FERTILIZER TYPES ON CORN YIELDS (*Zea mays* L.) IN KAMPAR PERAK

By

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ABSTRACT

FERTILIZER TYPES ON CORN YIELDS (*Zea mays* L.) IN KAMPAR PERAK

Wong Eu Jeff

The global population is increasing, and optimizing food production has become a crucial way to address this challenge. Sweet corn (*Zea mays* L.) is a staple crop because it is both nutritious and affordable. However, in Malaysia, sweet corn production has not been self-sufficiency due to a paucity of knowledge in fertilizer management. This study investigated the effects of NPK 12:12:17, calcium boron (Ca/B), and biostimulant on the yield and anthesis timing of different sweet corn varieties commonly grown in Kampar, Perak, Malaysia. A split-plot design was done in UTAR Agriculture Park B, with two varieties, which were King Corn F1 316 and Sweetcorn King Raja SC 9001, and five different treatments: control (no fertilizer), NPK 12:12:17, NPK 12:12:17 + Ca/B, NPK 12:12:17 + biostimulant, and NPK 12:12:17 + Ca/B + biostimulant. The corn variety of F1 316 performed statistically significantly better than SC 9001 for cob's fresh weight (g), cob length (cm), cob girth (cm), and the number of kernels per column. Both varieties showed statistically insignificant in 100-kernel weight (g). For fertilizer treatment, NPK 12:12:17

was statistically significant than control in producing a heavier 100-kernels weight (g). Moreover, a significant interaction effect was observed between variety and fertilizer type for 100-kernel weight (g), with the combination of variety F1 316 and NPK 12:12:17 yielding the heaviest kernels (g). These highlights the importance of distinguishing between apparent yield (whole cob) and actual yield (only kernels), suggesting that farmers should prioritize the corn varieties and types of fertilizer that may lead to a higher actual yield. NPK 12:12:17 can improve corn yield, while Ca/B supplementation is essential when deficiency is detected, and glycine-based biostimulants are beneficial when plants experience drought stress. Future studies should investigate how different fertilizer types affect the quality traits (i.e., shelf-life, physicochemical properties and nutrient content) of sweet corn.

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DECLARATION

I hereby declare that this final year project report is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

Wong Eu Jeff

APPROVAL SHEET

This final year project report entitled "FERTILIZER TYPES ON CORN YIELDS (*Zea mays* L.) IN KAMPAR PERAK" was prepared by WONG EU JEFF and submitted as partial fulfillment of the requirements for the degree of Bachelor of Science (Honours) Agricultural Science at Universiti Tunku Abdul Rahman.

Approved by

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Dr. Tong Pei Sin Date: 24 April 2025

Supervisor

Department of Agricultural and Food Science

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UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF SCIENCE

Date: 25 April 2025

SUBMISSION OF FINAL YEAR PROJECT

I, Wong Eu Jeff (ID No: 21ADB01807) herby certify that I have completed the final year project titled "FERTILIZER TYPES ON CORN YIELDS (*Zea mays* L.) IN KAMPAR PERAK" under the supervision of Dr. Tong Pei Sin from the department of Agricultural and Food Science, Faculty of Science.

I understand that the University may upload the softcopy of my final year project in PDF to the UTAR Institutional Repository, which may be made accessible to the UTAR community and public.

Your truly,

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(Wong Eu Jeff)

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ATP	Adenosine triphosphate
B	Boron
Ca	Calcium
Ca/B	Calcium boron
CEC	Cation exchange capacity
cm	Centimeter
cmol/kg	Centimoles per kilogram
Cu	Copper
Co	Control
EC	Electrical conductivity
et al.	et alia
g	Gram
G:S	Grain-to-stover ratio
HI	Harvest Index
K	Potassium
kg/ha	Kilogram per hectare
N	Nitrogen

P	Phosphorus
ppm	Part per million
ROS	Reactive oxygen species
SPSS	Statistical Package for the Social Sciences
US	United States
USDA	United States Department of Agriculture
µS/cm	MicroSiemens per centimeter

CHAPTER 1

INTRODUCTION

1.1 Introduction

Corn can be categorized into grain corn and sweet corn. Grain corn is mainly used to produce livestock feeds while sweet corn is usually for human consumption (Nik Syafiah Anis Nik Sharifulden, 2023). Human population in 2100 is projected to be 10.4 billion, which is 20% increase from the current population (Penuelas, Coello and Sardans, 2023). The surging of human population will increase world's food consumption. In simpler terms, food supply will need to be improved in achieving food security. Corn has become a staple food to support the food supply as it is a good source of energy at the same time it is nutritious, inexpensive, and relatively easy to grow (Fathima, Nallamuthu and Khanum, 2017). Annually, the average sweet corn consumption per capita across the world is 18.5 kg per year (Erenstein, et al., 2022). To support the 10.4 billion people, 192 billion kg of corn per year will be needed.

In Malaysia, sweet corn is more widely cultivated than grain corn. This is because compared to grain corn, sweet corn has a shorter maturity period (around 70 days) and higher profitability (Nik Syafiah Anis Nik Sharifulden, 2023). Additionally, sweet corn can be planted for 3 cycles in a year as compared to grain corn only 2 planting cycles in a year, and sweet corn does not require any drying process (Nik Syafiah Anis Nik Sharifulden, 2023). The annual average sweet corn production in Malaysia is 64,000 Metric tons (Mt) (Nik Syafiah Anis Nik Sharifulden, 2023). Among the states, Johor produces the highest production of sweet corn which accounts for 26% of Malaysia's total production while Perak is the fourth largest in production of corn which accounts for 11% of the total corn production (USDA, 2025). However, the annual consumption of sweet corn in Malaysia is 360,000 Mt and Malaysia is yet to be self-sufficient in the production of sweet corn (Nik Syafiah Anis Nik Sharifulden, 2023). To support the domestic demand, Malaysia imports sweet corn from other countries, whereby China, India, and Indonesia accounting for more than a quarter of the total importation around the world (WorldBank, 2023).

The Ministry of Agriculture and Food Security (MAFI) has developed the Grain Corn Industry Development Plan to achieve Malaysia's self-sufficiency in grain corn by attracting more farmers to plant grain corn (Mohamad Hifzan Rosali, et al., 2019; Nik Syafiah Anis Nik Sharifulden, 2023). However, there is no policy like the Grain Corn Industry Development Plan to improve the current situation for sweet corn. Research has also shown that there is still a lack of understanding of optimum fertilizer application for crop production in Malaysia including sweet corn (Gill, Singh and Ahmed, 2022; Penuelas, Coello and Sardans, 2023).

Therefore, it is important to understand fertilizer management to improve the yield of sweet corn in Malaysia, especially in the Perak area.

Fertilizer management consists of four aspects which are rate, timing, placement, and type (Hochmuth, Mylavarapu and Hanlon, 2014). With optimum fertilizer management, potential yields of a single crop could be maximized. An ideal type or source of fertilizer can be defined as the suitable fertilizer used that could deliver nutrients that are needed to the plants (Hochmuth, Mylavarapu and Hanlon, 2014). With a suitable source of fertilizer, crop yields can be increased, with production cost being brought down as the nutrient used has increased (Hochmuth, Mylavarapu and Hanlon, 2014).

After the Green Revolution, chemical fertilizer has become a source of nutrients for the plants. The use of chemical fertilizers could be reduced through fertilizer management while total elimination is not possible. An equal ratio fertilizer NPK 15:15:15 has proven to increase the vegetative growth of the plants while NPK 12:12:17 flowering fertilizer can induce the flowering of the plants (Kautsar, Rambe and Suryanti, 2022; Nwokwu, 2020). In the past decade, the usage of biostimulants and micronutrients have also started to gain more attention among the farmers. Biostimulants are found to improve nutrient use efficiency and stress tolerance of the plant, and the quality of crops in various plants (Landeta and Marchant, 2022). Micronutrients like calcium are found to improve the drought stress resilience of the plants (Akhtar, et al., 2022). Boron is found to react with other nutrients in the plant which can improve the yield of the crop (Long and Peng, 2023). However, NPK 12:12:17, biostimulants, calcium, and boron are not well studied in relating to corn yields, especially in the tropical regions.

1.2 Problem statement

Over the years, sweet corn production has accounted for the largest portion of total corn production in Malaysia (Sharifulden, 2023). Although sweet corn production makes up the largest portion, Malaysia has yet to become self-sufficient in sweet corn (Sharifulden, 2023). One of the reasons that causes the low domestic production of sweet corn is the lack of understanding of the optimum fertilizer application for corn production (Gill, Singh and Ahmed, 2022; Penuelas, Coello and Sardans, 2023). Despite the importance of sweet corn production, the government prioritizes grain corn production (Sharifulden, 2023). The Ministry of Agriculture and Food Security (MAFS) developed Grain Corn Industry Development Plan to support the production of grain corn, but no policies were proposed (Sharifulden, 2023). Thus, this research aimed to improve the yield of corn in Malaysia through fertilizer management.

Several studies on corn showed that different rates of fertilizer could significantly affect the yield and optimize the growth of corn across the world (Guo, Liu and He, 2022; Nkebiwe, et al., 2016; Onasanya, et al., 2009). This shows the importance of having a better understanding of fertilizer management to improve the yield of corn, at the same time minimize the cost of production which eventually increases the productivity of the corn.

Besides different rates of fertilizer, the different types of fertilizer are taken into consideration by the farmers. The research on different fertilizer ratios, macro and micro-nutrients and biostimulants on affecting the yield of various type of crops were flourished in the 2000s (Long and Peng, 2023; Jardin, 2015). Research showed that NPK 12:12:17 and Ca/B can positively increased the yield of *Abelmoschus esculentus* (okra) and *Fragaria ananassa* (strawberries), respectively (Jallow, Sey and Manneh, 2021; Wójcik and Lewandowski, 2003). However, none of the research was done on these fertilizer types affecting the yield of corn. Thus, studies were conducted on the effect of NPK 12:12:17, Ca/B and biostimulant on the yield of the corn.

1.3 Objectives:

The objectives of this study are:

1. To examine the effects of NPK 12:12:17, biostimulant, and Ca/B on the corn yields.

2. To study the effects of NPK 12:12:17, biostimulant, and Ca/B on the duration from germination to anthesis formation.

CHAPTER 2

LITERATURE REVIEW

2.1 Fertilizer management

Fertilizer management, also known as nutrient management, is defined as the optimal use of fertilizer, prioritizing the efficacy of nutrient absorption by the plants while minimizing environmental impacts and maintaining productivity (Reddy, 2017). It can be categorized into four aspects which are rate, timing, placement, and type (Hochmuth, Mylavarapu and Hanlon, 2014). Rate is the amount of fertilizer being applied to the plant. A meta-analysis showed that different crops required different rates of fertilizer to maximize the growth and yield (Guo, Liu and He, 2022). For example, the suitable N fertilization rate for wheat is 189 kg/ha, for corn is 150 kg/ha, and for rice is 130 kg/ha. Timing is the application of fertilizer at different growth stages (vegetative stage and reproductive stage) of the plant. Research showed that the application of fertilizer at different growth stages improved the corn yields (Davies, Coulter and Pagliari, 2020). Split application treatment improved the yield of corn by up to 30% compared to pre-planting application (Davies, Coulter and Pagliari, 2020).

Placement is the application of fertilizer, which improves the accessibility of the fertilizer to the plant and maximizes nutrient efficiency (Hochmuth, Mylavarapu and Hanlon, 2014). The different fertilizer placement methods include seed placement, surface band, shallow subsurface, and deep subsurface (Nkebiwe, et al., 2016). Study showed that the optimum fertilizer placement improved the yield of the plant up to 3.7% and improved the nutrient content in the plant by 3.7% (Nkebiwe, et al., 2016).

Fertilizer types are the variations of fertilizer that can be applied to the plant, which could maximize the growth of the plant (Hochmuth, Mylavarapu and Hanlon, 2014). Research showed that different crops required different types of fertilizer, and the application of a suitable fertilizer type increased the yield of the crop up to 119.7% (Lu, 2019). Different fertilizer types can be further categorized into organic or synthetic, compositions, and ratios (Hasnain, et al., 2020; Nadarajan and Sukumaran, 2021; OECA, 2018).

2.2 Different Fertilizer Composition (N, P, K, Ca, B) on the growth and yield of the crop

In terms of different compositions of the fertilizer, nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) are considered micronutrients while boron (B) is a micronutrient for plants. N plays an important role in the plant metabolism system as it is a building block of amino acid and chlorophyll in plants (Shah Jahan Leghari, et al., 2016). N also stimulates the shoot and the growth of leaves (Shah Jahan Leghari, et al., 2016). Phosphorus is also considered a macronutrient as it is involved in the metabolic response in plants because it makes up the structural skeleton of ATP, NADPH, nucleic acids, and other secondary metabolites (Bechtaoui, et al., 2021). Sufficient phosphorus in plants can improve the root development of the plant (Bechtaoui, et al., 2021). K serves as an activator in various types of enzymes such as protein synthesis, sugar transportation and photosynthesis (Xu, et al., 2020).

K is involved in the reproductive development of the crop, for example, the anthesis of the plants (Oosterhuis, et al., 2014). Ca is important in plants as it is used for cell division and controls enzyme activities (Quiles, et al., 2004). Besides, it stabilizes the cell wall structure by forming calcium pectinate, which is found in the middle lamella of cell walls (Quiles et al., 2004). For micronutrient, B is involved in stabilizing the structure of cell walls in plants (Long and Peng, 2023). Research showed that the application of B can stabilize the cell wall of the strawberries, making the plant more resilient and reducing the chances of infection by *Botrytis* (Wójcik and Lewandowski, 2003).

