	0.555
	Nitrogen	2	0.62	0.545
	hybrids. Nitrogen	8	0.43	0.899
Dry matter(kg)	Hybrids	4	1.45	0.234
	Nitrogen	2	0.01	0.988
	hybrids. Nitrogen	8	0.27	0.973
Dry weight(g)	Hybrids	4	1.96	0.119
	Nitrogen	2	0.22	0.802
	hybrids. Nitrogen	8	0.88	0.538
Efficiently%	Hybrids	4	1.96	0.119
	Nitrogen	2	0.22	0.802
	Hybrids. Nitrogen	8	0.88	0.538
Emergence pcs	Hybrids	4	0.74	0.569
	Nitrogen	2	0.02	0.980
	Hybrids. Nitrogen	8	0.22	0.986
Emergence%	Hybrids	4	0.74	0.569
	Nitrogen	2	0.02	0.980
	Hybrids. Nitrogen	8	0.22	0.986
Fresh weight(g)	Hybrids	4	0.71	0.589
	Nitrogen	2	0.57	0.568
	Hybrids. Nitrogen	8	0.24	0.980
Number rows	Hybrids	4	0.68	0.609
	Nitrogen	2	0.13	0.882
	Hybrids. Nitrogen	8	0.05	1.000
Number seeds	Hybrids	4	0.56	0.696
	Nitrogen	2	0.12	0.891
	Hybrids. Nitrogen	8	0.12	0.998
Plant height(cm)	Hybrids	4	0.82	0.519
	Nitrogen	2	0.01	0.989
	Hybrids. Nitrogen	8	0.02	1.000
Weight cobs/without leaf	Hybrids	4	0.73	0.576
	Nitrogen	2	0.75	0.481
	Hybrids. Nitrogen	8	0.14	0.997
Weight/cobs	Hybrids	4	0.60	0.668
	Nitrogen	2	0.09	0.916
	Hybrids. Nitrogen	8	0.11	0.998
Yield kg /ha	Hybrids	4	0.73	0.574
	Nitrogen	2	0.23	0.792
	Hybrids. Nitrogen	8	0.16	0.995
Yield/pcs	Hybrids	4	0.25	0.906
	Nitrogen	2	0.69	0.509
	Hybrids. Nitrogen	8	0.88	0.542

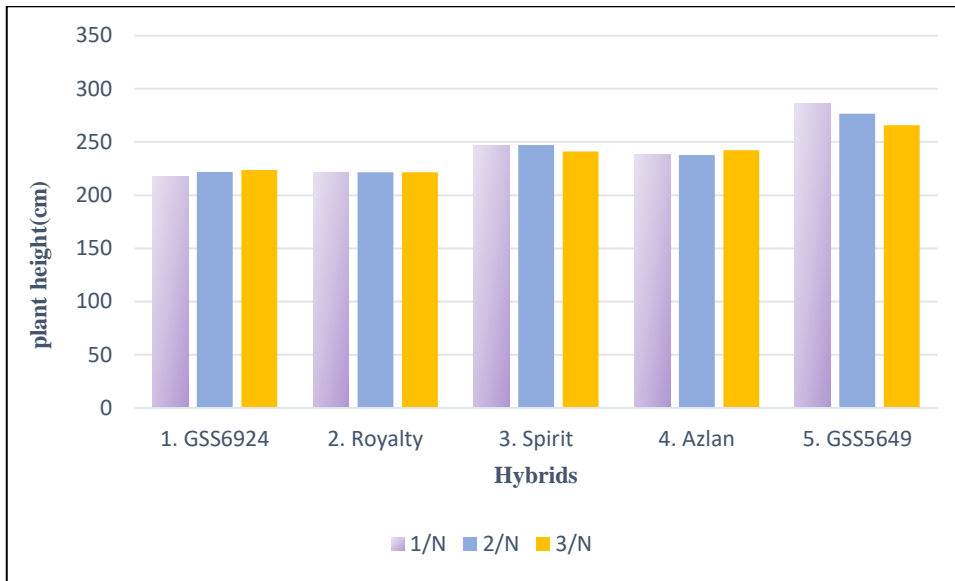


Figure 14 Effect of Different Nitrogen Fertilizer Levels on Plant height(cm) of Five Sweet Corn Hybrids, 2023 Season

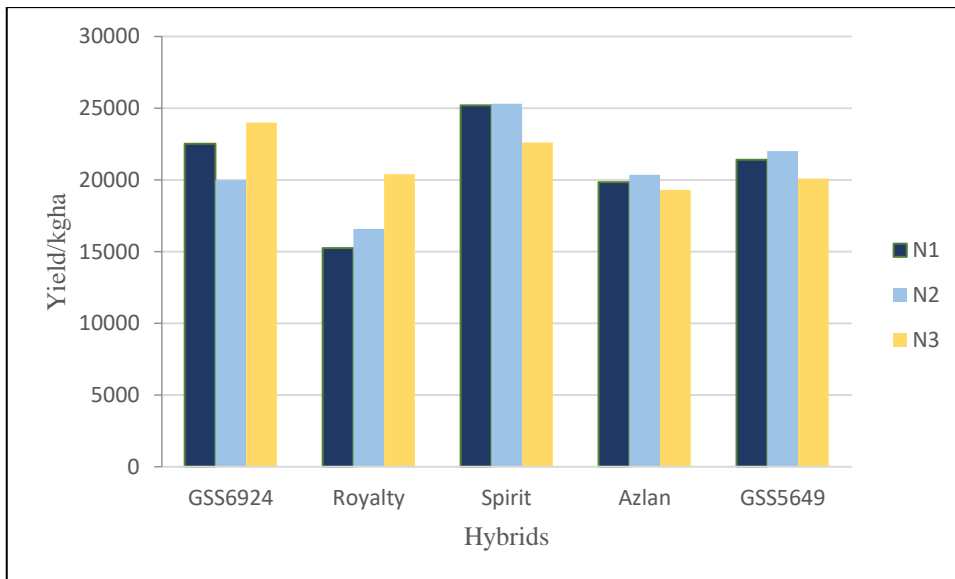


Figure 15 Effect of Different Nitrogen Fertilizer Levels on the Yield (kg/ha) of Five Sweet Corn Hybrids, 2023 Season

4.4 Analysis of variance for different sowing dates on the traits of sweet corn hybrids during the 2023 season.

The combined analysis of variance for different sowing dates indicated that nearly all evaluated parameters exhibited highly significant differences, with the exception of the six-leaf developmental stage, dry matter content, and nitrogen use efficiency, which remained statistically unaffected. The interaction between sowing date and genotype

was also found to be highly significant for the majority of traits, except for the six-leaf stage, grain yield, fresh biomass weight, number of seeds per cob, harvest density, dry matter, efficiency, yield per kilogram, and cob weight without husk. However, significant differences were observed in emergence percentage, emergence count per unit area, plant height, and the number of rows per cob.

The effect of genotype alone resulted in highly significant differences for most traits, except for the six-leaf stage, fresh weight, number of rows, number of seeds, dry matter content, and dry weight, which showed no significant variation. In contrast, traits such as grain yield, plant height, harvest density, emergence percentage, emergence count, yield per kilogram, cob weight, and cob weight without husk exhibited statistically significant variation among genotypes.

Data from the 2023 sowing season trials with sweet corn highlighted that the crop achieved optimal development and maximum yield on the earliest sowing date. Notably, the hybrid Azlan produced an average yield of 25,300 kg/ha when sown on the first date. In contrast, yields declined significantly on later dates, with a reduction of 13,641 kg/ha recorded on the third and fourth sowing dates.

These findings are in line with earlier research confirming that sowing date plays a pivotal role in maize growth, development, and yield. For instance, *Getnet (2022)* demonstrated that earlier sowing dates significantly improved phenological development and yield, while delayed planting shortened the growing period and exposed crops to suboptimal environmental conditions, ultimately reducing productivity. Similarly, *Amanullah et al. (2009)* reported that maize genotypes exhibited diverse responses to sowing times. While early sowing generally promoted enhanced growth and yield, some genotypes showed better adaptation under delayed conditions. These genotype-by-sowing date interactions emphasize the importance of aligning genotype selection with the most suitable sowing window to optimize yield outcomes.

Detailed results supporting these observations are presented in Table 17 and Figures 16 and 17.

Table 17 Analysis of Variance of Sweet Corn Hybrid Traits Across Different Sowing Dates, 2023 Season

Traits	Source	CV%	L.S.D%	Se	F-value	P-value
100% male	Hybrids Sowing Hybrids.sowing	0.0	0.794	1.116	0.00 7841.25 0.00	1.000 .001 1.000
100% silking	Hybrids Sowing Hybrids.sowing	0.0	0.5200	0.7303	0.00 18291.25 0.00	1.000 .001 1.000
50% male	Hybrids Sowing Hybrids.sowing	0.0	0.637	0.894	0.00 12055.83 0.00	1.000 .001 1.000
50% silking	Hybrids Sowing Hybrids.sowing	0.0	0.621	0.872	0.00 13065.44 0.00	1.000 .001 1.000
6 th /leaves stage (phenological)	Hybrids Sowing Hybrids.sowing	7.6	0.4355	0.6115	0.15 1.38 0.30	0.927 0.261 0.970
Fresh weight	Hybrids Sowing Hybrids.sowing	10.2	18.88	26.51	0.18 9.48 0.44	0.906 .001 0.904
Number/rows	Hybrids Sowing Hybrids.sowing	3.3	0.3940	0.5533	0.60 22.24 1.28	0.616 .001 0.276
Number/seeds	Hybrids Sowing Hybrids.sowing	5.0	1.332	1.871	0.59 9.40 0.19	0.623 .001 0.994
Plant height	Hybrids Sowing Hybrids.sowing	6.0	9.04	12.69	1.99 61.23 1.35	0.128 .001 0.240
Dry matter	Hybrids Sowing Hybrids.sowing	8.9	1.661	2.332	0.62 2.89 0.23	0.609 0.045 0.988
Dry weight	Hybrids Sowing Hybrids.sowing	12.7	6.14	8.62	0.60 9.46 0.49	0.618 .001 0.871
Efficient%	Hybrids Sowing Hybrids.sowing	7.0	2.205	3.096	7.24 1.14 0.26	.001 0.342 0.982
Emergence %	Hybrids Sowing Hybrids.sowing	4.9	2.969	4.169	1.45 10.47 1.13	0.240 .001 0.360
Weight the cob without the leaf	Hybrids Sowing Hybrids.sowing	8.8	0.1896	0.2662	2.55 17.77 0.16	0.068 .001 0.997
Weight cob	Hybrids Sowing Hybrids.sowing	7.4	0.2047	0.2874	1.61 13.10 0.48	0.2000 .001 0.878
Yield kg/ha	Hybrids Sowing Hybrids.sowing	14.5	1933.1	2714.6	2.89 22.09 0.84	0.046 .001 0.583

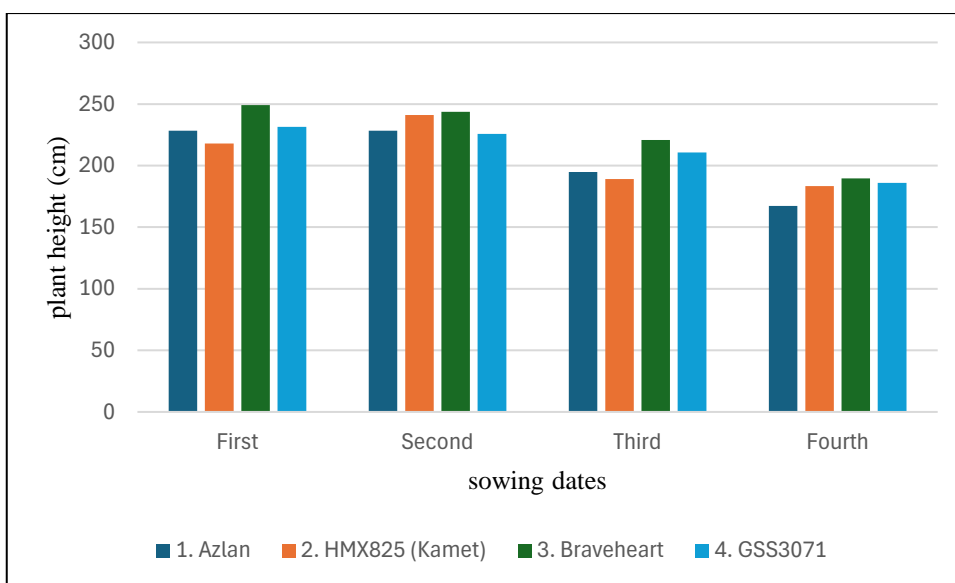


Figure 16 Effect of various sowing dates on plant height (cm) of sweet corn hybrids, season 2023

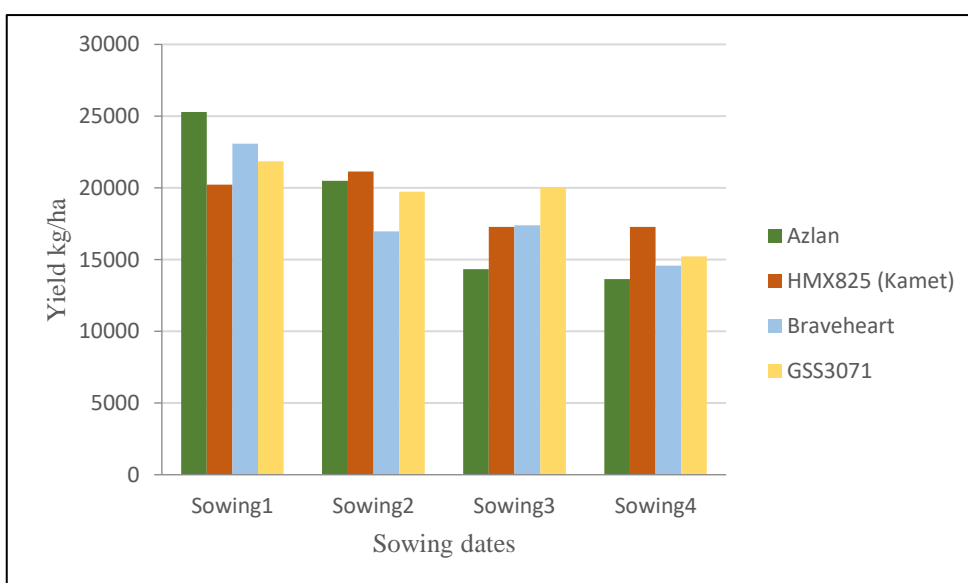


Figure 17 Effect of Different Sowing Dates on the Yield (kg/ha) of Sweet Corn Hybrids, 2023 Season

4.5 A simple Analysis of Variance of Estimation of Yield Potential on traits of Sweet Corn Hybrids, Season 2023

The results of the analysis of variance revealed that most traits did not exhibit statistically significant differences, with the exception of grain yield, number of seeds per cob, number of rows per cob, cob weight, and cob weight without husk, which showed significant variation. Among the evaluated hybrids, Dessert 78 achieved the highest average grain yield at 23,233.33 kg/ha, whereas Azlan produced the lowest yield,

averaging 9,850 kg/ha. These findings are comprehensively presented in Tables 18 and 19 and Figures 18 to 21.