2.2.1 Interaction between elements N, P and K in fertilizer

Individual effects of these fertilizers, elements N, P, and K, also show interaction effects between each other. Research showed that N, P, and K have some antagonistic relationships; if K is not applied together with N and P, there will be a severe yield loss (Li, et al., 2019). Study showed that N and P have a negative interaction effect on fruit yields (Choi, et al., 2012). When P is high, it may lead to an increase in absorption of N in the leaves, which reduces carbon assimilation in fruit and reduces the fruit yields (Choi et al., 2012). On the other hand, N and K showed a positive interaction effect towards the growth of the plant (Li, et al., 2019). This is because nitrate ions serve as companion anions during the uptake and transportation of K ions (Zhang, et al., 2010). P and K also showed an interaction effect in affecting the fruit quality (Li, et al., 2019). However, the excess of one of these elements will affect the reduction of absorption of another element, which causes the yield loss in the plant (Li, et al., 2019). With the concept of interaction effects between different compositions of fertilizer, the ratios of NPK become important in the context of fertilizer management to maximize the efficacy of the fertilizers.

2.2.2 NPK fertilizer ratios on affecting the yield and anthesis of crops

In terms of different ratios of fertilizer, the effect of a balanced fertilizer (NPK 15:15:15) can vary compared to the flowering fertilizer (NPK 12:12:17) in growth and reproductive stages, respectively (Akinrinola and Babajide, 2023; Nwokwu, 2020). Different fertilizer ratios are suggested for different types of crops and these ratios can affect the growth and yields of different plants (Deng and Li, 2022). NPK 15:15:15 improved the vegetative growth and the yield of *Abelmoschus esculentus* (okra) but it did not affect the anthesis formation of the okra (Jallow, Sey and Manneh, 2021). NPK 15:15:15 improved the yield of okra by contributing to a better partitioning of photosynthetic materials (Jallow, Sey and Manneh, 2021). NPK 15:15:15 also improved the growth of the tuber of *Dioscorea rotundata* (yam) and improved the yield of the yam to 15,125 kg/ha (Akinrinola and Babajide, 2023). On the other hand, NPK 12:12:17 was shown to shorten the days to anthesis in *Vigna unguiculata* (cowpea) (Nwokwu, 2020). With the reduction in days of anthesis, the yields of the cowpea were increased (Nwokwu, 2020).

2.2.3 Interactions between element Ca and B on the growth of crop

The interactions between Ca/B and NPK are not well studied, and further investigation should be done (Vera-Maldonado, et al., 2024). However, there are interactions observed between Ca and B. Ca/B had an antagonistic effect, where when the Ca concentration in the soil increases, the B absorption of the plant will be reduced (Long and Peng, 2023). This is because B and Ca will form calcium borate complexes in the soil, which could reduce the availability of the B (Long and Peng, 2023). Besides, Ca and B also show another interaction effect in plants. In the cell wall, B and Ca were observed to form cross-linking of the pectin polysaccharide (Vera-Maldonado, et al., 2024). Ca can stabilize the B that binds to the carboxyl group of the polygalacturonase acid region (Liu, et al., 2019).

2.3 Biostimulant and its effects on the growth of the crop

Biostimulant refers to any substance or microorganism applied to plants to enhance nutrition efficiency, abiotic stress tolerance, and crop quality traits, in the absence of nutrient contents (Jardin, 2015). Plant biostimulants can be categorized as products containing humic and fulvic acid, amino acids and peptides mixtures, seaweed extracts, and botanicals (i.e., substances extracted from plants in the form of chemical elements needed by plants but not essential or beneficial microbes). Research showed that amino acid-based biostimulants could increase corn yield, and with the presence of amino acids, the rate of N fertilizer can be reduced (Halpern, et al., 2015). The amino acids are mainly derived from the extraction of animal epithelial tissue, alfalfa protein hydrolysate and meat flour (Halpern, et al., 2015). The absorption of the amino acid-based biostimulants can be through roots or the leaves (Halpern, et al., 2015).

Amino acid-based biostimulants have several functions. Firstly, they improved the nutrient uptake of plants (Halpern, et al., 2015). Research showed that they can improve the nutrient uptake efficacy of N, and with the presence of an amino acid-based biostimulants, the N fertilization rate can be reduced by half (Maini, 2006). Secondly, amino acid-based biostimulants improved the soil microbial activities as these amino acids serve as the food source of microbes in the soil (Halpern, et al., 2015). In addition, amino acids like cysteine were found to be the chelating agent for Cu in the maize (Halpern, et al., 2015). Moreover, amino acid-based biostimulants also improved the stress tolerance of the crop (Ashraf and Foolad, 2007). Glycine and proline can improve environmental stress tolerance such as drought, salinity, extreme temperature (above 40°C for 3 consecutive days), UV radiation, and heavy metals (Ashraf and Foolad, 2007). Other than that, amino acid-based biostimulants also improved the translocation of the micronutrients, stimulation for root growth and NO_3 assimilation enzymes in plants (Halpern, et al., 2015).

2.4 Existing fertilizer study on affecting the yield and anthesis timing of corn

Different countries may have their studies on the effect of fertilizer on affecting the yield and anthesis timing of the corn. Therefore, the status of different countries' studies and research was subcategorized into temperate, subtropical and tropical countries.

2.4.1 Temperate countries

In temperate countries, research is far more advanced compared to tropical countries. Research started to focus on the fertilizer types that are in trend in recent years, such as biostimulants and Ca/B. A study showed that amino acid-based biostimulants increased the grain yield of corn up to 6.21%, and the recommended dosage was 3.5 L/ha (Francis, Earnest and Bryant, 2016). However, the results were inconsistent and varied between locations in the US (Francis, Earnest and Bryant, 2016). The inconsistent effect of biostimulants could be due to interactions between the biostimulants with the environmental factors such as climate, disease pressure, cultivar, and other variables (Francis, Earnest and Bryant, 2016). Another research in Poland showed that the application of biostimulants can improve 1000 kernels weight and kernel yield by 5.08% and 8.78%, respectively (Kapela, et al., 2020). Additionally, research in Pakistan showed that the application of B with 12 kg/ha significantly improved the cob diameter, cob length, number of kernels per row, number of kernels per column, and 1000 kernels weight of the corn (Adnan, 2020). However, no research was done on how biostimulants and Ca/B can affect the timing of anthesis formation of the corn in the tropical countries.

2.4.2 Subtropical regions

In the subtropical countries, research is also a step forward compared to the tropical countries, where the research mainly covered biostimulants and Ca/B. Research in Iraq showed that prolin, a type of amino acid-based biostimulant, can improve the grain yield of corn by 7.38% and the 1000 kernels weight by 9.57% (Al-Janabi, Abood and Hamdan, 2021). Another research in Iraq observed that the application of B together with P improved the grain yield of the crop by 8.39% (Salimi, et al., 2013). For Ca, it was observed to have a better effect on improving the yield of corn under drought conditions compared to normal conditions in Egypt (Abbas, Abdel-Lattif and Shahba, 2021). The increment of yield was at 20% under drought conditions compared to the normal condition (Abbas, Abdel-Lattif and Shahba, 2021). Unfortunately, no research was done on how biostimulants and Ca/B can affect the timing of anthesis formation of the corn.

2.4.3 Tropical countries

In the tropical countries, most of the research were still focusing on the rate of fertilizer and the interaction between the elements N, P, and K on the corn yields. The recommended dosage of N and P was 120 kg/ha and 40 kg/ha, respectively (Onasanya, et al., 2009). Studies in Africa showed that N affected the yield of corn the most, followed by P and K (Balemi, et al., 2019). The effect of K and micronutrient influenced by location, soil properties and weather as these environmental factors could affect the availability of these nutrients (Balemi, et al., 2019). Additionally, studies reported that B did not significantly affect the grain yield of the corn in Brazil (Nogueira, et al., 2019). There has been little research on the effect of different fertilizer types on the yields of corn in tropical countries. Moreover, no research was done on how biostimulants could affect the yield and the anthesis timing of corn. In short, research is lagging behind compared to the tropical and subtropical countries.

CHAPTER 3

METHODOLOGY

3.1 Site description

The study area was located at UTAR Agricultural Park B, Kampar, with the coordinates 4°20'34.9"N 101°08'27.3"E. The experiment was carried out from October 2024 to January 2025 which was during the rainy season. The total plot size was 10 m × 10 m, and the soil series were considered mixed tailing soil (GeoTanih, 2017). Table 3.1 showed the result of different parameters from the soil analysis. According to DOA (2024), the soil of the experimental site was considered less fertile soil with a soil pH of 6.25, cation exchange capacity (CEC) of 1.97 cmol/kg, and electrical conductivity (EC) of 8.80 µs/cm. Besides, the nitrogen content (N) in the soil was 0.03%, phosphorus content (P) was 6.97 ppm and the potassium content (K) was 0.03 cmol/kg.

Table 3.1. Results and interpretations of the soil analysis (DOA, 2024)

Parameters	Result (depth from 0-25 cm)	Interpretation	Optimum range
pH	6.25	Slightly high	5.50 – 6.50
Cation exchange capacity, CEC (cmol/kg)	1.97	Very Low	15 – 20
Electrical conductivity, EC (µS/cm)	8.80	Very Low	151 – 500
Total N (%)	0.03	Very Low	0.23 – 0.34
P (ppm)	6.97	Low	16 – 25
K (cmol/kg)	0.03	Very Low	0.45 – 0.80
Ca (cmol/kg)	1.15	Moderate	1.0 – 2.5
Mg (cmol/kg)	0.09	Very low	1.0 – 3.0
Organic matter (%)	0.75	Very low	>4

3.2 Corn seeds and fertilizers

Two corn varieties used in this research were the Sweetcorn King Raja SC 9001 seeds from CropPower, Malaysia and F1 316 King Corn from Agroniche, Malaysia (Table 3.1). Both seeds were chosen because they were widely planted in the Kampar Area. The fertilizers and biostimulant were from Yara and Syngenta, respectively.

Table 3.2. Sources of corn seeds, fertilizers and biostimulant.

Materials	Brand	Company	Country of manufacturing
Corn seeds	Sweetcorn King Raja SC 9001 seeds	CropPower, Malaysia	Malaysia
	F1 316 King Corn	Agroniche, Malaysia	Malaysia
NPK 15-15-15	YaraMila 15-15-15	Yara, Norway	Norway
NPK 12-12-17	YaraMila 12-12-17	Yara, Norway	Norway
Calcium boron fertilizer	YaraLiva NITRABOR	Yara, Norway	Norway
Amino acid-based biostimulant	Isabion	Syngenta, Switzerland	China

3.3 Land preparation and seed germination

A 10 m × 8 m area was first measured, and the border was plotted out. The land was then tilled, and herbicides were sprayed. A total of 12 rows of soil beds were prepared which were arranged into two sets of 6 rows side by side. The inter-row and intra-row spacing were 75 cm (Al-Kaisi and Yin, 2003; Gagnon, Ziadi and Grant, 2012; Widdicombe and Thelen, 2002). After the spraying of herbicides, the land was left untouched for 1 week to allow the herbicide residual periods to dissipate (Figure 3.1). In parallel to waiting for the land, the seeds were germinated in the seeding tray (Figure 3.2). Two corn varieties which were F1 316 King Corn and Sweetcorn King Raja SC 9001 were germinated on 12 November 2024. The seeds were kept moist during the germination period, where a sprayer was used to moisten the soil. The soil was considered moist when it reached full saturation, where water starts to drain out from the holes at the bottom of the germination tray. Once the seeds started to germinate, the seedling tray was moved to an area with direct sunlight. The seedlings were transplanted to the experimental site on 22 November 2024 which was 10 days after germination.

Figure 3.1. Experimental site after tillage and spraying of herbicide on 15 November 2024.

Figure 3.2. Seeds germination on 12 November 2024.

3.4 Experimental design

A split-plot layout was designed with corn varieties as the main plot and fertilizer types as the subplots. A total of six replicates were done, and the split-plot layout was randomized using statistical analysis software, JMP Pro. Two corn varieties were used in this experiment, and five different treatments were carried out (Table 3.3). The five different treatments included control (Co), T1 (N) with NPK 12:12:17, T2 (NCaB) with NPK 12:12:17 + Ca/B, T3 (NIs) with NPK 12:12:17 + Isabion and T4 (NCaBIs) with NPK 12:12:17 + Ca/B and Isabion. The treatments began on the 35th day after transplanting which was on 27 December 2025.

Table 3.3. Five treatments in this study.

Treatment	Details
Control (Co)	-
T1 (N)	NPK 12:12:17
T2 (NCaB)	NPK 12:12:17 + CaB
T3 (NIs)	NPK 12:12:17 + Isabion
T4 (NCaBIs)	NPK 12:12:17 + CaB + Isabion

All the seedlings were transplanted to the soil bed in the experimental site according to the split-plot layout (Figure 3.3). A total of 2 seedlings were transplanted to each hole, and the distance between each hole was 30 cm (DOA, 2008). This made up 5 different holes in each soil bed and the total number of corn plants for the 12 soil beds was 120. The corn plants were irrigated when necessary; otherwise they relied on the water from precipitation. The first fertilization of the plants were done with NPK 15:15:15 on the 20th day (12 December 2024) after transplantation.

V1	V1	V1	V2	V2	V1
Control	T2	T4	Control	T3	T4
T2	T4	T1	T2	T2	T1
T4	Control	Control	T1	T4	Control
T1	T1	T2	T3	Control	T2
T3	T3	T3	T4	T1	T3

V2	V2	V1	V2	V2	V1
T2	Control	T2	Control	T1	T2
T4	T4	T4	T4	T2	T4
Control	T1	Control	T1	T3	T1
T3	T3	T3	T2	T4	Control
T1	T2	T1	T3	Control	T3

Figure 3.3. The split-plot layout of this experiment. V1 indicated F1 316 while V2 indicated SC 9001.

On the 35th day after transplanting, the tassel of the corn started to form, and the treatments for the experiment began. The fertilization rate and timing were shown in Table 3.4. For NPK 12:12:17 and Ca/B, 8 g and 2 g were applied to each plant, respectively. Side banding placement method was used. Isabion at 0.05 ml was applied to each plant as a foliar application. For the application timings, all the fertilizers were applied thrice where first application was on the 35th day (27 December 2025), second application was on the 46th day (7 January 2025), and third application was on the 58th day (19 January 2025) after transplantation.

In terms of pest management, pesticides were applied in a 14-day interval together with hand weeding after transplantation. For the first round of application, Alika and Miravis from Syngenta were used with a dosage of 1.0 ml/L and 0.5 ml/L, respectively. For the second round of application, Proclaim and Miravis from Syngenta were used with a dosage of 1.0 ml/L and 0.5 ml/L, respectively. For the third application, Voliam Flexi and Armistatop from Syngenta were used with a dosage of 0.5 ml/L and 1.0 ml/L, respectively.

Table 3.4. Application rates and timing of different fertilizers.

Fertilizer types	Rates	Application timings
NPK 12:12:17	8 g/plant	1 – 35th day 2 – Around anthesis formation (46th day) 3 – 58th day
CaB	2 g/plant	
Isabion	0.05 ml/plant	

3.5 Parameters measured in this study

All the corn was harvested on the 70th day (31 January 2025), and data were collected, which included the cob length (cm), cob girth (cm), number of rows of kernels, number of kernels in each row, percentage of fertilization, 100 kernels weight (g) and duration from germination to anthesis formation (days) (Table 3.5). After the collection of data, statistical analyses were conducted using Statistical Package for Social Sciences, SPSS. All the parameters were tested for normality using Shapiro-Wilk test. For the data that showed normality, two-way ANOVA was used to test for significance, while data that did not show normality, Friedman test and Wilcoxon signed rank test were used.

Table 3.5. The parameters of the data that were collected in this research.

Parameters	**Descriptions**
Duration from germination to anthesis formation	Duration from the sowing of the seed to the formation of silk and tassel
Cob length (cm)	Length was measured from the base to the tip of the cob
Cob girth (cm)	Girth was measured from the center of the cob
Number of kernels per row	Number of kernels in each row
Number of kernels per column	Number of kernels in each column
Fresh weight of corn (g)	Weight of corn harvest
100 kernels weight (g)	Average weight of all kernels harvested multiply by 100

CHAPTER 4

RESULTS

4.1 Statistical analysis

4.1.1 Normality test

Table 4.1 showed the result of normality test and the assumption of normality were tested using Shapiro-Wilk test. The data collected that were normally distributed included cob length (W* = 0.986, p = 0.236), cob girth (W* = 0.983, p = 0.126) and 100 kernels weight (W* = 0.992, p = 0.706). The data that did not have normality were fresh weight (W* = 0.977, $p < 0.05$) fertilization percentage (W* = 0.697, $p < 0.05$), number of kernels per row (W* = 0.918, $p < 0.05$), number of kernels per column (W* = 0.941, $p < 0.05$), and the duration from germination to anthesis formation (W* = 0.842, $p < 0.05$).

Table 4.1. Shapiro-Wilk test results for normality assessment.

Parameters	Shapiro-Wilk test	
	W*	*p*-value
Fresh weight (g)	0.977	0.041
Cob length (cm)	0.986	0.236
Cob girth (cm)	0.983	0.126
Fertilization percentage (%)	0.697	0.000
Number of kernels per row	0.918	0.000
Number of kernels per column	0.941	0.000
100 kernels weight (g)	0.992	0.706
The duration from germination to anthesis formation (days)	0.842	0.000

4.1.2 Two-way ANOVA

For data that were normally distributed which are cob length (cm), cob girth (cm) and 100 kernels weight (g), two-way ANOVA were used to analyse for statistically significant data. Table 4.2 showed the p-value for cob length (cm), cob girth (cm), and 100 kernels weight (g). When $p < 0.05$, it showed that there were statistically significant difference between the groups of the variable.

In terms of cob length (cm) and cob girth (cm), there were statistically significant difference in corn varieties but there was no statistically significant difference between fertilizer types, respectively ($p < 0.05$). The 100 kernels weight (g) showed statistically significant difference between fertilizer types but did not show statistically significant difference in corn variety ($p < 0.05$). On the other hand, the interaction effect between corn variety and fertilizer types were not statistically significant in cob length (cm) and cob girth (cm) but were statistically significant in 100 kernels weight (g) ($p < 0.05$).

Table 4.2. The *p*-value of cob length (cm), cob girth (cm), and 100 kernels weight (g) using two-way ANOVA.

	p-value		
Source of variation	Cob length (cm)	Cob girth (cm)	100 Kernels weight (g)
Corn varieties	0.004	0.003	0.754
Fertilizer types	0.138	0.775	0.012
Fertilizer × variety	0.931	0.339	0.003

4.1.3 Friedmann's test and Wilcoxon signed rank test

The Friedman test was used for data that were not normally distributed and have more than three groups in the variables. For example, the effect of fertilizer types on fresh weight (g), percentage of fertilization (%), number of kernels per row, number of kernels per column, and duration from germination to anthesis formation (days). On the other hand, data that are not normally distributed and have less than three groups in the variables Wilcoxon signed rank test are used. For example, the effect of corn varieties on fresh weight (g), percentage of fertilization (%), number of kernels per row, number of kernels per column, and duration from germination to anthesis formation (days). Table 4.3 showed the p-value for fresh weight (g), percentage of fertilization (%), number of kernels per row, number of kernels per column, and duration from germination to anthesis formation (days). When $p < 0.05$, it showed that there were statistical significant differences between the groups of the variable.

For the fresh weight (g), fertilization percentage (%), number of kernels per column, number of kernels per row, and anthesis timing (days) no interaction effect was analysed as the data are not normally distributed. Fresh weight (g) and number of kernels per column both showed statistically significant differences between corn varieties, but did not show statistically significant differences between fertilizer types, respectively ($p < 0.05$). On the other hand, fertilization percentage (%) and number of kernels per row did not show statistically significant differences between corn variety and fertilizer types ($p < 0.05$). Duration from germination to anthesis formation (days) showed statistically significant differences in both corn variety and fertilizer types ($p < 0.05$).

Table 4.3. The *p*-value of the fresh weight (g), fertilization percentage (%), number of kernels per row, number of kernels per column, and duration from germination to anthesis formation (days) using Friedman test and Wilcoxon signed rank test.

	p-value				
Source of variation	Fresh weight (g)	Fertilization percentage (%)	Number of kernels per row	Number of kernels per column	Duration from germination to anthesis formation (days)
Corn varieties	0.005	0.116	0.250	0.003	0.000
Fertilizer types	0.161	0.840	0.659	0.835	0.029

4.2 Fresh Weight, cob Length, and cob Girth

The mean differences in corn fresh weight (g), cob length (cm), and cob girth (cm) of two different varieties of corn, F1 316 and SC 9001 were shown in Figures 4.1, 4.2, and 4.3. Compared to variety SC 9001, variety F1 316 showed statistically significant increase in fresh weight (g), cob length (cm), and cob girth (cm) ($p < 0.05$). The mean values of fresh weight (g), cob length (cm), and cob girth (cm) of variety F1 316 were 420.64 ± 8.82 g, 19.9 ± 0.20 cm, and 15.8 ± 0.13 cm, respectively, while for variety SC 9001 were 387.26 ± 8.82 g, 19.0

± 0.20 cm, and 15.2 ± 0.13 cm, respectively. F1 316 had an increase of 8.62%, 4.47%, and 3.79% in terms of fresh weight (g), cob length (cm), and cob girth (cm), respectively by comparing to SC 9001.

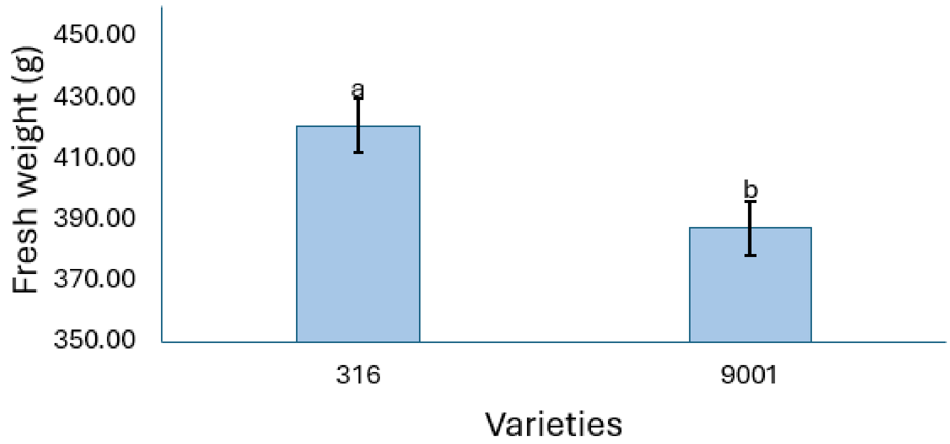

Figure 4.1. Mean differences in corn fresh weight (g) of different corn varieties. Different letters indicate statistically significant differences between groups at $p < 0.05$.

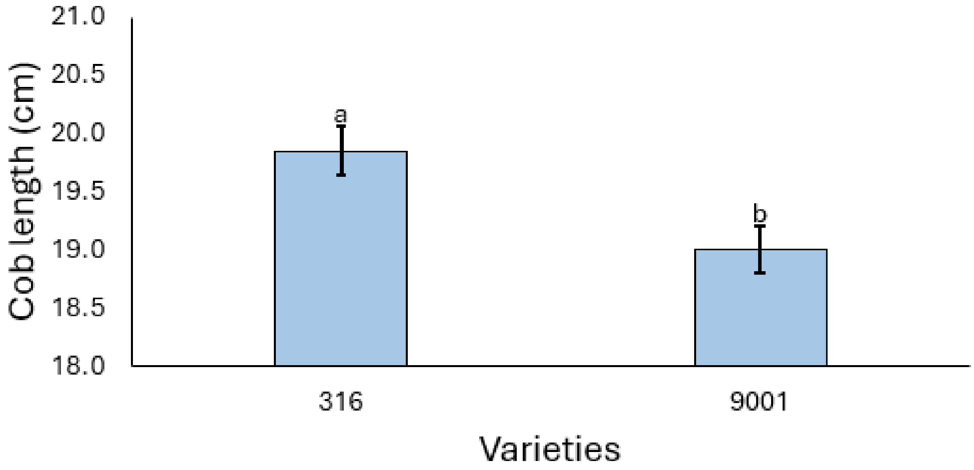

Figure 4.2. Mean differences in corn cob length (cm) of different corn varieties. Different letters indicate statistically significant differences between groups at $p < 0.05$.

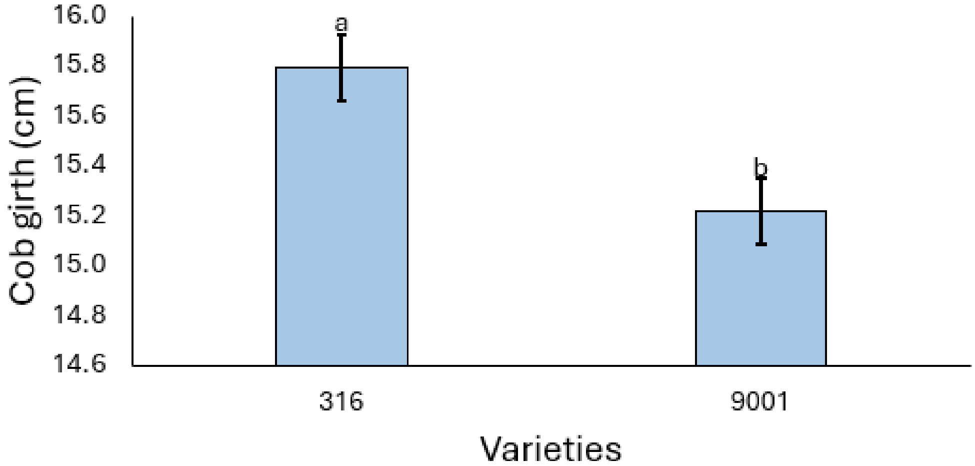

Figure 4.3. Mean differences in corn cob girth (cm) of different corn varieties. Different letters indicate statistically significant differences between groups at $p < 0.05$.

Figures 4.4, 4.5, and 4.6 showed the mean differences in corn fresh weight (g), cob length (cm), and cob girth (cm) of the 5 different treatments: control (Co), T1 (N), T2 (NCaB), T3 (NIs) and T4 (NCaBIs). There was no statistically significant difference ($p < 0.05$) between treatments in terms of fresh weight (g), cob length (cm), and cob girth (cm). NPK 12:12:17 (T1) had the highest fresh weight of 431.60 ± 13.95 g, while NPK 12:12:17 + Ca/B + Isabion (T4) had the lowest fresh weight of 381.11 ± 13.95 g. In terms of cob length, NPK 12:12:17 (T1) was the longest while NPK 12:12:17 + Isabion (T3) was the shortest with values of 19.99 ± 0.33 cm and 18.83 ± 0.33 cm, respectively. Moreover, NPK 12:12:17 (T1) had the biggest cob girth of 15.70 ± 0.21 cm while control had the smallest cob girth of 15.35 ± 0.21 cm. It was observed where NPK 12:12:17 (T1) had the heaviest fresh weight (g), longest cob length (cm), and largest cob girth (cm) compared to other treatments.

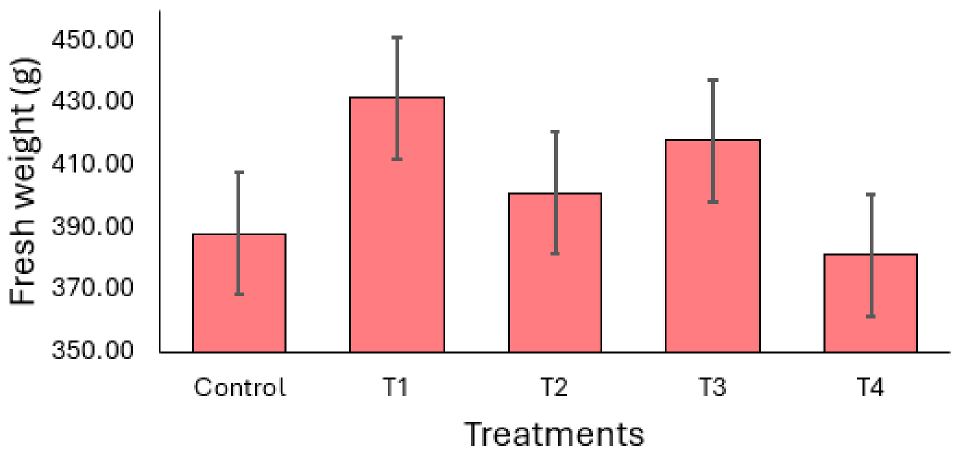

Figure 4.4. Mean differences in corn fresh weight (g) of different fertilizers used.