For plant height, the hybrid Gss6924 recorded the tallest plants with an average height of 277.75 cm, while Spirit had the shortest stature, measuring 205.55 cm. With regard to emergence percentage, both Azlan and Gss6924 registered the highest average at 86.31%, while Dessert 78 had the lowest emergence percentage, averaging 73.13%.

In terms of dry matter content, Spirit led with the highest value of 38.55 grams, whereas Impress and Dessert 78 both had the lowest at 23.4 grams. When evaluating dry weight, Spirit again exhibited superior performance with a mean of 86.34 grams, while Impress recorded the lowest value at 52.3 grams. For fresh weight, Dessert 78 topped the hybrids with 263.74 grams, and Azlan had the lowest fresh weight, averaging 212.29 grams.

In terms of efficiency, Azlan and Impress showed the highest values, recording 46.75 and 46.18, respectively, while the lowest efficiency was observed in Gss6924 with a value of 42.13.

These results are consistent with the findings of *Campoy (2020)*, who highlighted that maize hybrids with strong agronomic traits and adaptability tend to perform better across different environments. Likewise, *Rahimi-Moghaddam (2019)* emphasized the significant influence of environmental factors, including soil characteristics, temperature, and rainfall, on the yield potential of maize hybrids, with more adaptable genotypes showing superior results. *Sedhom (2024)* also underlined the importance of genetic improvement in boosting maize hybrid productivity across various ecological zones, reinforcing the idea that both genetic traits and environmental compatibility play crucial roles in achieving high-yielding performance.

Table 18 Analysis of Variance of Yield Potential and Selected Traits of Sweet Corn Hybrids, 2023 Season

Parameters	F-value	P-value	Cv%	L.SD%	Se
100%male	0.20	0.934	0.0	9.67	6.27
100 %silking	0.20	0.934	0.0	10.44	6.77
6/leaves stage(pheno logical)	0.20	0.934	14.0	1.723	1.118
Grain/yield(g)	1.23	0.348	10.3	0.2763	0.1793
Day emergence	0.20	0.934	0.0	1.218	0.791
Density harvesting	0.08	0.988	11.4	13.22	8.58
dry matter	0.26	0.900	27.5	12.04	7.81
Dry weight	0.66	0.633	25.3	25.32	16.43
efficiency%	0.45	0.771	5.3	3.710	2.408
Emergence %	0.50	0.737	8.3	10.33	6.71
Fresh weight	0.56	0.696	13.1	46.38	30.10

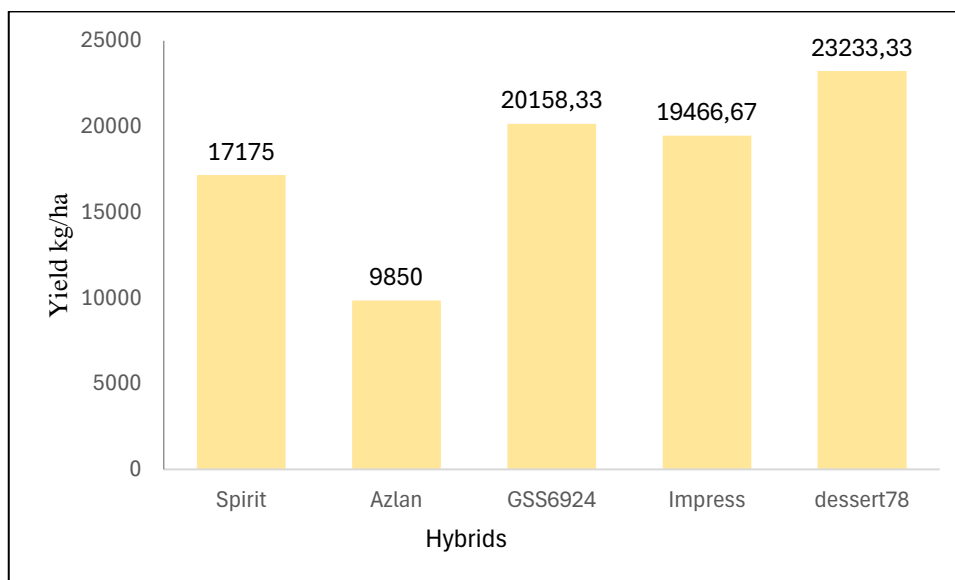


Figure 18 Potential Yield kg/ha between Five Sweet Corn Hybrids, Season 2023

Table 19 Analysis of Variance of Yield Potential and Selected Characters of Sweet Corn Hybrids, 2023 Season

Parameters	F-value	P-value	CV%	L.S.d%	Se
Number/seeds/row	1.85	0.184	6.9	4.049	2.628
Number/rows	1.50	0.263	9.8	2.551	1.656
Plant emergence	0.50	0.737	8.3	5.192	3.370
Plant height	0.17	0.947	14.8	56.68	36.79
Total Weight of the cob without the leaf	2.36	0.112	6.4	0.3030	0.1967
Total weight of the cob	1.47	0.270	8.9	0.5318	0.3452
Yield/kg	0.69	0.615	31.2	12.95	8.41
Yield/kg/ha	0.69	0.615	31.2	8634.4	5604.3
Yield/pcs	0.66	0.629	24.8	28.44	18.46
50%silking	0.20	0.934	0.0	9.97	6.47

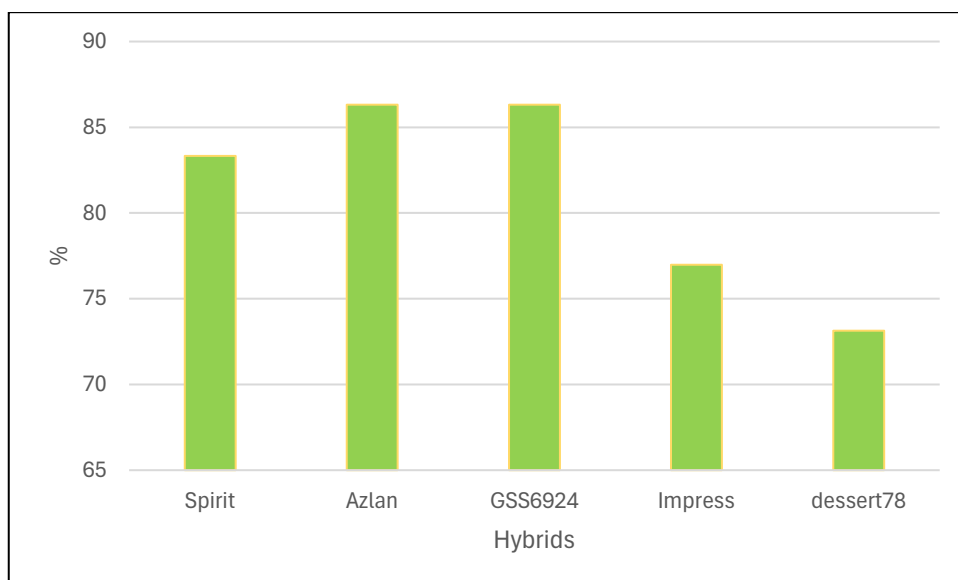


Figure 19 Emergence% between five hybrids of sweet corn season 2023

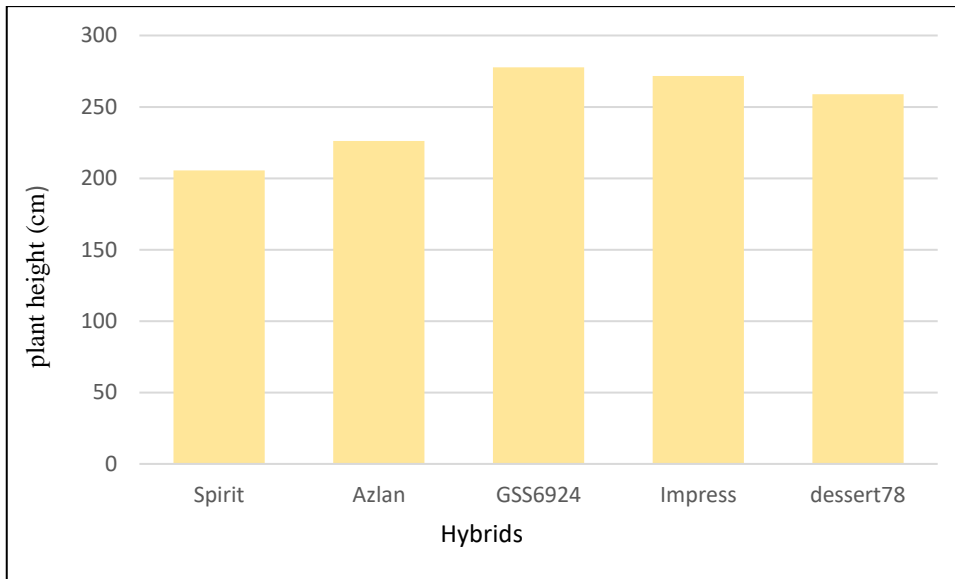


Figure 20 Plant height (cm) of five sweet corn hybrids, season 2023

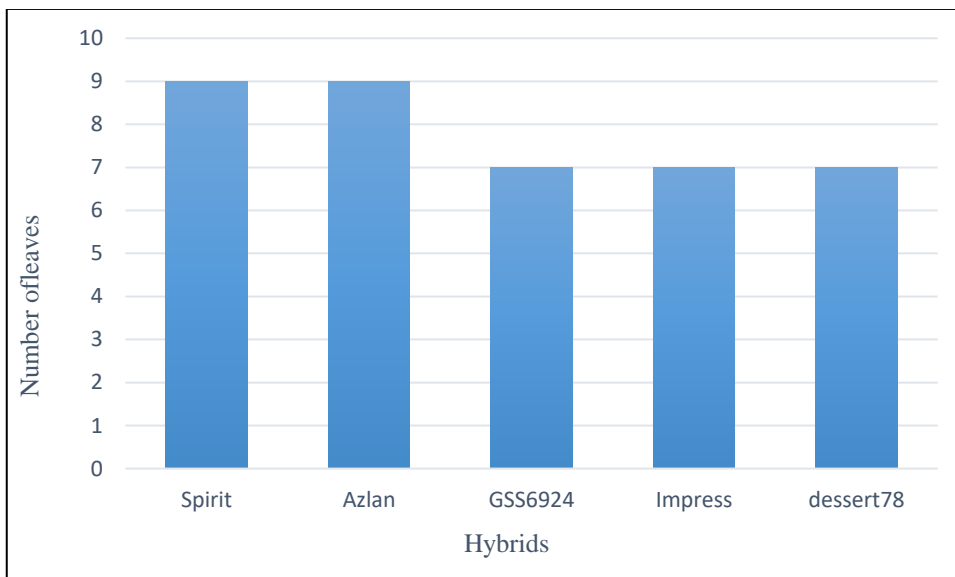


Figure 21 Phenological stage (6/leaves stage) of five sweet corn hybrids, season 2023

4.6 Analysis of variance of the Effect of Different Plant Densities on traits of Four Sweet corn hybrids, Season 2022

The analysis of variance indicated that the four sweet corn hybrids differed significantly for several traits, including emergence percentage, number of ears per plant, number of lodged plants, total plant count, plant height, ear diameter, number of kernels, and number of rows per ear. Significant differences were also observed among the hybrids for moisture content and ears with husk, with detailed results presented in Table 21.

In the plant density trial, the highest yield was recorded at a density of 60,000 plants per hectare. Increasing the density to 70,000 and 80,000 plants per hectare resulted in yield reductions of approximately 1,923 kg/ha and 1,407 kg/ha, respectively, compared to the maximum yield of 17,519 kg/ha obtained at the lower density.

These findings agree with *Daljeet Singh (2021)*, who reported that plant densities ranging from 9,900 to 79,000 plants/ha influenced crowding stress levels in sweet corn. While denser planting resulted in a gradual increase in marketable ear mass (approximately 0.8 Mt/ha per decade), yield per plant remained relatively stable across density levels. His research also indicated that crate yield, an important indicator for fresh market suitability, improved in newer hybrids. However, there was little advancement in processing-related traits such as fresh kernel weight and kernel recovery. Furthermore, modern hybrids exhibited fewer tillers and reduced shoot biomass, characteristics favorable for high-density planting.

In contrast, these findings differ from those of *Bosco Justin (2022)*, who reported a positive relationship between higher plant density and grain yield. However, they are consistent with the observations of *Renan Soares (2013)*, who found that increasing plant density from 40,000 to 100,000 plants/ha improved the yield of husked commercial ears in the Tropical Plus and RB-6324 hybrids, although it resulted in a reduction in ear size and diameter.

Supporting this, *Adrienne (2013)* demonstrated that dense canopies could improve weed suppression due to reduced light penetration. Nonetheless, extremely high plant densities negatively affected ear size and overall productivity. Her study tested three plant population levels, 29,936, 63,615, and 97,293 plants/ha, and identified significant differences in morphological and yield-related traits across hybrids.

Martin Williams (2021) also reported that increased planting density may heighten the risk of root lodging. Trials conducted across the U.S. Midwest, incorporating both natural and artificially induced lodging, highlighted that lodging could hinder harvest efficiency and reduce yield. However, the study emphasized that determining optimal plant densities for profitability did not necessarily increase lodging severity.