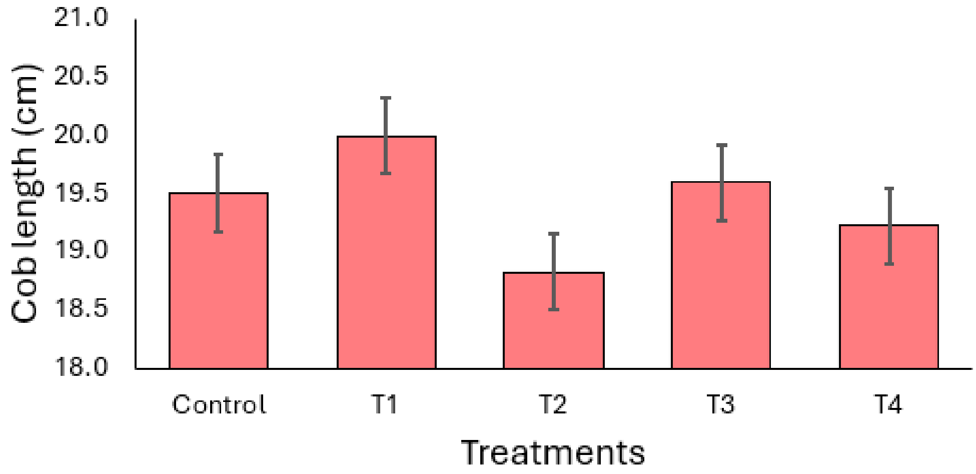

Figure 4.5. Mean differences in corn cob length (cm) of different fertilizers used.

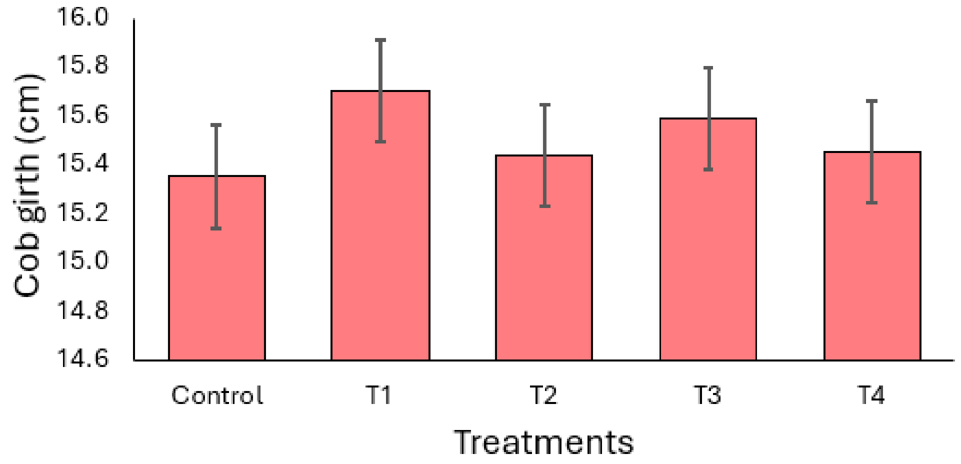

Figure 4.6. Mean differences in corn cob girth (cm) of different fertilizers used.

4.3 Fertilization percentage

Fertilization percentage was used to measure the rate of successful pollination and filling of the kernels in the corn. The higher the fertilization percentage, the higher the filling rate of kernels and the higher the yield of the corn. Among the corn varieties and fertilizer types, neither showed statistically significant differences ($p < 0.05$) in improving the fertilization percentage. Variety SC 9001 (94.89 ± 1.09%) had a slightly higher fertilization percentage than F1 316 (93.58 ± 1.09%), with 1.3% better (Figure 4.7). Whereas, for the treatments, NPK 12:12:17 (T1) showed the highest fertilization percentage of 96.1 ± 1.09%, while NPK 12:12:17 + Isabion (T3) showed the lowest fertilization percentage of 93.0 ± 1.09% (Figure 4.8).

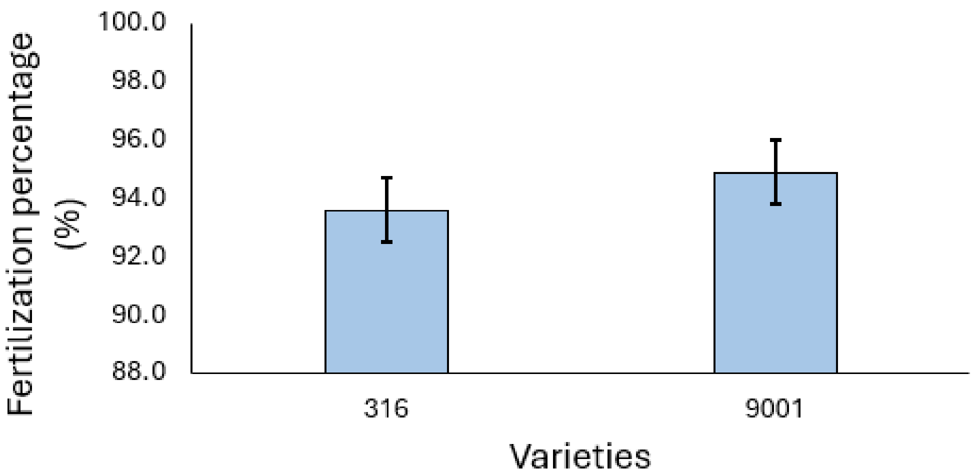

Figure 4.7. Mean differences in corn cob fertilization percentage of different corn varieties.

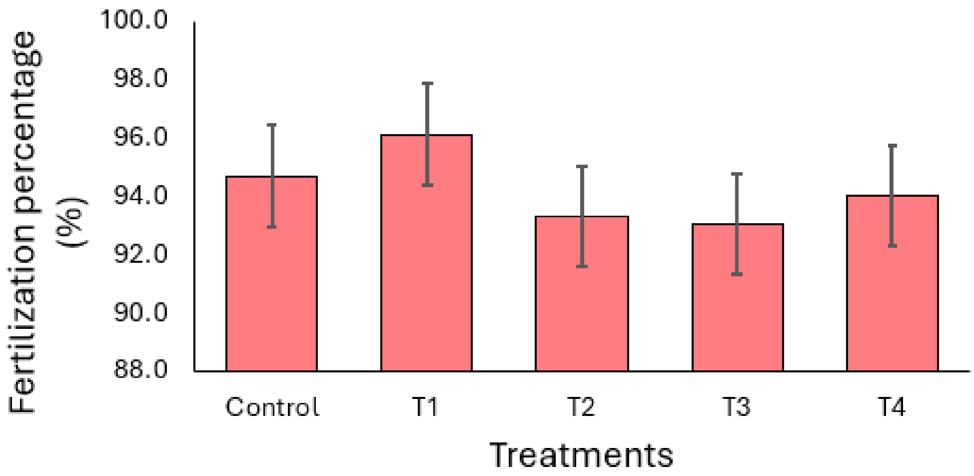

Figure 4.8. Mean differences in corn cob fertilization percentage of different fertilizers used.

4.4 Number of kernels per row and number of kernels per column

In terms of the number of kernels per row, both varieties did not have statistically significant differences ($p < 0.05$) from each other. The 5 treatments did not have a statistically significant difference ($p < 0.05$) in the number of kernels per row (Figure 4.9 & 4.10). Variety F1 316 (39.97 ± 0.59) showed a higher number of rows than SC 9001 (39.01 ± 0.59), with a difference of 1 row. Whereas, for treatments, NPK 12:12:17 (T1) had an average of 40.4 ± 0.59 kernels per row, which was the highest among the treatments, while NPK 12:12:17 + Isabion (T3) had an average of 38.5 ± 0.59 kernels per row, which was the lowest among the treatments.

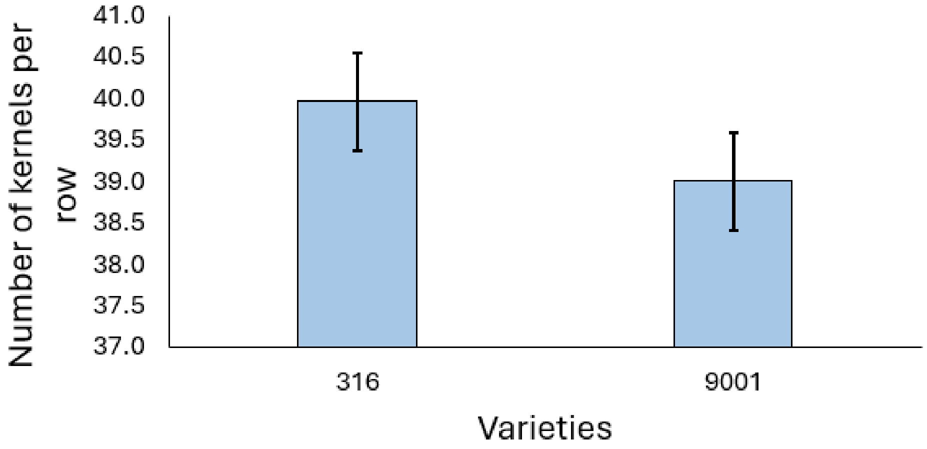

Figure 4.9. Mean differences in the number of kernels per row of different corn varieties.

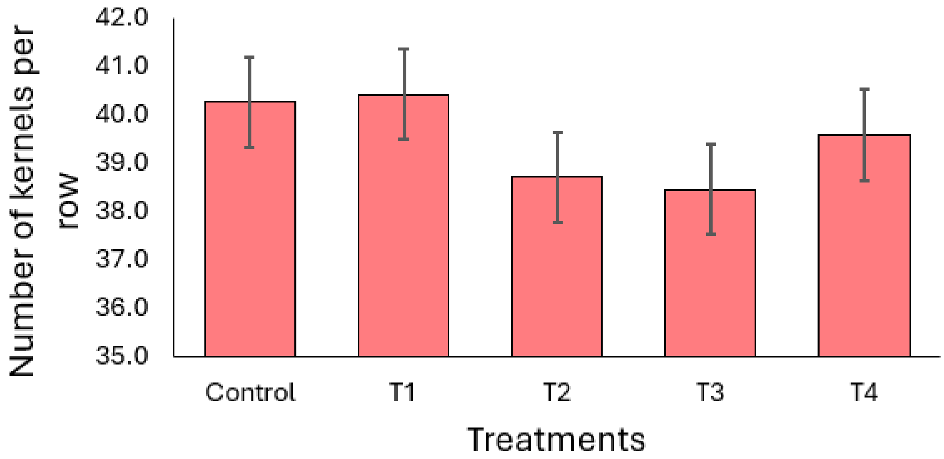

Figure 4.10. Mean differences in the number of kernels per row of different fertilizers used.

In terms of the number of kernels per column, there were statistically significant differences ($p < 0.05$) where variety F1 316 had a higher number of kernels per column compared to SC 9001 (Figure 4.11). The average number of kernels per column for F1 316 was 15.6 ± 0.25 while for SC 9001 was 14.6 ± 0.25. The increment of the number of kernels per column was 6.99%. For treatments, there were no statistically significant differences between each other at $p < 0.05$ (Figure 4.12). Both control and NPK 12:12:17 + Isabion (T3) had the highest number of kernels per column with a value of 15.3 ± 0.40 kernels per column while NPK 12:12:17 + Ca/B (T2) had the lowest number of kernels per column with a value of 14.8 ± 0.40 kernels per column.

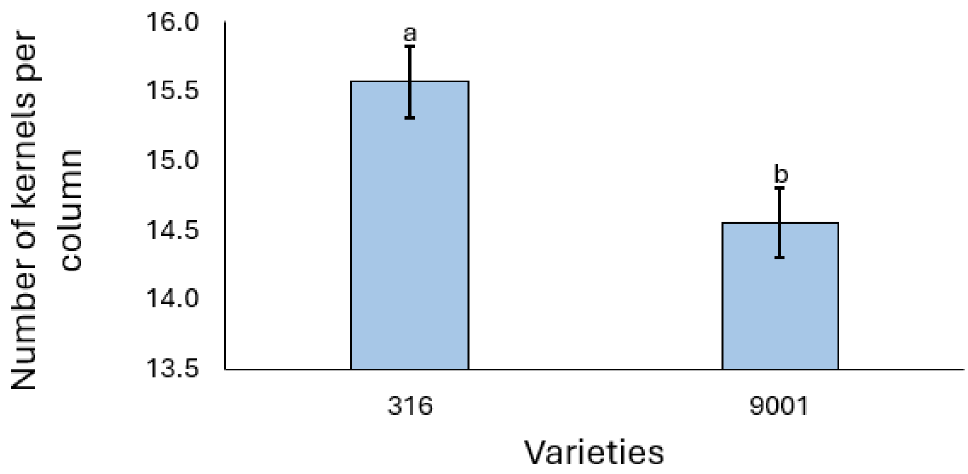

Figure 4.11. Mean differences in the number of kernels per column of different corn varieties. Different letters indicate statistically significant differences between groups at $p < 0.05$.

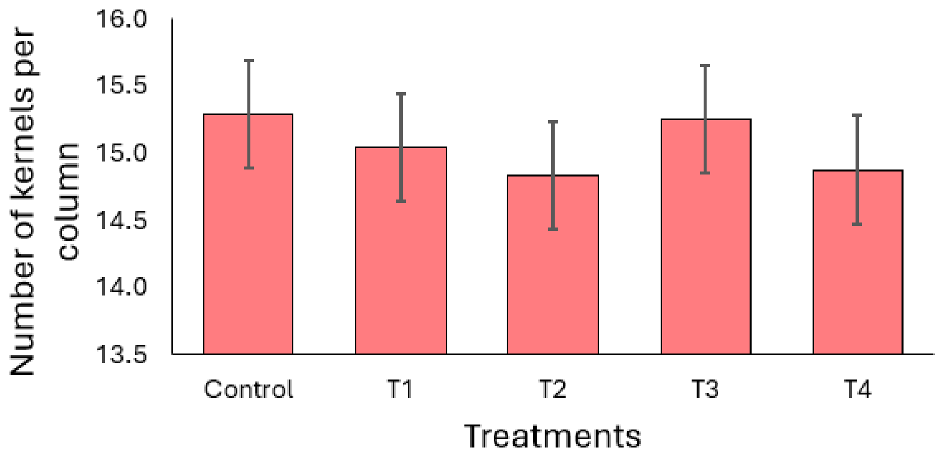

Figure 4.12. Mean differences in the number of kernels per column of different fertilizers used.

4.5 100 kernels weight

Figures 4.13 and 4.14 showed the mean difference in 100 kernels weight (g) of corn of different varieties and different treatments, respectively. There were no statistically significant differences in 100 kernels weight (g) between variety F1 316 and variety SC 9001. Variety SC 9001 showed a slightly heavier 100 kernels weight of 23.0 ± 0.5 g, which was 0.3 g heavier compared to F1 316. In terms of treatments, there were statistically significant differences between control, NPK 12:12:17 (T1), NPK 12:12:17 + Ca/B (T2), NPK 12:12:17 + Isabion (T3), and NPK 12:12:17 + Ca/B + Isabion (T4). NPK 12:12:17 (T1) showed the heaviest 100 kernels weight of 24.6 ± 0.83 g, followed by NPK 12:12:17 + Ca/B (T2), NPK 12:12:17 + Isabion (T3), and NPK 12:12:17 + Ca/B + Isabion (T4) with 24.0 ± 0.83 g, 22.8 ± 0.83 g, and 22.1 ± 0.83 g, respectively. The lightest 100 kernels weight (g) were from the control. According to Turkey's HSD test ($p < 0.05$), there were statistically significant differences between the control and NPK 12:12:17 (T1). Whereas NPK 12:12:17 + Ca/B (T2), NPK 12:12:17 + Isabion (T3), and NPK 12:12:17 + Ca/B + Isabion (T4) did not show any statistically significant differences compared to control and T1, but they formed an intermediate group between control and T1.

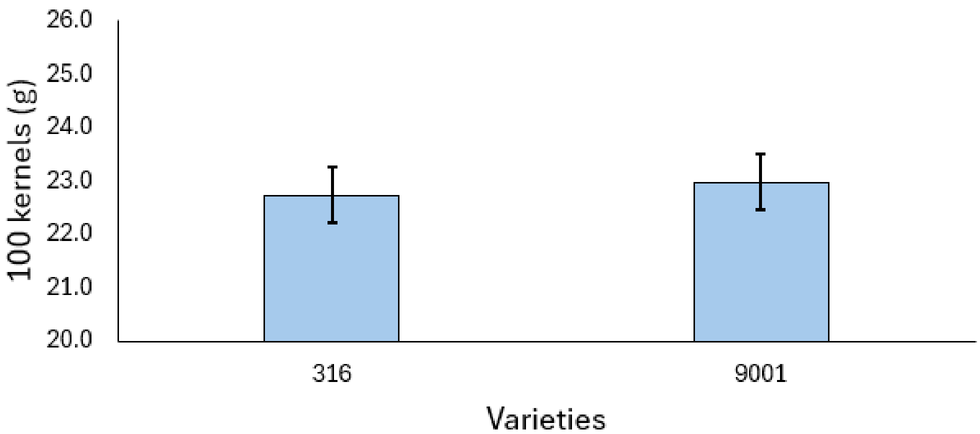

Figure 4.13. Mean differences in 100 kernels weight (g) of the corn of different corn varieties.

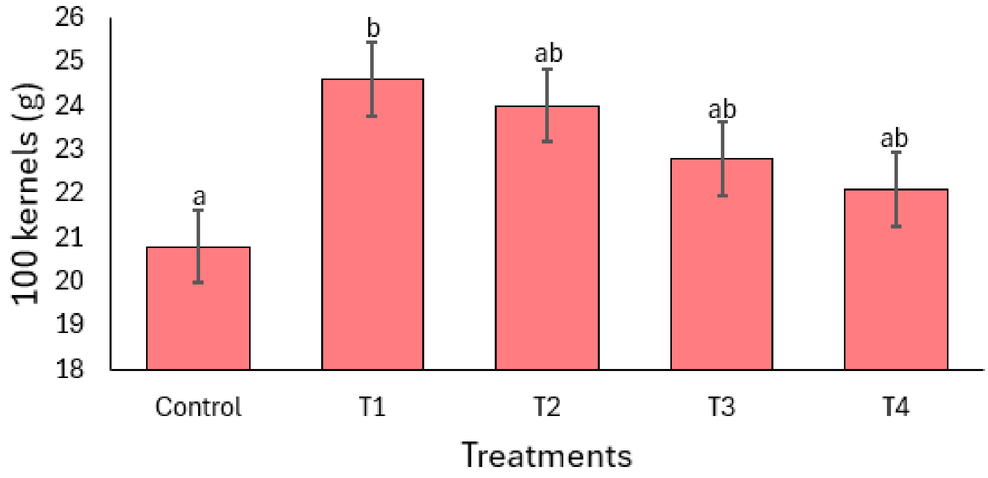

Figure 4.14. Mean differences in 100 kernels weight (g) of the corn of different fertilizers used. Different letters indicate statistically significant differences between groups at a significant level of $p < 0.05$.

Table 4.4 showed the interaction effect of type of fertilizer and corn variety on 100 kernels weight (g). According to the Turkey HSD, 3 groups with significantly different means of 100 kernels weight (a, b, c) were identified ($p < 0.05$). The interaction of F1 316 x NPK 12:12:17 showed the highest 100 kernels weight of 26.71 g, and it showed a statistically significant difference compared to all the other groups. F1 316 x control had the lowest 100 kernels weight of 18.71 g, and it shows a statistically significant difference compared to all the other groups.

Table 4.4. Interaction effect of type of fertilizer and variety on 100 kernels weight (g) of corn. Superscript letters indicate statistically significant differences between groups at $p < 0.05$.

Interaction (type of fertilizer x variety)	100 kernels weight (g)
F1 316 x control	18.71^{a}
F1 316 x NPK 12:12:17	26.71^{c}
F1 316 x NPK 12:12:17 + Ca/B	24.70^{bc}
F1 316 x NPK 12:12:17 + Isabion	21.17^{ab}
F1 316 x NPK 12:12:17 + Ca/B + Isabion	22.39^{abc}
SC 9001 x control	22.96^{abc}
SC 9001 x NPK 12:12:17	22.54^{abc}
SC 9001 x NPK 12:12:17 + Ca/B	23.28^{abc}
SC 9001 x NPK 12:12:17 + Isabion	24.33^{bc}
SC 9001 x NPK 12:12:17 + Ca/B + Isabion	21.73^{abc}
Level of significance	0.001

4.6 Duration from germination to anthesis formation

Figures 4.15 and 4.16 showed the duration from germination to anthesis formation of different corn varieties and different types of fertilizer used, respectively. There were statistically significant differences between the duration from germination to anthesis formation in terms of corn varieties as well as fertilizer types ($p < 0.05$). Variety F1 316 showed statistically significant in longer duration from germination to anthesis formation (41.3 ± 0.15 days) compared to variety SC 9001 (40.1 ± 0.15 days) ($p < 0.05$). The difference between them was only 1.2 days which means variety SC 9001 flowered earlier than variety F1 316.

In terms of different fertilizers used, both NPK 12:12:17 (T1) and NPK 12:12:17 + Isabion (T3) were statistically significant in having a longer duration from germination to anthesis formation of compared to control NPK 12:12:17 + Ca/B (T2) while NPK 12:12:17 + Ca/B + Isabion (T4) ($p < 0.05$). NPK 12:12:17 (T1) and NPK 12:12:17 + Isabion (T3) had the longest duration from germination to anthesis formation of 41.3 ± 0.34 days, while NPK 12:12:17 + Ca/B (T2) was the shortest, which was 40.4 ± 0.34 days. The difference between them was 0.9 days.

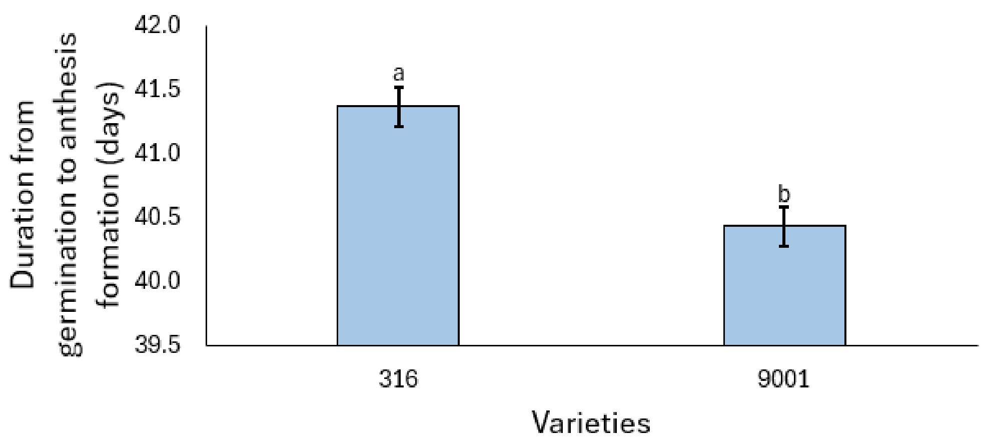

Figure 4.15. Mean differences of duration from germination to anthesis formation of the corn of different corn varieties. Different letters indicate statistically significant differences between groups at $p < 0.05$.

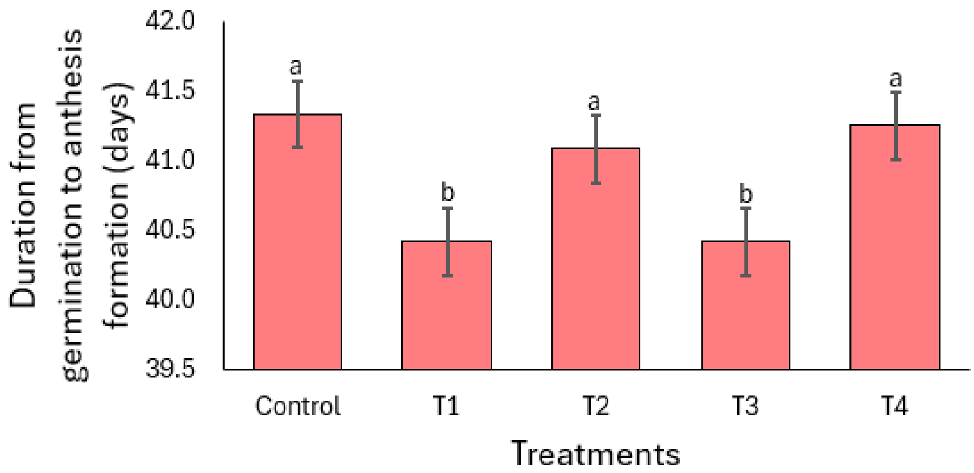

Figure 4.16. Mean differences of duration from germination to anthesis formation of the corn of different fertilizers used. Different letters indicate statistically significant differences between groups at $p < 0.05$.

CHAPTER 5

DISCUSSION

5.1 Different varieties on corn yield

In this study, variety F1 316 statistically performed better than variety SC 9001 for cob fresh weight (g), cob length (cm), cob girth (cm), and number of kernels per column ($p < 0.05$). The number of kernels per row of F1 316 was also higher than SC 9001. Besides, the two-way ANOVA, did not show any statistically significant interaction effect between corn varieties and fertilizer types in terms of cob length and cob girth. This indicated that all types of fertilizer used in this experiment had the same effect on cob length and the cob grith, regardless of the variety. Similar research showed that different varieties of corn produced different cob length, cob girth, and fresh weight of the cob (Calley and Lum, 2022).

The indifference of interaction effects between corn varieties and fertilizer types can be explained because both seeds are F1 hybrid seeds. F1 hybrids seeds are produced through two homozygous parent lines and with this, the seeds produced will be constant in terms of the desired traits (Khan, 2017). Research has shown that the heritability of cob length and cob grith are 55.73% and 58.36%, respectively which was considered as high (Bennett, et al., 2014; Sudika, Sutresna and Anugrahwati, 2022). Besides, the cob fresh weight was also shown to be highly heritable (Niji, et al., 2018). Another research also showed that cob length, cob girth, number of kernels per row, and number of kernels per column heritability were 79.11%, 89.08%, 85.72%, and 74.57%, respectively (Seshu, Jabeen and Jhansi, 2013).

This explains why variety F1 316, had a higher average fresh weight of cob (g), cob length (cm), cob grith (cm), number of kernels per column, and number of kernels per row compared to the SC 9001 as F1 316 may have a better gene. However, heritability only describes a particular population based on their phenotype difference (Hill, 2013). Under heritability, the variance of environmental and variance of the interactions between environmental and genotype are considered (Hill, 2013). Insufficient research was done on both variety F1 316 and variety SC 9001 in different locations. Thus, further research should be done on the heritability of these traits for varieties F1 316 and SC 9001.

For 100 kernels weight (g), variety SC 9001 had a higher weight 0.3 g at 1.3% compared to variety F1 316. Research showed that 100 kernels weight had a 98.18% heritability (Seshu, Jabeen and Jhansi, 2013). Although both varieties did not have significant differences in terms of the 100 kernels weight, it could be due to the genes of both varieties have similar performance on these traits.

5.2 Different fertilizers on corn yields.

5.2.1 NPK 12:12:17

The study showed that NPK 12:12:17 (T1) was better in terms of the fresh weight (g), cob length (cm), cob girth (cm), number of kernels per row, and 100 kernels weight (g) compared to other treatments. For 100 kernels weight, NPK 12:12:17 (T1) was statistically significant in producing a heavier 100 kernels weight compared to the control. This indicated that NPK 12:12:17 is important in improving the yield of the corn. A similar result by other researchers found the application of K improved the cob length, cob girth, number of kernels per row, and 100 kernels weight of the corn (Ali, et al., 2020). However, there was also research showed that N affects the yield of corn the most followed by P and K (Balemi, et al., 2019).