Likewise, *Daljeet Singh (2020)* observed that at low planting density (9,900 plants/ha), crowding stress was absent, whereas higher densities (up to 79,000 plants/ha) imposed such stress. Marketable ear mass per area increased at 0.8 Mt/ha per decade, while per-

plant yield remained relatively unchanged, suggesting that plant density had a limited impact on individual plant productivity. Grain yield, often used as a fresh market performance indicator, improved over time with modern hybrids. However, traits like fresh kernel mass and kernel recovery showed minimal progress. Modern hybrids also produced fewer tillers and less fresh shoot biomass, potentially enabling the adoption of higher plant densities.

Furthermore, *Dhaliwal (2021)* reported that higher planting densities might delay crop maturity and reduce kernel count per ear, which can negatively impact total yield. This indicates that excessive density can be detrimental and emphasizes the importance of managing inter-plant competition effectively.

Echoing this view, *Stansluos (2024)* concluded that sweet corn hybrids developed for greater density tolerance demonstrated increased productivity under high-density planting. Still, certain hybrids responded better at lower densities, producing heavier kernels, which suggests that optimal planting density is hybrid-specific and depends on production objectives.

4.6.1 LSD %Analysis

The analysis revealed that the highest emergence percentage was recorded by Messenger at 95.12%, while Tyson exhibited the lowest value at 77.50%. In terms of kernel count, SF1379 achieved the highest number with 42.29 kernels, whereas Tyson again showed the lowest value at 35.83. Regarding the number of cobs, Messenger outperformed the other hybrids with 175.5, while Tyson registered the lowest at 124.7.

The results also indicated that GSS6924 produced the longest ears, with an average length of 23.76 cm, whereas Tyson had the shortest ears, measuring 18.55 cm. Conversely, Tyson recorded the tallest plants at 186.6 cm, while SF1379 had the shortest plant height, with an average of 128.4 cm.

In terms of yield, Messenger led with the highest value of 17,300 kg/ha, whereas SF1379 recorded the lowest yield at 15,333 kg/ha. For ear diameter, Tyson exhibited the largest measurement at 52.05 mm, while GSS6924 had the smallest at 47.99 mm. Finally, Tyson also recorded the highest number of rows per ear at 19.01, while SF1379 showed the lowest value at 16.70. These findings are presented in Table 20 and Figures 22 and 23.

4.6.2 Correlation Analysis

The correlation analysis revealed a highly significant positive relationship between ear diameter and both the number of rows and plant height, with correlation coefficients of 0.575** and 0.459**, respectively. Additionally, the number of leaves at the sixth stage exhibited strong positive correlations with emergence percentage and the number of cobs, with correlation values of 0.635** and 0.657**, respectively.

Moreover, time to silking showed significant positive correlations with plant height (0.554**), time to tasseling (0.955**), and moisture percentage (0.450**). Similarly, plant height exhibited strong positive associations with ear diameter (0.459**), time to silking (0.554**), and time to tasseling (0.465**). Moderate positive correlations were also recorded between plant height and both emergence percentage (0.302*) and moisture content (0.286*).

Time to tasseling also exhibited highly significant positive correlations with time to silking (0.955**), plant height (0.465**), and moisture content (0.454**). Furthermore, the number of cobs was significantly and positively correlated with the number of leaves at the sixth stage (0.657**), emergence percentage (0.444**), and yield per hectare (0.610**), as summarized in Tables 22 and 23.

The presence of a strong and positive correlation between the number of kernels and the number of cobs with yield supports the consistency between the correlation and regression analyses. These findings are consistent with previous studies. For instance, *Devi (2001)* and *Mohsan (2002)* reported a significant positive association between cob number and yield in maize, including sweet corn. Similarly, *Malik (2005)* found that the number of cobs per plant positively correlated with yield-related traits such as cob length and the number of kernels per cob. Furthermore, *Saleh (2018)* observed that the number of cobs per plant was positively associated with yield, cob length, and grain number per row. *Ayer (2017)* also emphasized the importance of cob number in their correlation and path coefficient analysis, noting its substantial contribution to total yield.

Overall, the majority of traits examined showed positive and significant correlations with yield. These results suggest that the breeding population used in this study possesses sufficient genetic variability, which can be effectively utilized through selection to improve crop performance. The results are illustrated in Figure 25.

4.6.3 Regression Analysis

The relationships between morphological and agronomic traits have been investigated in various crops, with genotypes evaluated using stepwise regression to identify the key parameters that most strongly influence performance in individual genotypes or genotype groups (Al-Naggar *et al.*, 2015). In this study, the regression analysis revealed a strong, significant, and positive relationship between yield and both the number of cobs and the number of kernels, suggesting that improvements in these traits substantially enhance yield (kg/ha). Furthermore, the analysis identified significant associations between yield and additional traits, including ear length, ear diameter, number of rows per ear, emergence percentage, time to emergence, the six-leaf stage, plant height, moisture content, and the number of lodged plants. These results are presented in Tables 24, 25, and 26.

4.6.4 Factor Analysis

A factor analysis was performed, revealing that the first principal factor, strongly linked with the six-leaf stage, exhibited the highest positive loading and accounted for approximately 29% of the total observed variance. This trait emerged as the most influential among all those evaluated. The second factor, which was predominantly associated with silking time, explained around percent % of the total variance, highlighting its substantial impact on yield outcomes.

The third factor was related to tasseling time and contributed roughly 13% to the total variance, showing a continued positive influence on yield performance. Additionally, the fourth factor, representing the number of plants, accounted for approximately 7% of the total variation. The fifth factor was linked to the number of cobs and explained about 5% of the variance, indicating a notable contribution to yield, particularly under varying environmental conditions.

These results are detailed in Table 27 and visually represented in Figure 24. The factor analysis, which was conducted on the correlation matrix, yielded 22 latent trait factors. Their relative importance and distribution are illustrated in the scree plot shown in Figure 27. According to the eigenvalue > 1 criterion (Kaiser, 1960), the first factor (29%) was found to be broadly associated with all measured traits, whereas the second factor (17%) was specifically linked to sweet corn yield.

Table 20 LSD% test on parameters of different plant densities of sweet corn

Hybrids	Emergence%	Group	Moisture content%	Group	Number/kernels	Group	Number/cobs	Group
SF1379	77.65	a	66.61	ab	42.29	c	140.8	a
Tyson	77.50	a	75.57	b	35.83	a	124.7	a
Gss6924	88.41	b	75.25	b	36.15	a	139.9	a
Messenger	95.12	c	63.67	a	39.38	b	175.5	b
Hybrids	Length/ear(cm)	Group	Number/plants	Group	Number/plants	Group	Plant height(cm)	Group
SF1379	20.6777	a	34.35	b	137.4	b	128.4	a
Tyson	18.55	a	31.08	a	124.3	a	186.6	c
Gss6924	23.76	a	33.15	b	132.6	b	183.2	bc
Messenger	19.18	a	45.60	c	182.4	c	173.7	b
Hybrids	Yield kg/ha	Group	Yield/kg(2-3 rows)	Group	Amount%	Group	Diameter/ear(mm)	Group
SF1379	15333	a	46.00	a	37.23	a	48.63	a
Tyson	17246	a	31.74	a	36.53	a	52.05	b
Gss6924	15756	a	47.27	a	36.73	a	47.99	a
Messenger	17300	a	51.900	a	37.23	a	48.46	a
Hybrids	Ear without husk	Group	Ear with husk	Group	Grain/yield(g)	Group	Number/rows	Group
SF1379	3.867	a	3.021	a	1.439	a	16.70	a
Tyson	4.133	b	3.204	a	1.513	a	19.01	c
Gss6924	3.896	a	3.029	a	1.431	a	18.54	c
Messenger	3.967	ab	3.021	a	1.468	A	17.47	b

* Treatments sharing the same letter are not significantly different

Table 21 Analysis of Variance of Selected Traits of Sweet Corn

Parameters	Source	d.f	F-value	P-value
Emergence%	Hybrids	3	89.58	.001
	Density	2	9.37	.001
	Hybrids. density	6	4.29	0.003
Moisture%	Hybrids	3	4.00	0.016
	Density	2	1.17	0.322
	Hybrids. density	6	0.92	0.494
Number cobs	Hybrids	3	8.96	.001
	Density	2	1.52	0.234
	Hybrids. density	6	0.32	0.923
Number of damaged Plants	Hybrids	3	1.46	0.244
	Density	2	1.03	0.369
	Hybrids. density	6	3.09	0.016
Number of lodged plants	Hybrids	3	0.00	1.000
	Density	2	10.17	.001
	Hybrids. density	6	0.28	0.945
Number plants(2-3 rows) before harvest	Hybrids	3	87.64	.001
	Density	2	1.31	0.283
	Hybrids. density	6	1.71	0.149
Plant height(cm)	Hybrids	3	47.20	.001
	Density	2	0.51	0.603
	Hybrids. density	6	0.24	0.961
Yield kg/ha	Hybrids	3	1.04	0.390
	Density	2	1.33	0.278
	Hybrids. density	6	0.29	0.938
Yield rows/kg(2-3)	Hybrids	3	1.04	0.390
	Density	2	1.33	0.278
	Hybrids. density	6	0.29	0.938
Amount%	Hybrids	3	1.48	0.238
	Density	2	6.75	0.003
	Hybrids. density	6	1.38	0.251
Diameter/ear(mm)	Hybrids	3	20.32	.001
	Density	2	2.98	0.065
	Hybrids. density	6	1.38	0.267
Ear with husk	Hybrids	3	2.42	0.084
	Density	2	4.37	0.021
	Hybrids. density	6	2.31	0.057
Ear without husk	Hybrids	3	1.43	0.251
	Density	2	6.10	0.006
	Hybrids. density	6	1.80	0.130
Grain/yield(g)	Hybrids	3	1.40	0.261
	Density	2	4.27	0.023
	Hybrids. density	6	2.44	0.046
Length/ear(cm)	Hybrids	3	1.25	0.307
	Density	2	0.80	0.460
	Hybrids. density	6	0.80	0.577
Number/kernels	Hybrids	3	33.73	.001
	Density	2	2.08	0.141
	Hybrids. density	6	0.78	0.591
Number rows/ear	Hybrids	3	32.42	.001
	Density	2	0.23	0.798
	Hybrids. density	6	0.79	0.588

Table 22 Correlation Analysis of some traits of sweet corn hybrids

Characters	length/ear(cm)	diameter/ear(mm)	Number/rows/ear	Emergence%	6/leaves/stage	Time silking	plant height(cm)	Time/tasselling	Number/cobs	moisture content%	yield kg/ha
length/ear(cm)	1	-0.116	0.013	0.172	0.033	0.107	-0.19	-0.088	0.098	0.009	0.137
diameter/ear(mm)	-0.116	1	.575**	0.029	0.092	0.091	.459**	0.106	0.012	0.173	0.131
Number/rows/ear	0.013	.575**	1	0.08	0.085	0.078	0.268	-0.042	0.142	0.141	0.279

Table 23 Analysis of the correlation of some characteristics of sweet corn hybrids

Characters	Length/ear(cm)	Diameter/ear(mm)	Number/rows	Emergence%	6/leaves stage	Time/silking	Plant height(cm)	Time/tasselling	Number/cobs	Moisture%	Yield kg/ha
6/leaves stage	-0.033	-0.092	0.085	.635**	1	-.658**	-0.062	-.654**	.657**	-.399**	0.136
Time silking	-0.107	0.091	-0.078	-0.253	-.658**	1	.554**	.955**	-.449**	.450**	0.045
plant height	-0.19	.459**	0.268	.302*	-0.062	.554**	1	.465**	0.003	.286*	0.218
Time/tasselling	-0.088	0.106	-0.042	-0.231	-.654**	.955**	.465**	1	-.453**	.454**	-0.022
number/cobs	0.098	0.012	0.142	.444**	.657**	-.449**	0.003	-.453**	1	-0.221	.610**

Table 24 Analysis of the regression of some parameters of sweet corn

Characters	F-value	P-value
Number rows/ear	3.870	.055
Number/cos	27.242	.000
Diameter/ear	.807	.352
Length/ear(cm)	.883	.352
Number/kernels	7.680	.008
Grain/yield(g)	.001	.980
Plant height(cm)	2.302	.136
Emergence%	.535	.468
6/leaves stage	.876	.356
Time/silking	.092	.763
Time/tasselling	.023	.881
Time/Emergence	.870	.356
Number/plants	.576	.452
Number of lodged plants	1.000	.323
Number of damaged plants	.107	.745
Moisture%	.744	.393

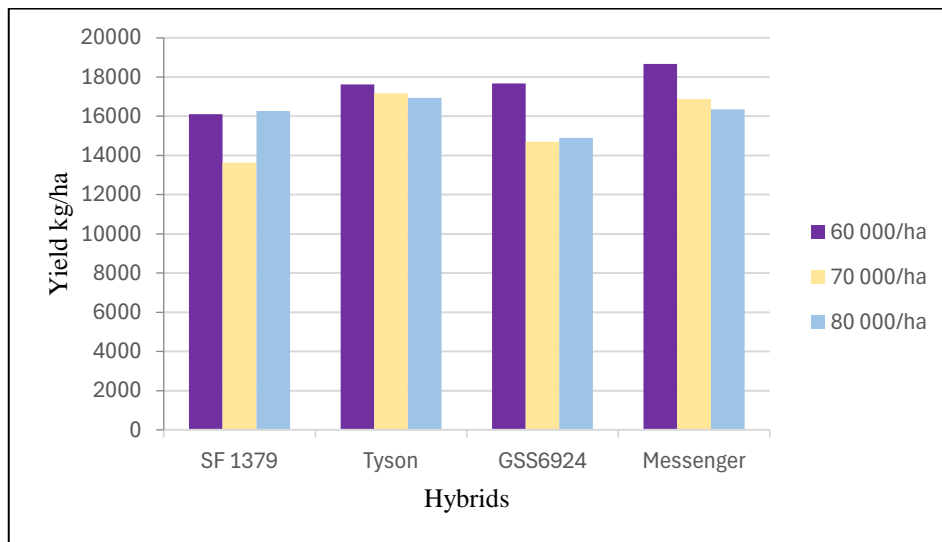


Figure 22 Effect of Different Plant Densities on Yield (kg/ha) of Four Sweet Corn Hybrids, 2022

Table 25 Regression analysis of vegetation and yield traits of sweet corn hybrids

Characters	R	R2	Adjusted Square	Significance
Length/ear(cm)	.137	.019	-.002	*
Diameter/ear(mm)	.131	.017	-.004	*
Number/rows	.279	.078	.058	*
Number/kernels	.378	.143	.124	**
Time/emergence	.136	.019	-.003	*
Emergence%	.107	.011	-.010	*
6/leaves/stage	.136	.019	-.003	*
Time/silking	.045	.002	.020	NS
Time tasselling	.022	.000	-.021	NS
Plant height(cm)	.218	.048	.027	*
Number/plants	.111	.012	-.009	NS
Number/lodged/plants	.146	.021	.000	*
Number/damaged/plants	.048	.002	-.019	NS
Number/cobs	.610	.372	.358	***
Moisture%	.126	.016	-.005	*

Significance was represented using the following codes: indicating $p < 0.001$, indicating $p < 0.01$, indicating $p < 0.05$, while NS denoted results that were not statistically significant.