From this study, it showed debatable that K is also important in affecting the yield of the corn. Firstly, K is important in corns for enzyme activities as they can increase carbohydrate production (Ali, et al., 2020). Carbohydrates are important as they are stored inside the corn kernels during the fruiting of the corn. Besides, K regulates the opening and closing of stomata, which enhances the water use efficiency of the plant (Serna, 2022). Moreover, the presence of K improves the carbon dioxide assimilation, and this increases the efficiency of the production of ATP (Han, et al., 2023). With all of these, the yield of the corn can be increased, and this explains why NPK 12:12:17 (T1) was better in terms of the fresh weight (g), cob length (cm), cob girth (cm), number of kernels per row, and 100 kernels weight (g) compared to all the other treatments.

5.2.2 Ca/b and NPK fertilizers

This study showed that NPK 12:12:17 + Ca/B (T2) had no significant difference compared to NPK 12:12:17 (T1) in terms of the fresh weight (g), cob length (cm), cob girth (cm), number of kernels per row, number of kernels per column, and 100 kernels weight (g). Moreover, NPK 12:12:17 + Ca/B (T2) showed a slight reduction in all these traits compared to NPK 12:12:17 (T1). Some of the traits, like cob length, number of kernels per row, and number of kernels per column, even show lower values compared to the control. This explains that the additional application of Ca and B in additional to NPK 12:12:17 not only has no positive effects on the yield of the plant, but also may affects the effect of NPK 12:12:17.

Firstly, the types of NPK fertilizer explain why the application of Ca/B has no significant effect on the yield of the corn. Research has shown that the type of N fertilizer used affects the absorption of B. In this experiment, the NPK 12:12:17 used was from YARA where the source of the N element is from both nitrate and ammonium. Long and Peng (2023) reported that plants will have lower absorption of B when nitrate served as the source of N compared to ammonium. This is because when the plant absorbs ammonium, H^+ will be released, which can reduce the soil pH. The reaction of H^+ and boron produces boric acid which favor the absorption by the plant. Therefore, Ca/B did not significantly increase the yield of the corn in this study.

Moreover, there is an antagonistic relationship between the absorption of B and K in corn. The increase in B absorption will reduce the K absorption and vice versa. This is because phosphate and borate share the same absorption and transport system, which makes them compete against each other (Aydin Günes and Mehmet Alpaslan, 2000; Long and Peng, 2023). Moreover, as mentioned in the literature review, B and Ca formed calcium borate complexes in the soil, which reduced the availability of the B (Long and Peng, 2023). With this, it might cause B deficiency in the plant. Although the results showed that there were no significant effects of the application of Ca/B on the yields of corn. However, there are possibilities that Ca/B could have effects on the quality of corn.

Besides the yield of corn, the quality of the corn is also an important factor in determining the marketable yield of corn. Research has shown that the application of Ca improved the shelf life of fruits (Álvarez-Herrera and Fischer, 2024; Marilcen Jaime-Guerrero, 2024). This is because Ca can delay the loss of firmness in fruits by forming calcium pectate (Álvarez-Herrera and Fischer, 2024; Marilcen Jaime-Guerrero, 2024). Calcium pectate forms a gel layer in the cell wall that can strengthen the cell wall, and this can slow down the activity of enzymes that are involved in cell wall degradation (Álvarez-Herrera and Fischer, 2024; Marilcen Jaime-Guerrero, 2024). Research had also shown that applying Ca on apples reduced fruit wilting rate by 7.8% and rotten fruit by 9.2% with a storage period of 5-week (Lien, et al., 2023).

B is also another micronutrient that affects the quality of the crop. B is important in protein synthesis and it can improve the vitamin C level and vitamin B level of fruits. Moreover, it can also improve the shelf life of the fruits. Research has shown that the application of B fertilizer improved the Brix levels and vitamin C level by 6.78% and by 1.47%, respectively (Lien, et al., 2023). However, there was no research being done on how Ca and B could improve the quality of the corn.

Ca/B did affect the yield of the fruits in other research. However, most of the research that showed positive results is using foliar Ca/B fertilizer. Lien, et al. (2023) described that the application of foliar B improved the yield of apples by 2.3 tonnes per hectare. Besides, the application of Ca/B as a foliar application had also shown a better effect on increasing the yield of cabbage compared to soil application (Gladis, et al., 2020). This could be the possible reason explaining the non-significant result of Ca/B in improving the yield of corn, as this study used soil application Ca/B . Therefore, the application of Ca/B as foliar or soil application should be discussed.

5.3 Biostimulant

Results in this study showed that the addition of biostimulant combined with NPK 12:12:17 did not show any significant differences in increasing the yield of the corn. A study showed that the application of glycine improved the yield of corn by 32% when the plants were under stress compared to the control (Trivedi, et al., 2022). This is because when corn is experiencing drought stress, they will experience oxidative damage due to the overproduction of reactive oxygen species (ROS) (Cruz de Carvalho, 2008). With this, plants synthesize glycine to maintain plant growth by improving the plant's oxidative defense system (Shafiq, et al., 2021). This could reduce the stress of the plant, and the plant can allocate their energy back to contribute to the yield.

This explains why in this study, the application of biostimulant on top of NPK 12:12:17 (T3 and T4) did not show significant differences compared to the control and NPK 12:12:17 (T1). This is because water was sufficient to the plant throughout the planting period of the corn.

Besides, the application of glycine together with inorganic nitrogen fertilizer found to improve the soil nitrogen content by 22.8% compared to without applying any glycine (Wu, et al., 2023). Moreover, glycine improved the uptake of nitrogen by 35% and it improved the shoot and root growth (Wu, et al., 2023). From these two research stated above, glycine showed a better impact on the vegetative growth of the plant but not the fruiting or anthesis of the plant as they showed interaction effects with N. N is more important for the root and shoot development but not the fruit development (Shah Jahan Leghari, et al., 2016). However, the vegetative growth of the plant, such as the leaf number, plant height, and root length are less important in sweet corn as the vegetative part does not contribute to the yield of the corn.

Besides Ca/B, glycine also affects the quality of fruits. Research showed that glycine improved the quality of winter jujube fruits by inhibiting postharvest softening (Zhang, et al., 2023). Glycine is important in maintaining the cell wall component. This could enhance the antioxidant enzyme which eventually retarded the softening of the fruit (Zhang, et al., 2023). Another study also claimed that glycine improved the activity of antioxidants in citrus fruit, which increased the level of total phenols and flavonoids (Zheng, et al., 2023). However, no research on how glycine affects the quality of corn was done.

5.4 Fresh weight and kernel weight of corn.

Fresh weight (g) of variety F1 316 was significantly greater compared to SC 9001 statistically in this study ($p < 0.05$). However, in terms of the 100 kernels weight (g) of the corn, variety F1 316 showed no significant difference compared to SC 9001 ($p < 0.05$). Though F1 316 had a higher fresh weight, the weight was not distributed to the kernels but onto the stover (husk, pith, or silk). This may be the discussion of a new topic which is the apparent yield and the actual yield.

Apparent yield refers to the stover’s yield which includes the husk, pith, and silk of the corn cob, while the actual yield refers to the kernel's yield (Duvick, 2005). Actual yields can be discussed through two terms, which are the Harvest Index (HI) and Grain-to-Stover ratio (G:S) (Duvick, 2005; Kristin, 2021). HI refers to the ratio of grain yield to the biological yield, while (G:S) refers to the ratio of grain to stover (Duvick, 2005; Kristin, 2021). Both formulas reflect the actual yield of the corn grain.

Studies showed that the grain-to-stover ratio is genetically dependent and the G:S ratio can range from 30:70 to 50:50 (Kristin, 2021). This explains the result why both varieties F1 316 and SC 9001 had the same 100 kernels weight despite the different fresh weights. Kernel’s yield considers the actual yield and it is part of the corn that is nutritionally valuable and consumable. Thus, farmers or researchers should be prioritizing the actual yield in plant breeding compared to apparent yields.

A study reported that genetics of the plant played an important role in determining the HI and the G:S ratio. The selection in improving one trait will reduce other traits as fitness cost. In this case, to have a larger or heavier kernel means the weight of stover will be reduced (Rose, Sanju and Kidwai, 2022).

However, Duvick (2005) reported that the HI of corn had only little to no improvement from 1930 to 2004. Moreover, the little improvement in HI of the corn of several hybrids were because the newer hybrids were more suitable of the changing environments as compared to older hybrids (Duvick, 2005). In other words, the technology in improving the HI of corn through their gene have not advanced in decades. Thus, it is important to discuss other ways to improve the actual yield.

Fertilizer management can become one of the methods to improve the grain yield of corn. Results showed that NPK 12:12:17 (T1) was significantly greater in producing heavier 100 kernels weight (g) compared to the control statistically, while T2, T3, and T4 did not show statistically significant differences compared to T1 and the control. This indicated that the application of NPK 12:12:17 significantly improved the grain yield compared to the control. However, the existing farmer practices in Kampar Perak are applying a greater mixture of fertilizer believing that the practice could improve the yield of the corn. Thus, existing farmer practices on fertilizer application in Kampar, Perak are suggested to be reviewed.

5.5 Interaction effect of fertilizer and variety on corn yield

In this study, NPK 12:12:17 and variety F1 316 showed statistically significant interaction effect in influencing the 100 kernels weight of corn. This indicated that various impacts of different types of fertilizer in different varieties. This can be explained as different corn varieties having different sensitivities to different types of fertilizer. There is lack of similar studies on the interaction effect of fertilizer types and corn varieties. However, several studies showed that there was an interaction effect between corn varieties and the rate of fertilizer in affecting the yields of corn (Abera, Tolessa Debele and Dagne Wegary, 2017; Asaduzzaman, et al., 2014; Szulc, et al., 2016).

Djalovic, et al. (2024) reported a three-way interaction effect between the timing of fertilization, corn varieties, and N fertilization rate. This is because different varieties will have different flowering periods, and the corn variety with late flowering periods will have a more extended vegetative period to absorb the available N in the soil (Djalovic, et al., 2024). This can explain the result of why variety F1 316 had a heavier 100 kernels weight compared to SC 9001 in treatment NPK 12:12:17 (T1), as F1 316 took a longer time to flower compared to SC 9001; thus, it could store more nutrients.

5.6 Corn varieties and fertilizer types on the fertilization percentage

Neither the variety nor the types of fertilizer showed statistically significant differences in affecting the fertilization percentage (%). Study showed that fertilization percentages heavily influenced by the environment and the interaction between genotype and environment (Tucker, et al., 2020). Genetics, environment, and their interaction (genetics × environment) contributed to approximately 75% of the variation of the fertilization percentage (Tucker, et al., 2020). Of this 75%, genetics alone accounted for only 10% of the variations in fertilization percentage.

Different environmental conditions can impose stress on corn and affect their pollination (Bayer, 2023). For example, excessive precipitation can affect the transfer of pollen from the tassel to the silk, which could affect the rate of pollination. Different corn varieties exhibit varying stress tolerance levels; some may have greater salinity tolerance than others. As a result, the interaction between corn varieties and environmental factors has the strongest influence on fertilization percentage (Farooq, et al., 2015; Tucker, et al., 2020). Thus, this explains the result of this study why corn varieties and fertilizer types were not significantly different in improving the fertilization percentage.

However, different fertilizers do affect the fertilization percentage, but only in a lesser extent. Research showed that a relatively higher absorption of N and P during the pollination and grain filling periods of corn contributed to higher fertilization percentage (Bayer, 2023). The fertility of the soil affects the fertilization percentage, but to a lesser extent. In this research, a basal application of NPK 15:15:15 was applied in the vegetative stage before the treatment started. Thus, the soil was considered fertile.

5.7 The influence of corn varieties and fertilizer types on the anthesis timing

The result of this study showed that both the corn varieties and fertilizer types showed statistically significant differences in affecting the anthesis timing. Although the result showed statistically significant difference but the difference between groups is only at the range of 1.2 days for different corn varieties and 0.9 days for different fertilizers used. Research showed that the combination of organic N and inorganic N statistically reduced the days of tasseling and silking of corn (Bhatt, et al., 2020). However, no similar studies were conducted on the effect of NPK 12:12:17, Ca/B, and biostimulant on affecting the anthesis timing in corn.

In rice, K was statistically significant in promoting early flowering (Ye, et al., 2019). This is because when K is in deficit, the transportation of soluble carbohydrates to the apical meristem will be reduced (Ye, et al., 2019). The insufficient amount of soluble carbohydrates delays the flowering of the plant (Ye, et al., 2019). The optimum amount of K in rice was 180 kg/ha (Ye, et al., 2019). In this study, a baseline application of 87.5 kg/ha of K (from NPK 15:15:15) was already applied before the treatments and it may already reach the optimal rate of promoting earlier flowering in corn. Thus, this explains why the significant difference between all treatments were only 0.9 days.

Although no research showed that Ca/B can shorten the timing of anthesis, but it affected the rate of fruit setting in avocados (*Persea americana*) (Hapuarachchi, et al., 2022). This is because high boron in the pistil could increase the germination rate and the pollen tube's growth (Raissa, et al., 2023). On the other hand, glycine-based biostimulant was found to shorten the duration of anthesis (Ma, et al., 2021). This is because corn contains glycine-rich RNA-binding proteins (GR-RBPs), which are involved in controlling the anthesis timing (Ma, et al., 2021). The suppression or the overexpression of GR-RBPs might lengthen the anthesis timing of the corn (Ma, et al., 2021). However, the efficacy of the absorption and the utilization of this glycine-based biostimulant is not well studied. Thus, there is still a research gap on how Ca/B and biostimulant affects the anthesis timing of corn.