Table 26 Regression Analysis of Growth and Yield Parameters

Characters	Equation regression
Length/ear(cm)	$14997.393 - 68.726 \times 68.72$
Diameter/ear(mm)	$5787.190 + 215.529 \times 215.529$
Number/rows	$-33.572 + 917.079 \times 917.0079$
Number/kernels	$31695.841 + 398.227 \times -398.227$
Time/emergence	$-49888820.3 + 1116.667 \times 1116.667$
Emergence%	$12689.065 + 43.933 \times 43.933$
6/leaves/stage	$12880.779 + 604.819 \times 604.819$
Time silking	$-2546150.958 + 57.272 \times 57.272$
Time tasselling	$1401659.081 + 30.962 \times -30.962$
Plant height(cm)	$12154.881 + 25.326 \times 25.326$
Number/plants	$14148.833 + 62.698 \times 62.698$
Number/cobs	$5943.834 + 72.059 \times 72.059$
Moisture%	$13640.045 + 39.400 \times 39.400$

Table 27 Factor Analysis of some traits for growth and yield

Variables	Total	% of Variance	Cumulative %
6/leaves stage	6.400	29.089	29.089
Time silking	3.881	17.641	46.731
Time/tasselling	2.956	13.437	60.168
Number/plant	1.741	7.913	68.081
Number/plant	1.425	6.477	74.558
Number/cobs	1.199	5.450	80.008
Time/Emergence	.985	4.477	84.485
ear with husk	.842	3.826	88.311
ear mass husk	.599	2.725	91.036
Emergence%	.544	2.471	93.507
moisture content%	.452	2.054	95.562
diameter/ear(mm)	.246	1.117	96.679
grain/yield(g)	.216	.983	97.661
plant height(cm)	.157	.715	98.376
Number/rows/ear	.126	.574	98.950
yield/rows/kg	.118	.537	99.487
Yield kg/ha	.074	.337	99.825
Number/kernels	.038	.171	99.996
Number lodged	.001	.003	99.999
amount%	.000	.001	100.000
length/ear(cm)	2.516E-16	1.144E-15	100.000
Number of damaged plants	1.675E-18	7.611E-18	100.000

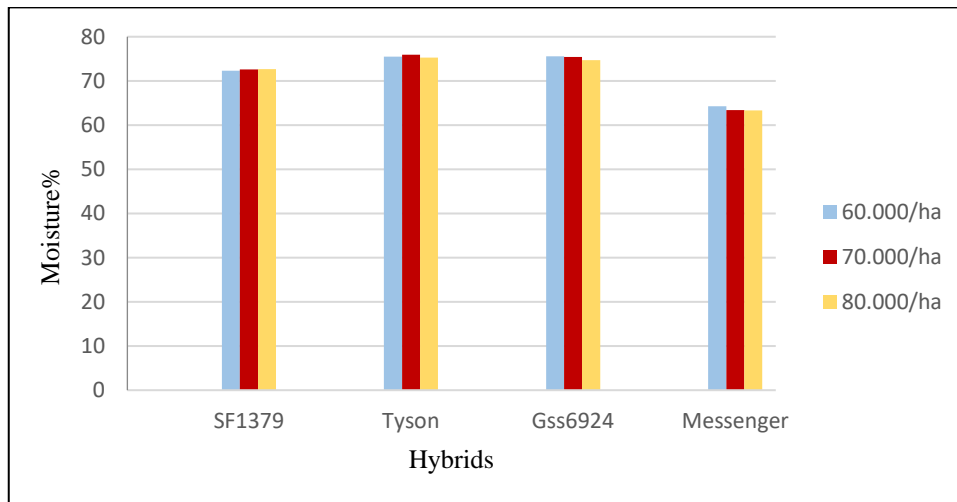


Figure 23 Effect of different plant densities on moisture% of four sweet corn hybrids, 2022

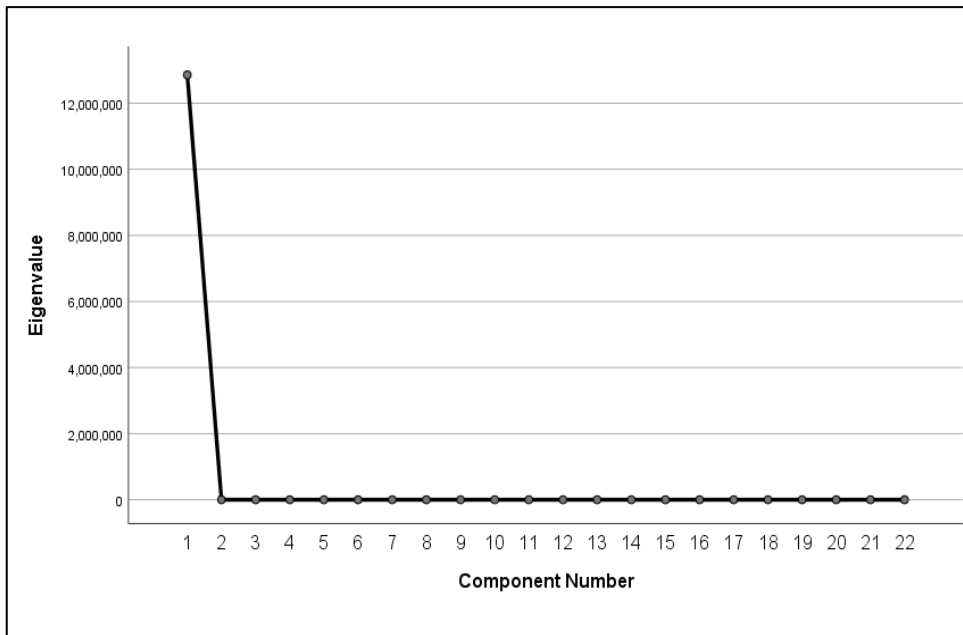


Figure 24 Scree plot showing eigenvalues and cumulative contribution to the total variance of 22 factors estimated from the coefficients of correlation among 22 traits of sweet corn.

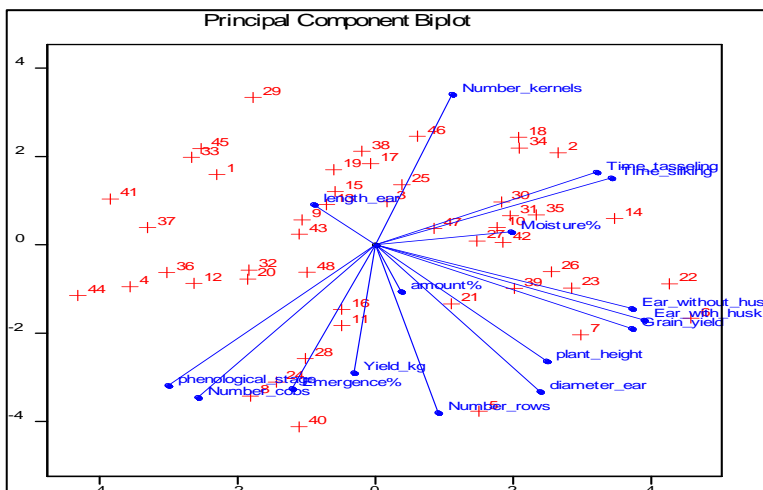


Figure 25 Principal component Biplot showed that the relationship between these traits, Number/kernels-length/ear-moisture%-time silking-time tasselling-amount%-Ear with husk-Ear without husk-grain yield-phenological stage leaves-Number/cobs-Emergence%-plantheight-yield/kg-Number/rows-diameter/ear of different plant density of sweet corn hybrids.

4.7 Analysis of variance on traits of Braveheart Hybrid Season 2022

For the GSS6924 hybrid, data normality was initially confirmed, followed by verification of variance homogeneity through Bartlett's test. The ANOVA results indicated that sowing dates exerted a highly significant effect on the number of rows per ear, emergence percentage, and moisture content. Additionally, several traits exhibited significant variation, including the number of lodged plants, lodging percentage, ear weight with husk, grain yield (g), total yield (kg/ha), ear weight without husk, kernel count, number of cobs, plant count before harvest, and ear length. In contrast, plant height and ear diameter showed no statistically significant differences. Detailed results are presented in Table 28, while Figure 29 provides a graphical illustration.

4.8 Analysis of variance on parameters of Braveheart Hybrid Season 2023

The analysis of variance revealed that sowing dates had a highly significant influence on 50% silking, 50% tasseling, and days to emergence. Significant differences were also detected for several traits, including the number of emerged plants, number of rows per ear, plant height, total cob weight without husk, yield (kg/ha), yield per cob, 100% male flowering, 100% silking, fresh weight, dry weight, dry matter content, number of seeds, total cob weight, six-leaf stage, grain yield, and plant density prior to harvest. In contrast, emergence efficiency percentage did not differ significantly across sowing dates. Comprehensive results are provided in Table 29, with corresponding graphical representations in Figure 30.

4.9 Analysis of variance on traits of Gss6924 Hybrid Season 2022

The ANOVA results for the 2022 season demonstrated that the four sowing dates had a highly significant impact on the emergence percentage of the GSS6924 hybrid. Significant variations were also recorded for plant height, number of cobs per plant, moisture content, and number of rows per ear. In contrast, no statistically significant differences were observed for grain yield (kg/ha), amount percentage of ears, ear diameter, ear length, kernel number, ear weight with husk, ear weight without husk, number of plants before harvest, or the number of lodged plants. Comprehensive results are presented in Table 30, with a visual summary provided in Figure 26.

4.10 Analysis of variance on parameters of Gss6924 Hybrid Season 2023

In the 2023 season, analysis of variance revealed that sowing dates had a highly significant effect at the sixth-leaf growth stage. Significant differences were also observed in nitrogen use efficiency, seed count, plant height, total cob weight, total cob weight without leaves, yield per kilogram, and yield per piece. In contrast, no statistically significant differences were found for grain yield, plant density before harvest, dry weight, dry matter content, emergence percentage and count, fresh weight, number of rows, or yield per hectare. Detailed results are presented in Table 31, with corresponding visual representations in Figures 27 and 28.

4.11 LSD% analysis of Gss6924 Hybrid on Traits of sweet corn season 2022

The LSD% test for the 2022 season highlighted significant differences in the response of the GSS6924 hybrid to varying nitrogen fertilizer levels. Grain yield was recorded at 1.433 t/ha under the 1N treatment, showing a slight rise to 1.443 t/ha and 1.460 t/ha under 2N and 3N, respectively. Ear length was longest at the 2N level (20.23 cm), followed by 1N (20.04 cm) and 3N (19.76 cm). The number of kernels per ear was greatest under 1N (37.35), with slight decreases observed under 2N (37.23) and 3N (35.98). Similarly, the number of rows per ear peaked at 1N (19.40), dropping to 18.62 at 2N and 18.52 at 3N.

Emergence percentage improved as nitrogen rates increased, rising from 62.44 % at 1N to 75.25 % at 2N and 79.97 % at 3N. Yield per plant showed a similar trend, increasing from 25.22 kg (1N) to 26.66 kg (2N), then slightly decreasing to 25.37 kg (3N). Ear weight without husk was 3.025 kg under 1N and 3.075 kg under both 2N and 3N. Plant height, however, was highest at 1N (198.4 cm), followed by 191.0 cm at 2N and 167.6 cm at 3N.

As shown in Table 33, the number of cobs per plot was highest under 2N (73.00), compared to 66.00 (1N) and 62.75 (3N). No lodging was observed under 1N, while 0.2500 lodged plants were recorded under both 2N and 3N. Moisture content showed a slight upward trend across treatments, with 74.63 % at 1N, 74.67 % at 2N, and 76.53 % at 3N. Yield per hectare followed a similar pattern, peaking under 2N at 17,775 kg, compared to 16,817 kg (1N) and 16,917 kg (3N).

The percentage amount recorded was 35.95 % (1N), 36.33 % (2N), and 36.67 % (3N). Ear diameter remained relatively consistent, ranging from 48.74 mm under 2N to 49.44 mm under 1N. Ear weight with husk reached its maximum under 2N (4.012 kg), followed by 3.987 kg (1N) and 3.937 kg (3N). The number of plants per plot was 60.75 (1N), 67.25 (2N), and 62.75 (3N). Comprehensive results are presented in Tables 32 and 33.

4.12 LSD% Analysis of GSS6924 Hybrids on Traits of sweet corn season 2023

The LSD% analysis for the 2023 season revealed that the highest number of sixth leaves (7.750) was observed under the 3N nitrogen treatment, which was significantly greater than the values recorded for 1N and 2N. Grain yield ranged between 1.715 and 1.775 t/ha, though the differences among nitrogen levels were not statistically significant. Plant density remained relatively stable, ranging from 82.25 to 87.00. Similarly, dry matter content showed minimal variation, fluctuating slightly between 28.93 and 29.39. The highest dry weight (84.37) was obtained at 3N, although this difference was not statistically significant.

Nitrogen use efficiency exhibited minimal variation across treatments, ranging from 44.03 to 45.36. Cob weight with husk remained consistent across all nitrogen levels, ranging from 3.825 to 3.975 kg. Emergence count varied slightly from 41.94 to 43.00, with emergence percentages ranging narrowly between 83.46 % and 85.57 %. Fresh weight showed a positive response to nitrogen, reaching its highest value (286.9) under 3N.

The number of rows per cob displayed a slight variation (17.30–17.70), while seed count per row was highest under 1N (38.43) and lowest under 3N (37.35). Total cob weight without husk ranged between 2.800 and 3.163 kg, with the highest value under 1N. Plant height increased with nitrogen application, with the tallest plants recorded at 3N (222.3 cm). Cob weight without husk followed a similar trend, ranging from 2.850 to 3.163 kg, with the highest weight under 1N.

Yield per hectare responded positively to nitrogen, peaking at 21,392 kg/ha under 3N. Yield per plant showed notable variation, with the highest value (97.75) at 3N. Yield per kilogram also reached its maximum under 3N (32.09). Detailed results for all measured traits are presented in Tables 34, 35, and 36.

4.13 LSD %Analysis of Braveheart Hybrid on Parameters of Sweet Corn Season 2022

According to the LSD 5% analysis, the second sowing date recorded the highest average emergence percentage (92.16%), whereas the lowest value was observed on the third sowing date (70.77%). Moisture content was greatest on the third sowing date (81.91%) and lowest on the second sowing date (75.86%). The first sowing date produced the highest average number of cobs per plant (70.00), while the third sowing date recorded the lowest (56.00). Similarly, the number of plants counted before harvest was highest under the second sowing date (72.00) and lowest under the third sowing date (55.25).

Regarding the percentage amount, the maximum value was obtained on the first sowing date (36.83%), with the minimum recorded on the third sowing date (34.63%). Grain yield also peaked at the first sowing date (1.624 t/ha) and dropped to its lowest under the third sowing date (1.285 t/ha). The number of rows per cob was highest on the first sowing date (18.60) and lowest on the second sowing date (16.60). Plant height reached its maximum on the second sowing date (194.1 cm) and was lowest on the first sowing date (176.8 cm).

Yield per hectare was highest on the first sowing date (18,825 kg/ha), compared with the lowest value on the third sowing date (11,650 kg/ha). A similar trend was observed for yield per row, which was greatest at the first sowing date (28.24) and smallest at the third (17.40). The number of lodged plants was highest on the third sowing date (6.750), while no lodging occurred on the first sowing date. Detailed data for these parameters are presented in Tables 37, 38, and 39.

4.14 LSD% Analysis of Braveheart Hybrid on Traits of Sweet Corn Season 2023

The analysis revealed that plant height reached its maximum on the second sowing date (242.7 cm), whereas the lowest value was observed on the fourth sowing date (184.8 cm). The first sowing date produced the greatest number of emerged plants (45.06), while the fourth sowing date recorded the fewest (39.25). Yield per plant (pcs) followed a similar pattern, peaking at 92.75 under the first sowing date and dropping to its lowest (63.25) under the fourth sowing date.

The average number of rows per cob was highest on the first sowing date (18.05) and lowest on the second sowing date (16.55). Seed count per row also peaked under the first sowing date (39.50), with the minimum value (36.00) recorded on the third sowing date. Cob weight without leaves was greatest on the first sowing date (3.175 kg) and lowest on the third sowing date (2.550 kg). The highest average cob weight (with husk) was observed on both the first and second sowing dates (3.988 kg), whereas the lowest weight (3.425 kg) occurred on the third sowing date.

Overall yield per hectare reached its maximum under the first sowing date (23,275 kg/ha) and declined to the lowest value under the fourth sowing date (15,092 kg/ha). Similarly, yield per kilogram was highest on the first sowing date (34.91) and dropped to its minimum (22.64) on the fourth sowing date. Full details of these results are presented in Tables 40, 41, and 42.

Table 28 Analysis of variance of different sowing dates of some traits of the Braveheart hybrid season 2022

Traits	Cv%	L.s.d%	Se	F-value	P-value
Number of lodged plants	137.2	5.539	3.202	5.72	0.041*
Amount%	2.1	1.318	0.762	9.49	0.014*
Diameter/ear(mm)	5.0	4.216	2.437	1.70	0.262
Ear with a husk	10.9	0.741	0.428	3.77	0.087*
Ear without husk	17.0	0.876	0.506	3.15	0.116*
Grain/yield(g)	10.5	0.2578	0.1490	5.99	0.037*
Number/grains	8.4	5.514	3.187	1.21	0.362*
Number/rows/ear	3.3	0.990	0.572	12.64	0.007**
Emergence %	8.3	10.65	6.66	11.03	0.004**
Moisture%	1.0	1.192	0.745	76.34	.001**
Number/cobs	20.9	21.81	13.63	1.36	0.305*
Number/plants(before harvest)	24.8	24.50	15.31	1.38	0.301*
Plant height (cm)	12.7	38.16	23.86	0.60	0.570
Yield kg/ha	21.3	5251.7	3283.2	4.82	0.038*
Yield/rows/kg(2-3 rows)	21.3	7.88	4.92	4.82	0.038*
Length/ear(cm)	6.5	2.157	1.246	1.91	0.228*

Table 29 Analysis of variance of varying sowing dates of some traits of the Braveheart hybrid season 2023

Traits	CV%	L.S.d%	Se	F-value	P-value
Efficient%	6.2	4.486	2.804	0.61	0.625
Emergent plants/row	4.5	3.054	1.910	6.85	0.011*
Fresh weight(g)	11.8	49.222	30.77	1.22	0.357*
Number rows/cob	4.4	1.202	0.751	3.46	0.064*
Number/seeds/rows	6.7	4.032	2.521	1.68	0.239*
Plant height(cm)	5.6	19.26	12.04	19.17	.001*
Total Weight of the cob leaf(kg)	8.0	0.3770	0.2357	5.90	0.016*
Total Weight cob(kg)	8.9	0.5431	0.3396	2.41	0.134*
Yield/kg/ha	14.7	4639.1	2900.2	5.47	0.020*
Yield/kg	14.7	6.96	4.35	5.47	0.020*
Yield/pcs	17.7	21.91	13.70	3.19	0.077*
Male100%	0.0	1.995	1.247	1568.25	.001*
Silking 100%	0.0	1.600	1.000	3658.25	.001*
Male 50%	0.0	1.600	1.000	2411.17	.001**
50% silking	0.0	1.560	0.975	2613.09	.001**
6/ leaves/stage	7.2	0.2287	0.1430	2.41	0.135*
Grain/yield	8.3	0.2287	0.1430	2.41	0.135*
Day /emergence	0.0	0.854	0.534	13341.29	.001**
Plant density before harvest(2-3 rows)	9.1	12.71	7.95	0.90	0.480*
Dry matter(g)	9.3	3.928	2.456	0.93	0.465*
Dry weight(g)	14.3	15.79	9.87	1.73	0.229*

Table 30 Analysis of variance of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2022

Traits	Cv%	L.s.d%	Se	F-value	F-Value
Plant height(cm)	15.2	18.26	28.17	9.28	0.015*
Yield/kg	25.0	4.812	6.4426	0.32	0.736
Yield kg/ha	25.0	3207.7	4284.1	0.32	0.736
Amount%	2.5	1.548	0.894	0.65	0.554
Diameter/ear(mm)	2.5	2.110	1.220	0.36	0.709
Ear with husk	7.8	0.5403	0.3122	0.06	0.942
Ear without husk	10.0	0.5278	0.3051	0.04	0.965
Grain/yield(g)	9.5	0.2376	0.1373	0.04	0.960
Length/ear(cm)	6.6	2.286	1.321	0.12	0.886
Emergence%	5.0	6.23	3.60	25.41	0.001**
Number/cobs	17.0	8.23	11.42	4.85	0.056*
Number/Lodged plants	115.5	0.763	0.192	0.43	0.670
Moisture%	1.9	2.482	1.435	2.29	0.183*
Number/plants before harvest	7.2	15.12	4.57	0.58	0.588
Number kernels	8.1	5.194	3.002	0.26	0.782
Number rows/cob	4.1	1.330	0.769	1.55	0.286*

Table 31 Analysis of variance of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2023

Traits	CV%	L.S.d%	Se	F-value	P-value
6%leaves/stage	4.0	0.4995	0.2887	13.00	0.007**
Grain/yield	7.0	0.2128	0.1230	0.24	0.794
Plant density before harvest	8.6	12.70	7.34	0.48	0.638
Dry matter(g)	2.7	1.362	0.787	0.42	0.674
Dry weight(g)	8.5	12.16	7.03	0.28	0.767
Efficient%	3.6	2.784	1.609	0.70	0.534*
Emergence/pcs	3.4	2.598	1.502	0.50	0.629
Emergence%	3.5	5.171	2.988	0.50	0.629
Fresh weight(g)	7.4	35.98	20.80	0.21	0.815
Number/rows/cob	3.5	1.051	0.607	0.47	0.646
Number/seeds/rows	2.2	1.439	0.831	2.00	0.216*
Plant height(cm)	2.4	9.09	5.26	1.59	0.280*
Weight of the cob/ without the leaf	7.9	0.3993	0.2308	2.90	0.132*
Yield kg/ha	26.2	9417.9	5443.2	0.07	0.929
Yield/ pcs	17.8	27.33	15.80	0.93	0.446*
Yield /kg	43.0	21.06	12.17	0.62	0.568*
Total weight/cob	3.5	0.2374	0.1372	1.21	0.363*

Table 32 LSD% Analysis on traits of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2022

Nitrogen levels	Grain yield	Length/ear	Number/kernels	Number/rows	Emergence date	Yield/kg	Ear without husk	Plant height
1/N	1.433a	20.04a	37.35a	19.40a	62.44a	25.22a	3.025a	198.4b
2/N	1.443a	20.23a	37.23a	18.62a	75.25b	26.66a	3.075a	191.0b
3/N	1.460a	19.76a	35.98a	18.52a	79.97b	25.37a	3.075a	167.6a

Table 33 LSD% Analysis on traits of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2022

Nitrogen levels	Number/cobs	Lodged plants	Moisture %	Yield kg/ha	Amount %	Diameter/ear	Ear with husk	Number/plants
1N	66.00ab	0.0000a	74.63a	16817a	35.95a	49.44a	3.987a	60.75a
2/N	73.00b	0.2500a	74.67a	17775a	36.33a	48.74a	4.012a	67.25a
3/N	62.75a	0.2500a	76.53a	16917a	36.67a	49.29a	3.937a	62.75a

Table 34 LSD% Analysis on traits of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2023

Nitrogen levels	6%Leaves	Grain/yard	Plant density	Dry matter	Dry weight	Efficient%	Total weight/cob
1/N	6.750a	1.750a	87.00a	29.36a	80.79a	44.03a	3.975a
2/N	7.000a	1.715a	86.25a	28.93a	81.76a	44.80a	3.825a
3/N	7.750b	1.775a	82.25a	29.39a	84.37a	45.36a	3.913a

Table 35 LSD% Analysis on traits of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2023

Nitrogen levels	Emergence pcs	Emergence%	Fresh weight	Number/rows	Number/seeds	Total weight/cob/without leaf
1/N	41.94a	83.46a	277.3a	17.30a	38.43a	3.163a
2/N	43.00a	85.57a	282.8a	17.70a	38.30a	2.800a
3/N	42.50a	84.58a	286.9a	17.40a	37.35a	2.850a

Table 36 LSD% Analysis on traits of different levels of Nitrogen fertilizer of GSS6924 hybrid season 2023

Nitrogen levels	Plant height	Weight cob/without leaf	Yield kg/ha	Yield/pcs	Yield/kg
1/N	215.7a	3.163a	19958a	84.00a	29.94a
2/N	219.5a	2.880a	21000a	85.25a	22.91a
3/N	222.3a	2.850a	21392a	97.75a	32.09a

Table 37 LSD% Analysis on parameters of different sowing dates of Braveheart hybrid season 2022

Sowing date	Emergence%	Moisture%	Number/cobs	Number/plants	Plant height	Yield kg/ha
First sowing date	76.62a	76.80a	70.00a	58.00a	176.8a	18825b
Second sowing date	92.16b	75.86a	69.50a	72.00a	194.1a	15840ab
Third sowing	70.77a	81.91b	56.00a	55.25a	190.8a	11650a

Table 38 LSD% Analysis on parameters of different sowing dates of Braveheart Hybrid Season 2022

Sowing date	Yield/rows	Number of lodged plants	Amount%	Diameter/ear	Ear with husk	Ear without husk
First sowing date	28.24b	0.000a	36.83b	49.32a	4.412a	3.487a
Second sowing date	23.76ab	0.250a	36.43b	49.75a	3.675a	2.788a
Third sowing date	17.48a	6.750b	34.63a	46.81a	3.712a	2.650a

Table 39 LSD% Analysis of parameters of different sowing dates of Braveheart hybrid Season 2022

Sowing date	Grain/yield	Length/ear	Number/kernel s	Number/rows
First sowing date	1.624b	19.88a	39.90a	18.60b
Second Sowing date	1.337a	19.30a	37.00a	16.60a
Third Sowing date	1.285a	18.18a	36.75a	17.27a

Table 40 LSD% Analysis on parameters of different sowing dates of Braveheart hybrid season 2023

Sowing date	Male100%	Silking 100%	50% male	50% silking	6/leaves/stages	Grain/yield
First sowing	45110a	45113a	45108a	45111a	8.000a	1.758ab
Second sowing	45132b	45135b	45129b	45132b	8.000a	1.853b
Third sowing	45155c	45157c	45153c	4515bc	8.250a	1.585a
Fourth sowing	45165d	45169d	45163d	45167d	8.000a	1.720ab

Table 41 LSD% Analysis on parameters of different sowing dates of Braveheart hybrid season 2023

Sowing date	Day emergence	Plant density	Dry matter	Dry weight	Efficient%	Plant height	Emergence plant	Yield pcs
First sowing	45052a	85.25a	27.29a	75.39a	44.58a	233.7c	45.06c	92.75b
Second sowing	45085b	90.75a	26.66a	71.23a	46.58a	242.7c	42.81bc	79.50ab
Third sowing	45110c	89.25a	27.34a	70.12a	46.39a	206.3b	40.94ab	74.50ab
Fourth sowing	45122d	82.50a	24.81a	60.06a	44.61a	184.8a	39.25a	63.25a

Table 42 LSD% Analysis on parameters of different sowing dates of Braveheart hybrid season 2023

Sowing date	Fresh weight	Number rows	Number/seeds	Weight the cob leaf	Weight cob	Yield kg/ha	Yield/kg
First sowing	281.9a	18.05b	39.50a	3.175b	3.975a	23275b	34.91b
Second sowing	263.1a	16.55a	38.18a	3.138b	3.988a	20217b	30.32b
Third sowing	253.1a	16.80a	36.00a	2.550a	3.425a	20192b	30.29b
Fourth sowing	241.8a	16.65a	36.35a	2.938b	3.850a	15092a	22.64a