CHAPTER 6

CHALLENGES AND IMPROVEMENTS

Several challenges were encountered in this study, and from these experiences, some improvements can be made to improve the accuracy and the reliability of the results. Firstly, the timing of seed germination should be considered to ensure smooth progress for the whole project. Two corn varieties were germinated simultaneously, where 100 seeds each were germinated in the seedling tray. However, variety F1 316 showed a low germination rate, where approximately 50% of the seeds were successfully germinated. This has caused insufficient seedlings and dragged the whole transplanting process.

To solve this problem, it is suggested to germinate more seeds for the transplantation (approximately two to three times the number of seeds needed for the experiment) to ensure an adequate supply of healthy seedlings. Moreover, a few batches of seed can be germinated simultaneously. The seeds can be germinated in two consecutive batches per day for two to three cycles. This ensured that if the first batch of seedlings encountered any problems, the second batch of seedlings would be ready in two days, rather than waiting for the 10-day germination cycle.

Secondly, during the transplantation of the seedling, the experimental site was experiencing heavy rain for two full weeks. This caused the entire experimental plot to flood, and all the seedlings drowned and started showing yellowing symptoms. Because of this, the whole research ended up restarting, and the entire experimental site was reset. By addressing this problem, the research period should avoid the rainy season so that the plants are not experiencing any stress and reduce the tendency of getting faulty results.

If the research period cannot be changed, several actions can be taken to allow the better thriving of plants. The soil bed can be raised higher (approximately 50 cm) so that the root of the corn will not be submerged in the water. This allows better aeration in the soil and avoids the root rot issue. Proper drainage can be prepared, which creates a slope for better flow of water. This can reduce the chances of the plot getting flooded.

CHAPTER 7

CONCLUSION

In conclusion, corn variety F1 316 had a statistically significantly higher apparent yield (fresh weight (g), cob length (cm), cob girth (cm), number of kernels per row) compared to SC 9001, but they were not statistically significant difference in actual yield (100 kernels weight, g). Thus, farmers and researchers should consider and identify varieties with high actual yield instead of the apparent yield, while plant breeders should breed a variety with high actual yield but not the apparent yield. This is because the actual yield reflects the edible part of the corn. With a high actual yield, food security can be improved and enhanced.

In terms of fertilizer management, results from this study show that NPK 12:12:17 statistically improved the actual yield of the corn, but not Ca/B and biostimulant. This indicates that a greater mixture of fertilizer is not necessary to improve the yield of corn, but NPK 12:12:17 alone is sufficient in improving the yield of the corn. Thus, the existing farmer practices on fertilizer application in Kampar, Perak are suggested to be reviewed.

More studies should be done on the interaction between K, Ca/B and biostimulants on the anthesis formation, as although K, Ca/B and biostimulants show statistically significant effects in shortening the duration from germination to anthesis formation but there is no similar research in supporting the findings. Other than that, subsequent studies should also consider the two-way interactions effect between biostimulant and NPK fertilizer, as well as a three-way interactions between biostimulant with Ca/B with NPK fertilizer on the actual yield of the corn or other crops.

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APPENDICES

Appendix A. The soil analysis results from the Department of Agriculture

BAHAGIAN PENGURUSAN SUMBER TANAH
Soil Resource Management Division
JABATAN PERTANIAN MALAYSIA
Department of Agriculture Malaysia
Kompleks Jabatan Pertanian Titi Gantong
32600 BOTA
PERAK DARUL RIDZUAN

Tel : 05 - 3761214
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Ruj. Tuan
Ruj. Kami : JP.TNH.PRK 207/7/439/18/3(70)
Tarikh : 19 September 2024

Universiti Tunku Abdul Rahman (UTAR)
Jalan Universiti,
31900 Kampar,
Perak.
u/p : Tong Pei Sin

Tuan,

LAPORAN KHIDMAT NASIHAT KESUBURAN TANAH

Dengan hormatnya merujuk kepada perkara di atas.

2. Bersama-sama ini dilampirkan Laporan Khidmat Nasihat Kesuburan bagi Kawasan Kampar (No. Laporan : 39/30/2023) untuk makluman dan tindakan pihak tuan selanjutnya.

3. Sebarang pertanyaan berkenaan laporan ini, pihak tuan boleh berhubung dengan pihak kami untuk maklumat lanjut.

Sekian, terima kasih.

"MALAYSIA MADANI"

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

....
(NOORHAFIZAH BINTI RAHIM)
Ketua Penolong Pengarah K/U
Bahagian Pengurusan Sumber Tanah
Titi Gantong, Perak

ANDA KAMI UTAMAKAN

Figure A1. Soil fertility advisory service report.

	KN-2 39/30 /2024
MAKLUMAT ASAS LADANG	
NAMA PETANI/ORGANISASI: Tong Pei Sin	**ALAMAT PROJEK** Universiti Tunku Abdul Rahman, Kampar
TARIKH LAWATAN: 3/7/2024	**KOORDINAT RSO:** X 349685 Y 480700
JENIS TANAMAN : Jagung Manis	**UMUR TANAMAN:** Belum bertanam
KELUASAN: 15m x 17 (plot saiz)	**SISTEM TANAMAN** Batas
JARAK TANAMAN Tiada	**HASIL TANAMAN:** Belum berhasil
TOPOGRAFI TANAH: Rata	**SIRI TANAH:** Mixed tailing
TANAMAN DI SEKELILING: Tiada	**TANAMAN MUSIM SEBELUM:** Jagung manis
ISU / MASALAH DIHADAPI	
Untuk mengetahui status kesuburan tanah	

GAMBARAN KAWASAN LADANG

Figure A2. Field condition.

LAPORAN AKHIR TEKNIKAL DAN PENGESYORAN KHIDMAT NASIHAT

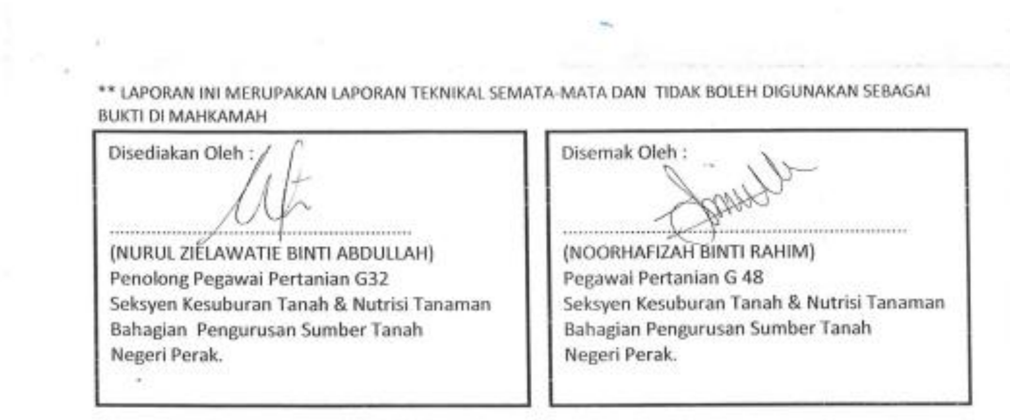
1. Keputusan Dan Interprestasi Analisis Tanah

Sifat Kimia dan Nutrien dalam tanah	Keputusan Analisis (kedalaman 0-25 cm	Interpretasi	Paras Optimum
pH	6.25	Sedikit Beralkali	5.50-6.50
KPK (cmol/kg tanah)	1.97	Sangat Rendah	15-20
Konduktiviti elektrik (µS/cm)	8.80	Sangat Rendah	151-500
Jumlah N (%)	0.03	Sangat Rendah	0.23-0.34
P (ppm)	6.97	Agak Rendah	16-25
K(cmol/kg tanah)	0.03	Sangat Rendah	0.45 - 0.80
Ca(cmol/kg tanah)	1.15	Sederhana	1.0 - 2.5
Mg(cmol/kg tanah)	0.09	Sangat Rendah	1.0 - 3.0
Bahan Organik (%)	0.75	Sangat Rendah	>4
Besi teroksida (%)	0.25	Rendah	<1.0

Figure A3. Results and interpretation of the soil analysis.

Bil	ISU/MASALAH	PENGESYORAN/TINDAKAN PEMBETULAN
1.	Bacaan *Potential of hydrogen* (pH) tanah adalah Optimum.	Hasil keputusan analisis bacaan nilai pH adalah berada di paras **Optimum iaitu 6.25** bagi kawasan tersebut.
2.	Bacaan Kadar Pertukaran Kation (KPK) tanah berada di paras Rendah iaitu 1.97Cmol/kg tanah	Keupayaan Pertukaran Kation (KPK) merupakan keupayaan tanah untuk menukarganti kation di antara tanah dan larutan tanah dan keupayaan menjerap kation. Ia juga digunakan untuk mengukur kesuburan tanah terutama semasa pemberian baja kepada tanah kerana ukuran tersebut dapat menentukan keupayaan tanah untuk memegang nutrient, mengimbangi bekalan nutrien dan melindungi air daripada pencemaran kation. Nilai KPK sangat dipengaruhi oleh tekstur tanah dan kandungan bahan organik. Secara umum, lebih tinggi kandungan liat dan bahan organik dalam tanah semakin tinggi nilai KPK .Penambahan bahan organik di atas tanah adalah digalakkan kerana ia dapat membantu meningkatkan CEC tanah dan ia juga dapat menjaga struktur tanah dan kelembapan tanah.
3.	Paras EC tanah : **8.80 µS/cm** *(Julat optimum 151-500 µS/cm)*	1.Konduktiviti tanah (EC) ialah ukuran untuk menentukan kandungan garam terlarut dalam tanah. Tanah kurang subur mengalami larut lesap yang tinggi @ nilai konduktiviti yang rendah. 2. Daripada analisis sampel tanah, didapati bacaan konduktiviti ladang ini berada di paras rendah iaitu **8.80 µS/cm.**
4.	Kandungan **P,K, Mg** dan **Bahan Organik** berada pada tahap yang **Sangat Rendah**.	Bahan organan seperti sisa-sisa tumbuhan (kompos) atau najis haiwan perlu di tambah pada tanah supaya memperbaiki keupayaan memegang air dan pengaliran udara tanah. Baja organan juga diperlukan bagi membaiki pH tanah, struktur dan tekstur tanah supaya tidak padat.
5.	Pengurusan pembajaan	Pembajaan yang optimum dan seimbang penting supaya tanaman boleh melengkapkan kitaran hidup dan pertumbuhan yang baik.
6.	Cuaca/Suhu	Cuaca terlalu panas dan kering semasa khidmat nasihat. Keadaan ini boleh menyebabkan tanaman menjadi layu dan nekrosis pada tanaman. Pengurusan pengairan amat penting bagi pertumbuhan tanaman.
7.	Pengurusan rumpai.	Pengurusan rumpai dilaksanakan dengan baik. Rumpai perlu dikawal bagi mengelakkan persaingan terhadap pengambilan nutrien daripada baja yang dibekalkan kepada tanaman. Pada peringkat awal, pengawalan rumpai secara manual disyorkan.
8.	Pengurusan Pengairan	Sistem pengairan sprinkler disediakan. Pengairan bagi mengelakkan sebarang

Figure A4. Results and interpretation of the soil analysis



** LAPORAN INI MERUPAKAN LAPORAN TEKNIKAL SEMATA-MATA DAN TIDAK BOLEH DIGUNAKAN SEBAGAI BUKTI DI MAHKAMAH

Disediakan Oleh : (NURUL ZIELAWATIE BINTI ABDULLAH) Penolong Pegawai Pertanian G32 Seksyen Kesuburan Tanah & Nutrisi Tanaman Bahagian Pengurusan Sumber Tanah Negeri Perak.	Disemak Oleh : (NOORHAFIZAH BINTI RAHIM) Pegawai Pertanian G 48 Seksyen Kesuburan Tanah & Nutrisi Tanaman Bahagian Pengurusan Sumber Tanah Negeri Perak.

Figure A5. Signature form the person in charge.

Appendix B. The result of two-way ANOVA on cob length, cob girth, and 100-kernel weight ($p < 0.05$).

Tests of Between-Subjects Effects

Dependent Variable: Length

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	42.027[a]	9	4.670	1.826	.071	.130
Intercept	45288.472	1	45288.472	17705.474	.000	.994
Fertilizer	18.224	4	4.556	1.781	.138	.061
Variety	21.630	1	21.630	8.456	.004	.071
Fertilizer * Variety	2.173	4	.543	.212	.931	.008
Error	281.367	110	2.558			
Total	45611.865	120				
Corrected Total	323.393	119				

a. R Squared = .130 (Adjusted R Squared = .059)

Figure B1. Two-way ANOVA results showing the effects of fertilizer types and corn varieties on the cob length ($p < 0.05$).

Tests of Between-Subjects Effects

Dependent Variable: Girth

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	16.612[a]	9	1.846	1.767	.082	.126
Intercept	28852.945	1	28852.945	27629.029	.000	.996
Fertilizer	1.863	4	.466	.446	.775	.016
Variety	9.961	1	9.961	9.538	.003	.080
Fertilizer * Variety	4.788	4	1.197	1.146	.339	.040
Error	114.873	110	1.044			
Total	28984.429	120				
Corrected Total	131.485	119				

a. R Squared = .126 (Adjusted R Squared = .055)

Figure B2. Two-way ANOVA results showing the effects of fertilizer types and corn varieties on the cob girth ($p < 0.05$).