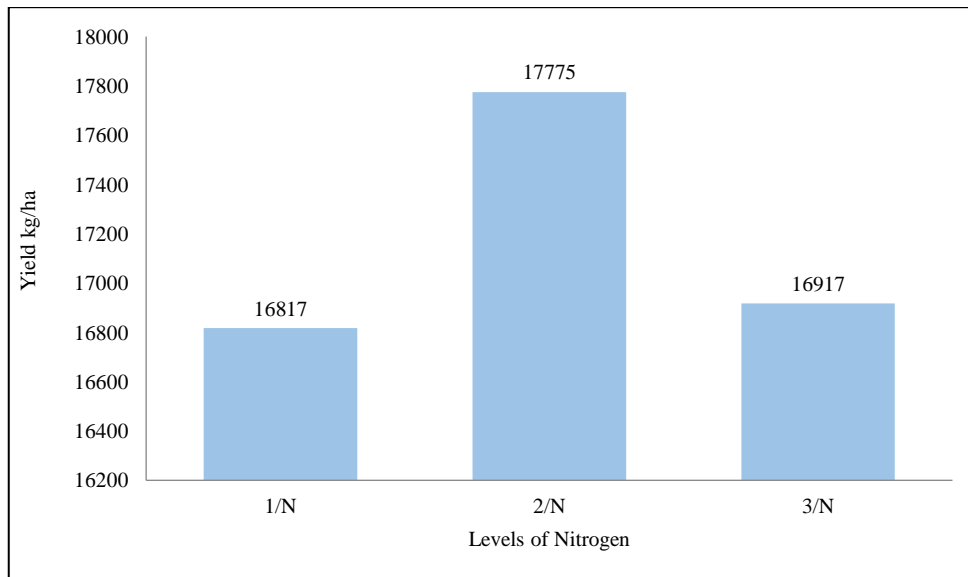


Figure 26 Effect of Different Nitrogen Fertilizer Levels on the Yield (kg/ha) of GSS6924 Hybrid in the 2022 Season

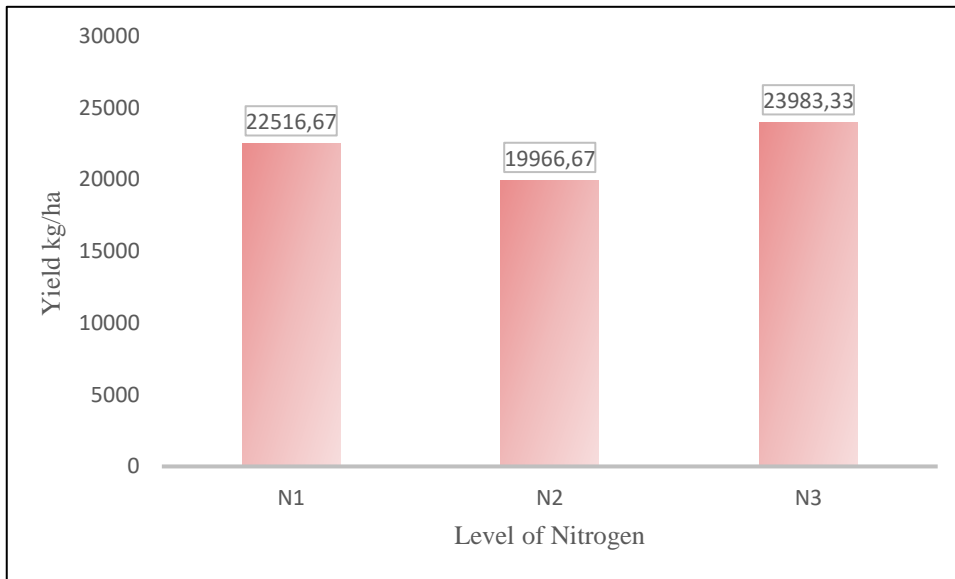


Figure 27 Effect of Different Nitrogen Fertilizer Levels on the Yield (kg/ha) of GSS6924 Hybrid in the 2023 Season

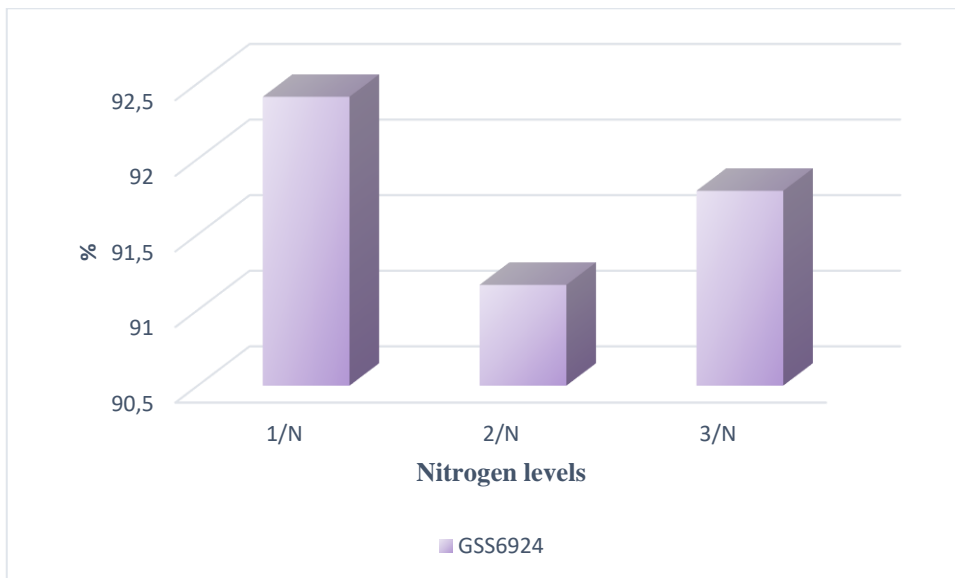


Figure 28 Effect of Different Nitrogen Fertilizer Levels on Emergence% of GSS692 Hybrid in the 2023 Season

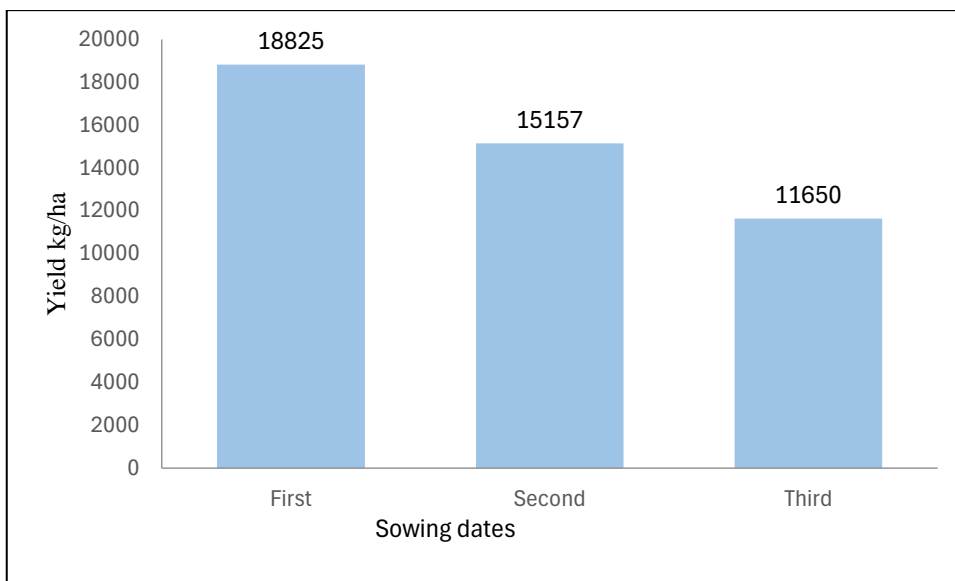


Figure 29 Influence of different sowing dates on the yield kg/ha of Braveheart hybrid season 2022

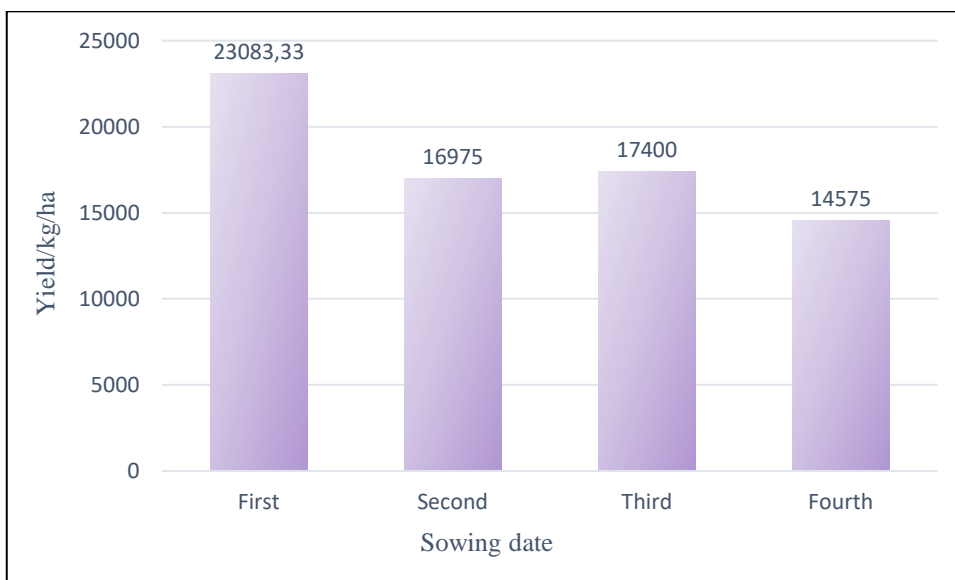


Figure 30 Effect of Different Sowing Dates on Yield (kg/ha) of Braveheart Hybrid in the 2023 Season

4.15 Correlation Analysis on Traits of Braveheart Hybrid Season 2022

The relationship between specific traits and other yield-contributing characteristics is critical for the indirect selection of genotypes aimed at enhancing grain yield (*Kumar et al., 2010*). While numerous studies have explored phenotypic and genotypic associations among key agronomic traits and maize yield, relying solely on simple correlations without considering interactions among yield components may lead to misleading conclusions and limit breeding efficiency (*Kaya et al., 2009*).

In the present analysis, a very strong positive correlation was observed between time to emergence and time to tasselling ($r = 0.997$). Emergence percentage was also significantly and positively associated with the six-leaf stage ($r = 0.813$). Silking time showed a highly positive correlation with tasselling time ($r = 0.996$), and tasselling time was positively correlated with moisture content ($r = 0.814$). Yield per row exhibited a strong positive correlation with the number of cobs per plant ($r = 0.877$). Additionally, ear weight with husk and ear weight without husk were very highly correlated ($r = 0.981$), and ear weight without husk was strongly associated with grain yield ($r = 0.958$).

4.16 Correlation Analysis of GSS6924 Hybrid Season 2022

The correlation analysis for the GSS6924 hybrid revealed highly significant positive associations between cob length and several yield-contributing traits, including the number of kernels, ear weight with husk, ear weight without husk, and grain yield, with correlation coefficients of 0.985, 0.921, 0.884, and 0.822, respectively. Ear weight with husk also exhibited strong positive correlations with the number of kernels, ear weight without husk, and grain yield ($r = 0.923$, 0.971 , and 0.949 , respectively). Additionally, ear weight without husk was positively correlated with both kernel number ($r = 0.877$) and grain yield ($r = 0.968$). Yield per kilogram showed a significant positive correlation with the number of cobs ($r = 0.927$). These relationships between morphological and agronomic traits have been widely documented in various crops, where stepwise regression analyses were employed to identify key traits influencing optimal genotype performance (*Al-Naggar et al., 2015*).

4.17 Cluster Analysis of Braveheart Hybrid on Traits

Phenotypic characterization was utilized in cluster analysis to identify homogeneous groups based on trait similarity and to assess how well the results corresponded with the pedigrees of the evaluated sweet maize inbred lines. Such clustering outcomes can provide valuable guidance for selecting genotypes in future breeding programs (*Babic et al., 2010*).

Analysis of the Braveheart hybrid across the first and second seasons revealed significant differences among clusters for all measured traits. In the first season, the largest ear diameter was observed in Cluster One, which included seven cases, compared to Cluster Two with five cases; the genetic distance between these two clusters was 6.77. Interestingly, Cluster One also exhibited the highest yield per kg/ha, despite containing

only two cases, whereas Cluster Two comprised ten cases. During the second season, Cluster One again recorded the highest yield per kg/ha. Comparable studies in maize using morphological traits and yield components have similarly grouped hybrids into three clusters, including two clusters represented by a single member.

4.18 Cluster Analysis of GSS6924 Hybrid on Characters

In both seasons, the largest ear diameter was observed in Cluster Two, which, along with Cluster One, contained six cases each. The genetic distance between the two clusters was 6.55, indicating considerable diversity. For the GSS6924 hybrid, yield (kg/ha) was the most influential trait distinguishing clusters. In the second season, the highest yields were recorded in Cluster Two. Notably, Cluster One had nine cases, while Cluster Two had only three.

According to *Muminov (2020)*, the considerable variation in green cob yield and related traits largely results from the extensive genetic diversity among clusters. Using genetically distant parents in hybridization enhances the potential for heterosis and improves hybrid performance. Hence, clustering patterns are vital in designing hybridization strategies, enabling breeders to select parent combinations with maximal trait diversity. Evaluating cluster means and inter-cluster distances assists in identifying superior genotypes suitable for breeding programs.

4.19 Performance Comparison of Braveheart Hybrid Across the 2022-2023 Seasons

The results for the Braveheart hybrid in the 2022 and 2023 seasons highlight the significant influence of sowing date on yield, plant growth, and reproductive development, with both similarities and differences observed between the two years.

In both seasons, early sowing consistently produced higher grain yields and accelerated developmental stages. The first sowing date achieved the highest grain yields, with Braveheart reaching 28.24 kg/ha in 2022 and 23,275 kg/ha in 2023. Early sowing also minimized plant lodging and improved ear traits, such as the number of rows per ear, across both seasons. However, the negative effect of delayed sowing was more pronounced in 2023. The fourth sowing date in 2023 recorded a substantially lower yield, whereas in 2022, the third sowing date still maintained a reasonable yield of 17.48 kg/ha. Delayed sowing in 2023 also led to more marked reductions in plant height and overall growth, indicating a stronger adverse effect compared to 2022.

Moisture content trends differed between the two seasons. In 2022, later sowing dates were associated with higher moisture levels, while in 2023, moisture content varied less across sowing dates. Overall, both seasons demonstrate that early sowing promotes optimal growth and yield, with the 2023 results emphasizing the heightened challenges and yield reductions associated with late sowing.

4.20 Comparing the Performance of GSS6924 Hybrid Across the 2022 and 2023 Seasons

In 2022, nitrogen levels had no significant impact on grain yield or ear characteristics. The highest nitrogen application rate (3/N) yielded results comparable to lower rates (1.460 kg/ha), showing minimal effects on ear weight or diameter. Grain yield depended more on sowing date and other factors than on nitrogen level. In 2023, nitrogen had a limited effect on grain yield; while the highest nitrogen level (3/N) produced the greatest yield per plant (97.75) and per hectare (21,392 kg/ha), the overall grain yield (32.09 kg) was only marginally higher than the lowest nitrogen treatment (29.94 kg). This indicates that nitrogen had a minor influence on productivity despite slight yield increases.

In 2022, nitrogen significantly affected plant height, with the highest nitrogen level (3/N) producing the shortest plants (167.6 cm), contrary to taller plants at lower nitrogen levels. In 2023, plant height gradually increased with nitrogen rate, from 215.7 cm at 1/N to 222.3 cm at 3/N. Despite nitrogen's effect on plant height, its influence on overall productivity was minimal. Nitrogen also delayed emergence in 2022, with the earliest emergence (62.44 days) at the lowest nitrogen level (1/N) and delayed emergence (79.97 days) at the highest (3/N), which likely hindered growth. Emergence in 2023 was more consistent across nitrogen levels, ranging between 83.46% and 85.57%, suggesting greater stability in plant development.

In 2022, nitrogen did not significantly affect ear diameter or ear weight (with husk). The second nitrogen level (2/N) recorded the highest numbers of cobs (73.00) and plants (67.25). Moisture percentage was slightly higher at the third nitrogen level (76.53%). In 2023, nitrogen's effects on cob traits, such as row number, seed number, and total cob weight, were negligible. However, higher nitrogen slightly improved foliage development and dry matter content. Total cob weight without leaves was somewhat lower at higher nitrogen levels (2/N and 3/N), indicating limited effects on cob development. The highest nitrogen level (3/N) in 2023 supported the most significant foliage growth, with the greatest percentage of 6% leaves (7.750) and the highest dry matter content (84.37%).

While nitrogen enhanced vegetative growth, this did not translate into significant increases in grain yield or plant density.

4.21 Estimation of 32 Sweet Corn Hybrids on Traits of Various Sowing Dates, Season 2023

Based on the analysis of 32 hybrids, mean values indicated that the tallest plants on the first sowing date were recorded in HMC305 (242 cm), whereas on the second sowing date, Impress attained the greatest plant height (251 cm). The highest hybrid yield on the first sowing date was achieved by HMC302 (29,300 kg/ha), while Messenger recorded the largest mean yield on the second sowing date (22,300 kg/ha).

Regarding dry matter per cob, hybrid 1218 showed the highest value on the first sowing date (31.544 g), whereas Royalty achieved the maximum on the second sowing date (34.996 g). For the number of cobs per plot, HMC302 had the highest mean on the first sowing date (114), while SVSK4540 recorded the largest mean on the second sowing date (89). The highest number of seeds per cob was observed in ZHY5022OD on the first sowing date (43.4), compared to ZHY5233OD on the second sowing date (43.7).

Overall, the highest mean grain yield on the first sowing date was observed in ZHY5022OD (2 t/ha), whereas SVSK2949 recorded the greatest mean yield on the second sowing date (2.02 t/ha). Ear length followed a similar pattern, with ZHY5022OD producing the longest ears on the first sowing date (22.6 cm), while ZHY5233OD had the largest ear length on the second sowing date (23.15 cm). The maximum number of rows per cob on the first sowing date was achieved by hybrid 1446 (20.2), whereas HMX832 and Messenger shared the highest value on the second sowing date (19 rows per cob).

These findings are consistent with the observations of *Horst (2021)*, who reported that certain maize hybrids, such as Xhy-2001, exhibited greater plant height on the first sowing date compared to others. Similarly, *Garcia (2009)* found that dry matter per cob was significantly higher on the first sowing date, with hybrids like SY-34 showing values around 31.5 g/cob. Comparable trends were also observed for ear length by *Wang (2020)*, where ZHY5022OD recorded the largest ear length (22.6 cm) on the first sowing date, while ZHY5233OD had a slightly longer ear length (23.15 cm) on the second sowing date. The results are illustrated in Figures 31-32.

Genetic improvement remains the most effective strategy in breeding programs. In sweet corn, progress has been limited compared to field corn due to a relatively narrow genetic

base, restricted germplasm sources, and poorly defined heterotic groups. Overall, this study, through the use of comprehensive morphological and molecular markers, provides valuable insights into the genetic diversity and population structure of sweet corn inbred lines, which will support germplasm enhancement and hybrid development (Mahato, 2018).

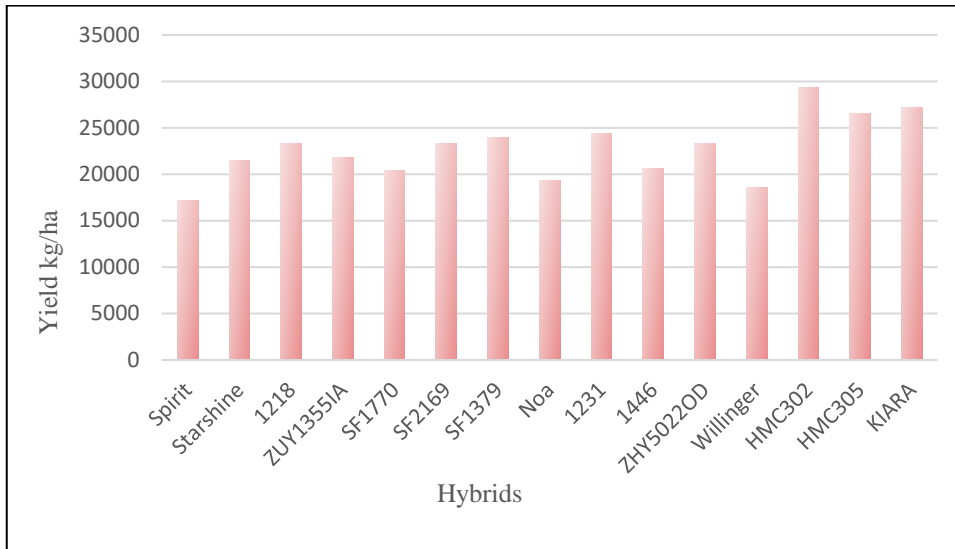


Figure 31 Estimation of different sweet corn hybrids on yield kg/ha of the first sowing date, season 2023

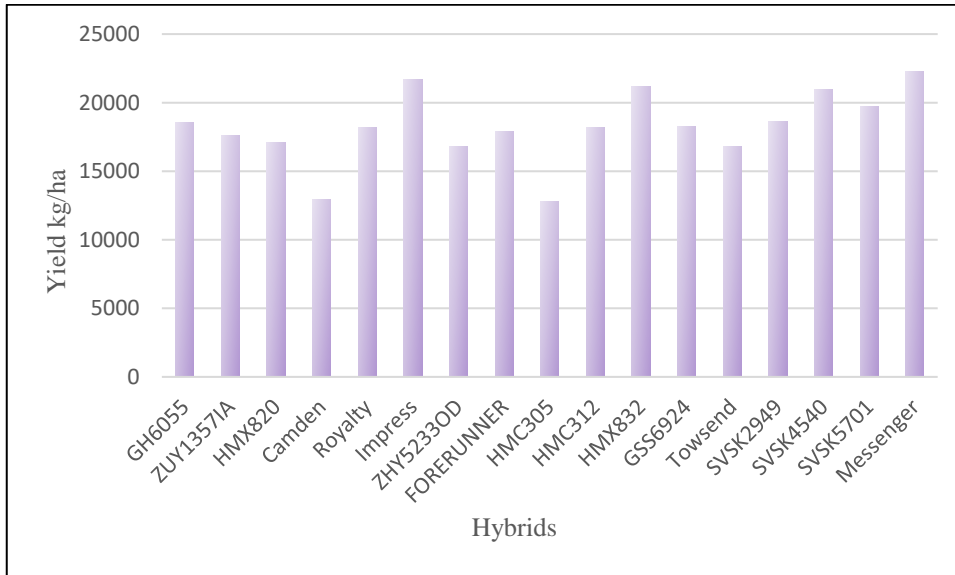


Figure 32 Evaluation of different sweet corn hybrids on yield kg/ha of the second sowing date, season 2023

5. CONCLUSION AND RECOMMENDATION

Sweet corn is a significant crop in Hungary, serving both domestic consumption and export markets. Hungary ranks among the largest producers and exporters of sweet corn in Europe, benefiting from favorable climate conditions, high-quality soils, and well-established agricultural practices.

The country actively participates in breeding programs focused on developing sweet corn varieties with improved resistance to diseases and environmental stresses such as drought and heat. These initiatives aim to sustain Hungary's competitive advantage in sweet corn production and export.

Variability between sweet corn hybrids plays a crucial role in cultivation, affecting yield, quality, and adaptability to diverse growing conditions. This variability is influenced by genetic, environmental, and market factors. Growers can select hybrids tailored to their specific requirements, considering yield potential, quality traits, adaptability, and disease resistance. A clear understanding of these differences is essential for optimizing production and maximizing profitability.

Proper nitrogen management is vital to achieving healthy, high-yield sweet corn crops. Following recommended nitrogen fertilizer application guidelines helps ensure effectiveness. Sweet corn yield can vary widely depending on variety, planting density, soil fertility, climate, and management practices. Plant density is a key factor for achieving profitable and quality crops; it should be adjusted according to local conditions, market demands, and variety-specific recommendations for optimal results.

Choosing the appropriate sowing date is critical to ensuring optimal germination, growth, and yield. Selecting the right timing helps avoid frost risks, promotes good germination, and allows the crop to mature within the growing season. Monitoring local conditions and following these guidelines enables growers to establish strong, productive sweet corn stands.

While high nitrogen fertilizer levels can encourage continuous plant growth, balancing nitrogen carefully is essential when the plant produces many cobs, to ensure vigorous growth and optimal cob development.

The nitrogen dose experiment on sweet maize confirmed the success of applying 100 kg N/ha. Higher doses of 150 and 200 kg N/ha negatively impacted yields, resulting in reductions during the 2022 season.

The Messenger hybrid is renowned for its high yield and prolific cob production, making it a top choice for maximizing harvest potential. This hybrid also produces a high number of leaves, supporting robust photosynthesis and overall plant health. Its high emergence rate ensures a strong, uniform stand, enhancing reliability and success in the field.

A balanced nitrogen (N) ratio significantly contributes to increased dry matter accumulation in sweet corn plants, improving overall biomass. This balance supports optimal growth conditions, resulting in thicker stems, more leaves, and well-developed cobs, ultimately leading to higher dry matter content at harvest.

Hybrids GSS6924, GSS5649, and Azlan are noted for early flowering, enabling quicker maturity and potentially earlier harvests. In contrast, the Royalty hybrid flowers later, extending the growth period, which may result in larger plants or other favorable traits linked to a longer growing season.

Applying a specific nitrogen ratio has produced high yields, with the hybrid Spirit particularly excelling under this regime, achieving impressive results during the 2023 season. Dry matter content in cobs was highest in sweet corn from the first sowing date, with similarly high values recorded for the second sowing, underscoring the benefits of early planting on cob development.

The first sowing date was identified as optimal, with the hybrid Azlan yielding significantly more than other hybrids planted simultaneously.

Among the varieties tested, the hybrid Spirit showed the highest yield potential and dry matter content in its cobs, indicating superior biomass accumulation compared to others.

A plant density of 60,000 plants per hectare was determined to be optimal, enhancing both vegetative growth and cob development to achieve maximum yield. The hybrid HMC305 achieved the highest yield among varieties in the first sowing date, outperforming others in production and efficiency. Meanwhile, Messenger demonstrated the highest yield when planted on the second sowing date, highlighting its adaptability to this schedule.

The highest cob weight recorded was 1,218 grams for sweet corn planted on the first sowing date, indicating robust growth and development. Conversely, the Royalty hybrid showed the highest dry matter content during the second sowing date, reflecting its efficiency in nutrient accumulation under optimal conditions.

6. NEW SCIENTIFIC RESULTS

The new scientific findings of this study include:

- 1.** Nitrogen fertilization was optimal at 100 kg N ha⁻¹, while higher rates (150–200 kg N ha⁻¹) reduced yield efficiency.
- 2.** A plant density of 60,000 plants ha⁻¹ ensured successful crop establishment and high yield performance.
- 3.** Early sowing enhanced crop development and yield, with HMC302, Messenger, Spirit, and Azlan showing superior performance and clear hybrid × sowing date interactions.
- 4.** Early flowering and adaptability were observed in GSS6924, GSS649, Azlan, Braveheart, and GSS3071, which reached tasselling and silking earlier and supported efficient cropping cycles, while Messenger demonstrated high adaptability under varying management conditions.

7. PRACTICAL UTILIZATION OF RESULTS

- 1.** Optimized agronomic practices should be applied, including early sowing (usually mid-April in Hungary) to extend the growing season, enhance crop development, and improve yield and harvest period.
- 2.** A planting density of 60,000 plants ha⁻¹ and 100 kg N ha⁻¹ of nitrogen fertilizer applied in split doses at planting and early growth stages ensures healthy growth, efficient nutrient use, and soil health.
- 3.** High-performing hybrids such as Messenger provide maximum yield and quality, while early flowering varieties like GSS6924, GSS649, and Azlan allow for early harvest, and Spirit and HMC305 increase overall productivity and maintain consistent quality.

8. SUMMARY

In Hungary, sweet corn is a significant crop with a well-established role in the agricultural economy, mainly for both fresh consumption and processing. Hungary is one of the leading sweet corn producers in Europe, benefiting from favorable growing conditions, skilled farming practices, and efficient processing facilities. The yield potential of sweet corn depends on factors such as genetics, plant density, soil fertility, climate, and management practices.

Sweet corn hybrids are specially bred varieties that offer advantages in yield, taste, disease resistance, and adaptability to different growing conditions. Modern hybrids are developed to produce sweet, tender kernels with high sugar content, making them popular for fresh consumption and processing. These hybrids vary in their growth characteristics, with some tailored for early-season planting, offering fast maturity, while others are designed for mid to late-season harvests for staggered production.

Nitrogen is essential for sweet corn's rapid growth and kernel development. Applications are typically split, with an initial dose before planting and additional applications during the growing season to support the high nitrogen demand, particularly during the vegetative and ear-filling stages. Insufficient nitrogen can lead to smaller plants and lower yields, while excess nitrogen can negatively impact kernel quality and environmental health. The optimal plant density for sweet corn generally falls between 60,000 and 75,000 plants per hectare, depending on the hybrid and field conditions. Higher densities can increase total yield per hectare but may reduce ear size and sugar content due to increased competition. Managing plant density is critical for achieving a balance between yield per area and individual ear quality. Early sowing in spring, once soil temperatures reach around 10°C, allows sweet corn to benefit from the full growing season, potentially increasing yield. However, very early planting in cool soils may delay germination. Sowing dates also influence pest and disease pressure, as well as harvest timing; for staggered harvests, multiple sowing dates can extend the marketable season.

Experiment on the Effects of Different Nitrogen Fertilizer Levels and Plant Densities on the Yield of Various Sweet Corn Hybrids

The experiment was conducted at the Látókép Plant Cultivation Research Center of the University of Debrecen during the 2022 growing season. A randomized complete block design with four replications was employed to evaluate the performance of four sweet corn hybrids. The study aimed to examine the effects of nitrogen fertilization and plant density on the yield and agronomic traits of these hybrids.

Results from the plant density trials indicated that optimal production for the tested hybrids was achieved at a lower plant density of 60,000 plants per hectare. Averaged across all hybrids, increasing plant density to 70,000 and 80,000 plants per hectare led to yield reductions of 1,923 kg/ha and 1,407 kg/ha, respectively, compared to the yield at 60,000 plants per hectare (17,519 kg/ha).

In the nitrogen fertilization experiments, application of 100 kg N/ha was found to be the most effective. Higher nitrogen levels, specifically 150 and 200 kg N/ha, had negative effects on yield, resulting in reductions of 461 kg/ha and 1,405 kg/ha, respectively.

During the 2023 growing season, analysis of variance (ANOVA) showed that nitrogen fertilizer levels had a highly significant effect ($p \leq 0.05$) on key phenological traits, including 50% and 100% silking, tasselling, and the six-leaf stage. In contrast, significant differences were observed for cob weight without leaves and emergence date, while no significant differences were found for traits such as grain yield, harvest density, dry weight, fresh weight, dry matter content, nitrogen use efficiency, emergence percentage, emergence per plant, number of kernels, number of rows, plant height, and yield per hectare.

The interaction between nitrogen fertilizer levels and sweet corn genotypes had highly significant effects on most evaluated traits, except for grain yield, harvest density, dry weight, fresh weight, dry matter content, nitrogen use efficiency, emergence per plant, number of seeds, yield per hectare, cob weight without husk, total cob weight, and emergence percentage. However, a significant interaction effect was observed specifically for emergence per plant.

Regarding the individual effect of genotypes, most traits did not show significant differences, except for emergence date, yield per kilogram, dry weight, dry matter content, and nitrogen use efficiency.

Experiment on the Effects of Different Sowing Dates on the Yield of Various Sweet Corn Hybrids

Sweet corn (*Zea mays* L. var. *saccharata* [Sturtev.] L.H. Bailey) is a type of maize whose morphological traits and cultivation practices largely resemble those of other maize varieties, with some distinct differences. Effective crop management is tailored to each cultivar, with particular emphasis on harvesting methods, plant establishment, population density, fertilization, irrigation, soil management, and pest and disease control.

The present study was conducted during the 2022 season at the Látókép Plant Cultivation Research Center, University of Debrecen. A randomized complete block design with four replications was used to evaluate the performance of four sweet corn hybrids under different sowing dates. Results indicated that the First sowing date provided the most favorable crop development and the highest overall yield. Among the hybrids, Messenger produced the highest yield at a specific sowing date, while GSS6924, being the earliest to tassel and silk, represents a valuable resource for future sweet corn breeding programs.

In the second season, combined analysis of variance revealed highly significant differences among sowing dates for most parameters, except for the six-leaf stage, dry matter content, and nitrogen use efficiency. The interaction between sowing dates and genotypes showed highly significant differences for most traits, with exceptions including the six-leaf stage, grain yield, fresh weight, number of seeds, harvest density, dry matter content, nitrogen use efficiency, yield per kilogram, cob weight, and cob weight without husk. Significant differences were observed for emergence percentage, emergence per plant, plant height, and number of rows. The highest yield in the second season was scored by Azlan (25.300kg/ha) in the first sowing date.

Regarding the individual effects of genotypes, highly significant differences were noted for most traits, except the six-leaf stage, fresh weight, number of rows, number of seeds, dry matter content, and dry weight. Significant differences were observed for grain yield, plant height, harvest density, emergence percentage, emergence per plant, yield per kilogram, cob weight, and cob weight without husk.

Experiment on Estimation of the yield potential of different sweet corn hybrids in the season 2023

The experiments were conducted at the Látókép Experimental Station of the University of Debrecen (47°83'30" N, 21°82'60" E, 111 m asl) during the 2023 growing season. The sweet maize trial was arranged in a randomized complete block design with four replications to evaluate the yield potential of five sweet corn hybrids.

Based on the results, hybrid Dessert 78 recorded the highest mean yield of 23,233.33 kg/ha, while hybrid Azlan had the lowest mean yield of 9,850 kg/ha. Regarding plant height, GSS6924 achieved the greatest mean height (277.75 cm), whereas Spirit had the smallest mean (205.55 cm). Emergence percentage was highest in Azlan and GSS6924 (86.31%), while Dessert 78 showed the lowest value (73.13%).

For dry matter content per cob, Spirit recorded the highest mean (38.55 g), whereas Impress and Dessert 78 had the lowest mean values (23.4 g).

Evaluation of 32 sweet corn hybrids on growth and yield components, season 2023

Based on the results, the Aset 32 hybrids revealed that the largest plant height was obtained by HMC305 (242)cm on the first sowing date, whereas the largest plant height was obtained by Impress (251) cm. However, the best hybrid of yield on the first sowing date was obtained by HMC302 (29300) kg/ha, therefore, the largest mean of yield on the second sowing date was attained by Messenger (22300)kg/ha. Furthermore, the results observed the highest value on dry matter /cob in the first sowing date scored by (1218) 31.54378 while in the second sowing date achieved by Royalty(34.99632) On the other hand, the results revealed that the larger mean on number/cob /plots recorded by SVSK4540(89) in second sowing date thus in first owing date obtained by HMC302 (114). Additionally, the highest value of the number of seeds /cob was obtained by ZHY5022OD (43.4) on the first sowing date, in contrast to the second sowing date observed by ZHY5233OD (43.7). Overall, the results between means showed the greatest hybrid on grain /yield registered by ZHY5022OD(2) on the first sowing date; however, in the second sowing, the biggest mean was registered by SVSK2949 (2.02). Moreover, the results showed between the comparison of means the highest value of length/ear was by ZHY5022OD (22.6) on the first sowing date while the larger value on the second sowing date was obtained by ZHY5233OD (23.15) ultimately the larger means on number/rows/cob in first sowing date achieved by 1446 (20.2) whereas in second sowing

date obtained by HMX832 and Messenger (19). The sowing date for sweet corn in Hungary typically depends on the climate and regional temperatures. In general, sweet corn is sown in Hungary from late April to mid-May, once the soil temperature reaches around 10-12°C (50-54°F), which is essential for good seed germination. Late spring is ideal as it avoids early spring frosts and allows for optimal growth as temperatures rise. For areas with warmer springs, earlier sowing may be possible, but it's important to ensure frost risk is minimal. Harvest typically occurs between July and September, depending on the sowing date and variety of corn planted.

Keywords: Nitrogen levels, plant density, sweet corn, yield potential, Sowing dates, Hybrids.

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10. Publication LIST



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Subject: PhD Publication List

Candidate: Hajer Mohamed Ibrahim Sidahmed
Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10099651

List of publications related to the dissertation

Hungarian scientific articles in Hungarian journals (3)

1. Bakos, Z., **Sidahmed, H. M. I.**, Nagy, J.: A Honey csemegekukorica (*Zea mays* L. convar. saccharata Koern) hibrid ásványianyag-, foszfor-, kálium-, magnézium-, cink- és vastartalmának elemzése.
Növénytermelés. 73 (1), 21-28, 2024. ISSN: 0546-8191.
2. Nagy, J., Demeter, C., Bakos, Z., Szabó, A., Sinka, L., **Sidahmed, H. M. I.**, Simon, K., Illés, Á.: A csemegekukorica (*Zea mays* conv. saccharata Koern) terméslemeinek elemzése öntözéses termesztésben.
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3. Nagy, J., Demeter, C., Bakos, Z., Simon, K., **Sidahmed, H. M. I.**: A csemegekukorica (*Zea mays* L. convar. saccharata Koern) hibridek betakarítási idejének értékelése a szárazanyag- és a szacharózzgyarapodásának dinamikája alapján = Harvest time evaluation of sweet maize (*Zea mays* L. convar. saccharata Koern) hybrids based on dry matter and sucrose yield dynamics.
Növénytermelés. 72 (1), 53-68, 2023. ISSN: 0546-8191.

Foreign language scientific articles in Hungarian journals (1)

4. **Sidahmed, H. M. I.**, Illés, Á., Almahy, A., Nagy, J.: Performance of agricultural factors on yield of sweet corn (*Zea mays* L. Saccharata) - A review.
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5. **Sidahmed, H. M. I.**, Vad, A., Nagy, J.: Advances in Sweet Corn (*Zea mays* L. saccharata) Research from 2010 to 2025: Genetics, Agronomy, and Sustainable Production
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6. **Sidahmed, H. M. I.**, Illés, Á., Vad, A., Nagy, J.: Effect of different sowing dates on yield of four hybrids of sweet corn (*Zea mays* L.) saccharates.
In: 21st Wellmann International Scientific Conference Book of abstracts / felelős kiadó Edit Mikó, szerk. Ingrid Melinda Gyalai, Szilárd Czóbel, University of Szeged Faculty of Agriculture, Hódmezővásárhely, 30, 2024. ISBN: 9789633069806
7. **Sidahmed, H. M. I.**, Illés, Á., Bojtor, C., Vad, A., Széles, A., Almahy, A., Nagy, J.: Estimation Of Yield Potential of Five Sweet Corn Hybrids (*Zea mays* L. Saccharates).
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8. **Sidahmed, H. M. I.**, Illés, Á., Vad, A., Nagy, J.: Effect of different nitrogen fertilizer and plant density on yield of four hybrids of sweet corn (*Zea mays* L. Saccharates).
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11. **Sidahmed, H. M. I.**, Nagy, J.: Effect of Agronomic Factors on yield of Sweet corn (*Zea mays* L.). A review.
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12. **Sidahmed, H. M. I.**, Ali, A., Alrasheed, R., Ocwa, A., Nagy, J.: Genetic variability of maize genotypes for growth, yield, and yield component.
In: Wellmann International Scientific Conference : Book of Abstracts. Ed.: Orsolya Kiss, University of Szeged, Hódmezővásárhely, 75, 2022. ISBN: 9789633068601





List of other publications

Foreign language Hungarian book chapters (1)

13. Ocwa, A., Acaye, F., Abakeer, R. A., Ahmed, A. E. M., **Sidahmed, H. M. I.**, Harsányi, E.:
Electrical conductivity and germinability of millet seeds from different accessions.
In: Conference Proceedings of the "Challenges of nowadays in the light of sustainability" 8th
VUA YOUTH scientific session. Ed.: Róbert Magda, Farheen Naz, Hungarian University of
Agriculture and Life Sciences, Gödöllő, 267-273, 2021. ISBN: 9789632699684

Foreign language scientific articles in international journals (2)

14. Mousavi, S. M. N., Illés, Á., Bojtor, C., Demeter, C., Bakos, Z., Vad, A., Abakeer, R. A.,
Sidahmed, H. M. I., Nagy, J.: Quantitative and qualitative yield in sweet maize hybrids.
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15. Demeter, C., Nagy, J., Bakos, Z., **Sidahmed, H. M. I.**, Széles, A.: Evaluation of the yield, mineral
and lutein content of sweet maize (zea mays. L. Convar saccharata koern).
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DOI: <http://dx.doi.org/10.31924/nrsd.v13i2.134>

Foreign language abstracts (3)

16. **Sidahmed, H. M. I.**, Vad, A., Széles, A., AlMahi, A., Ahmed, R., Elbokhary, S., Nagy, J.: Climate
Change and Sweet Corn Production: Risks, Adaptation Strategies, and Research Needs.
In: "Sustainable agriculture and environmental innovation for a greener future", International
Association for Innovation and Scientific Research, Kuala Lumpur, 37, 2025. ISBN:
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17. **Sidahmed, H. M. I.**, Illés, Á., Bojtor, C., Vad, A., Széles, A., Mohammed, M., Nagy, J.: Impact of
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Szeged Faculty of Agriculture, Hódmezővásárhely, 36, 2025. ISBN: 9789636880446





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18. **Sidahmed, H. M. I.**, ALmahi, A., Illés, Á., Saada., N. E. M., Nagy, J.: Effect of Biofertilizer on growth and Yield components of Lupine (*Lupinus Termis* L).
In: Plant science and agriculture Hybrid Event : Book of abstract, Magnus Group LLC, Valencia, 117, 2023.

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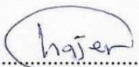
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11. DECLARATION

I prepared this dissertation within the framework of Kálmán Kerpely doctoral school of the University of Debrecen, in order to obtain a doctoral (PhD) degree from the University of Debrecen.

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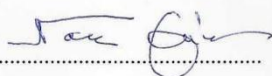

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DECLARATION

I certify that name; a doctoral candidate between (2021-2025) and within the framework of the above-mentioned doctoral school, has carried out his work under my guidance/direction. The independent contribution of the candidate to the results included in the dissertation, the dissertation is the independent work of the candidate. I suggest/recommend the acceptance of the dissertation.

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