Tests of Between-Subjects Effects

Dependent Variable: 100 kernel weight

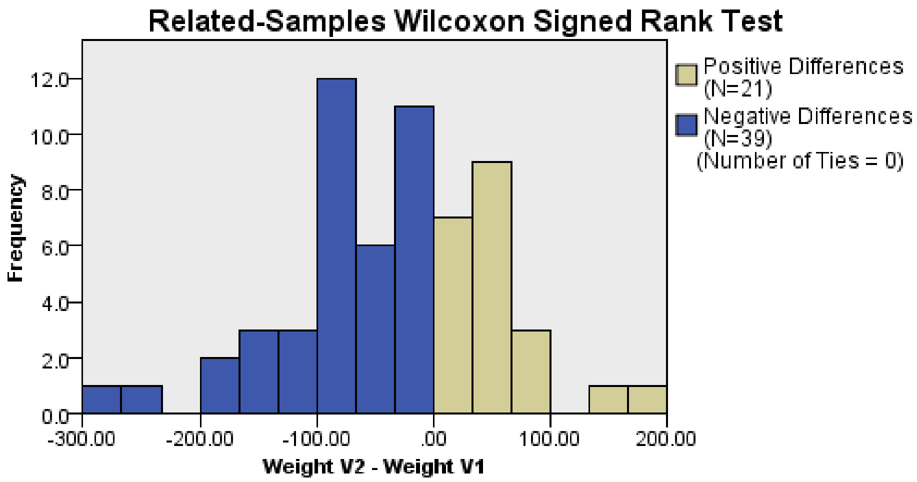
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	506.647[a]	9	56.294	3.442	.001	.220
Intercept	62661.215	1	62661.215	3831.551	.000	.972
Fertilizer	219.342	4	54.835	3.353	.012	.109
Variety	1.618	1	1.618	.099	.754	.001
Fertilizer * Variety	285.688	4	71.422	4.367	.003	.137
Error	1798.941	110	16.354			
Total	64966.803	120				
Corrected Total	2305.588	119				

a. R Squared = .220 (Adjusted R Squared = .156)

Figure B3. Two-way ANOVA results showing the effects of fertilizer types and corn varieties on the 100-kernel weight ($p < 0.05$).

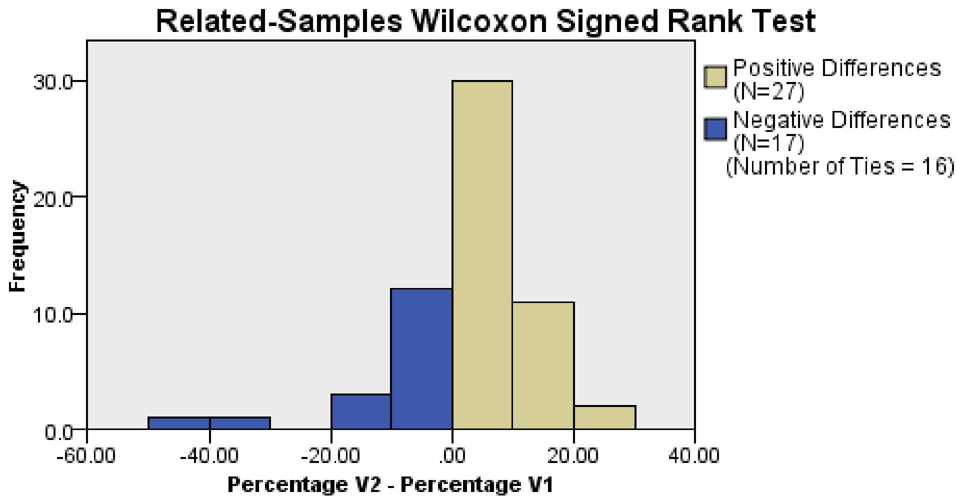
Appendix C. The result of Wilcoxon signed-rank test on fresh weight, fertilization percentage, number of kernels per row, number of kernels per column, and duration from germination to anthesis formation ($p < 0.05$).

Figure C1. Friedman test results showing the effects of corn variety on the fresh weight of corn ($p < 0.05$).



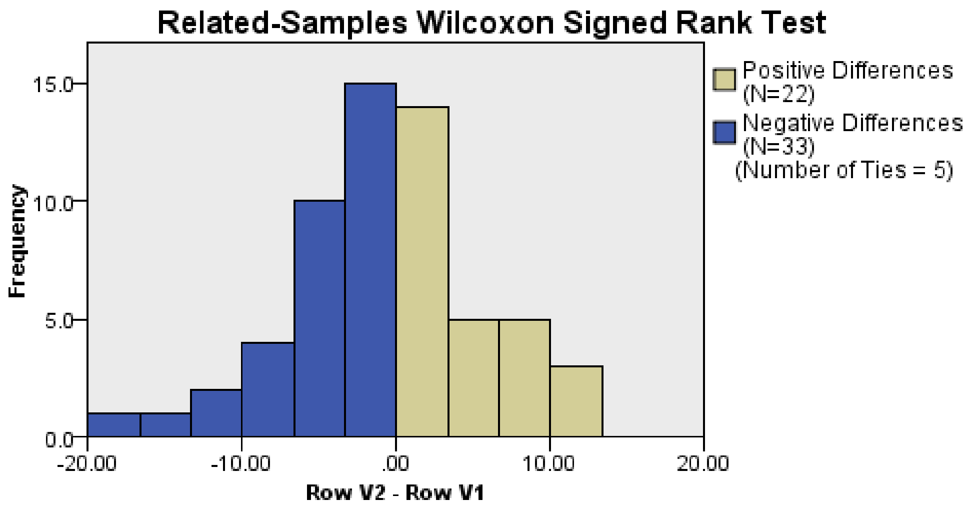
Total N	60
Test Statistic	537.000
Standard Error	135.840
Standardized Test Statistic	-2.783
Asymptotic Sig. (2-sided test)	.005

Figure C2. Friedman test results showing the effects of corn variety on the fertilization percentage of corn ($p < 0.05$).



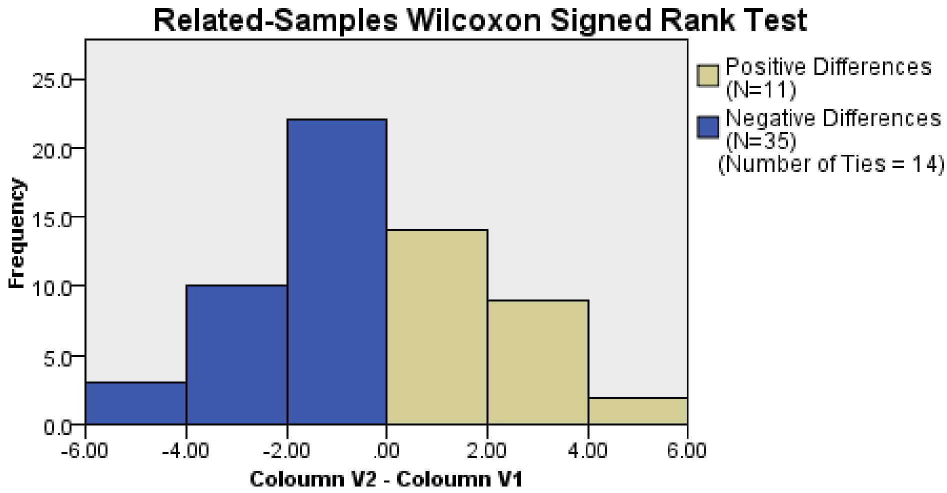
Total N	60
Test Statistic	629.500
Standard Error	85.687
Standardized Test Statistic	1.570
Asymptotic Sig. (2-sided test)	.116

Figure C3. Friedman test results showing the effects of corn variety on the number of kernels per row of corn ($p < 0.05$).



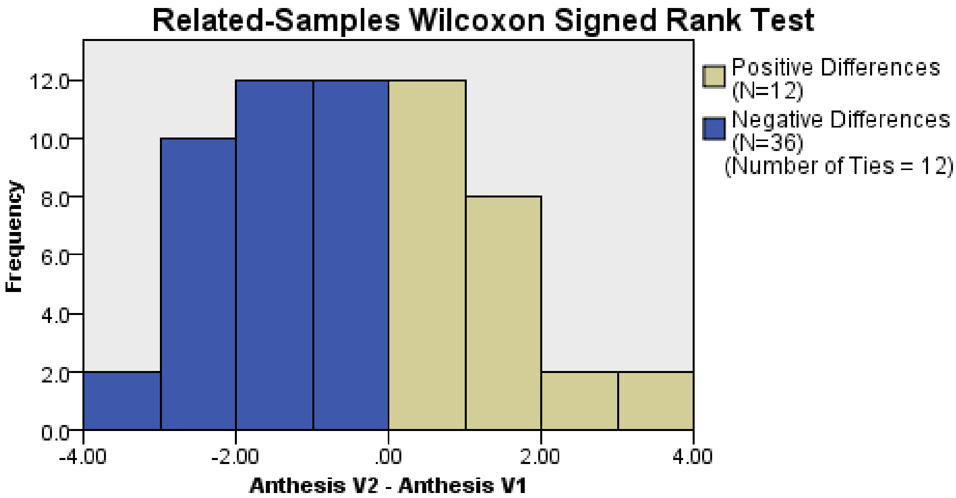
Total N	60
Test Statistic	633.000
Standard Error	119.185
Standardized Test Statistic	-1.149
Asymptotic Sig. (2-sided test)	.250

Figure C4. Friedman test results showing the effects of corn variety on the number of kernels per column of corn ($p < 0.05$).



Total N	60
Test Statistic	275.000
Standard Error	90.397
Standardized Test Statistic	-2.937
Asymptotic Sig. (2-sided test)	.003

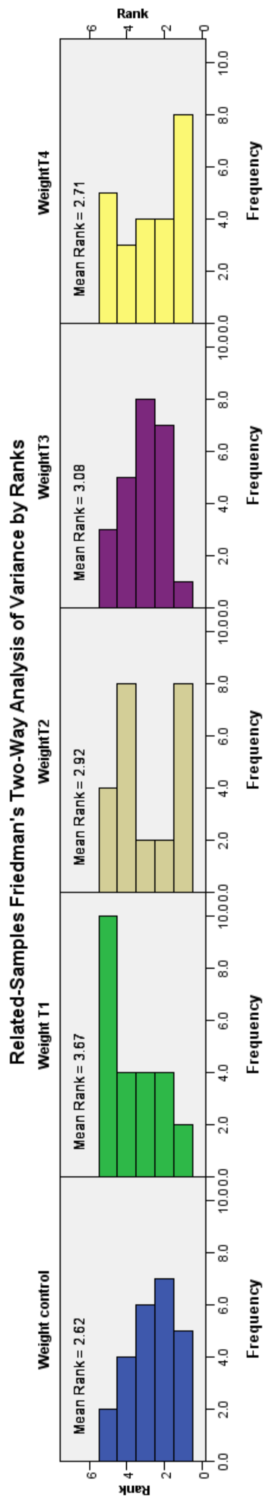
Figure C5. Friedman test results showing the effects of corn variety on the duration from germination to anthesis of corn ($p < 0.05$).



Total N	60
Test Statistic	220.000
Standard Error	96.161
Standardized Test Statistic	-3.827
Asymptotic Sig. (2-sided test)	.000

Appendix D. The result of Friedman test on fresh weight, fertilization percentage, number of kernels per row, number of kernels per column, and duration from germination to anthesis formation ($p < 0.05$).

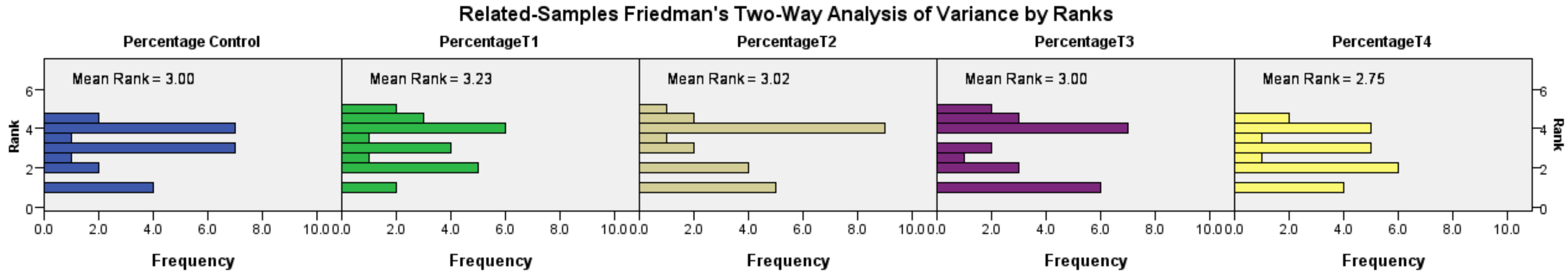
Figure D1. Friedman test results showing the effects of fertilizer types on the fresh weight of corn ($p < 0.05$).



Total N	24
Test Statistic	6.567
Degrees of Freedom	4
Asymptotic Sig. (2-sided test)	.161

1. Multiple comparisons are not performed because the overall test retained the null hypothesis of no differences.

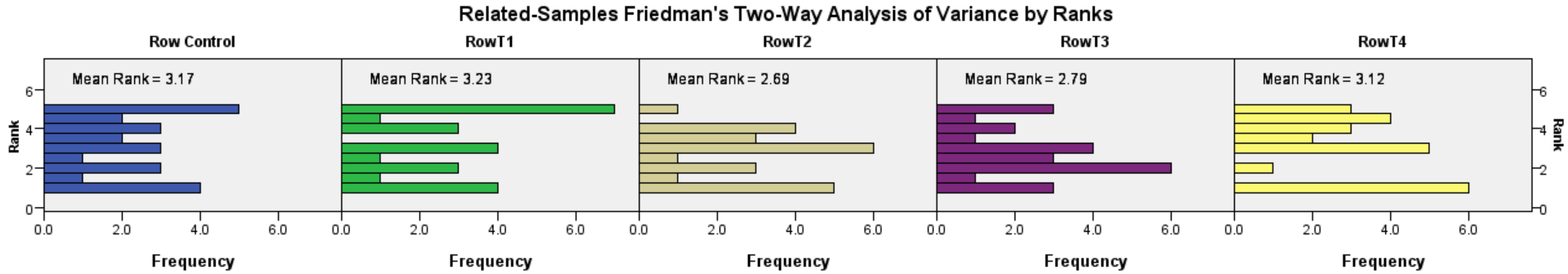
Figure D2. Friedman test results showing the effects of fertilizer types on the fertilization percentage of corn ($p < 0.05$).



Total N	24
Test Statistic	1.422
Degrees of Freedom	4
Asymptotic Sig. (2-sided test)	.840

1. Multiple comparisons are not performed because the overall test retained the null hypothesis of no differences.

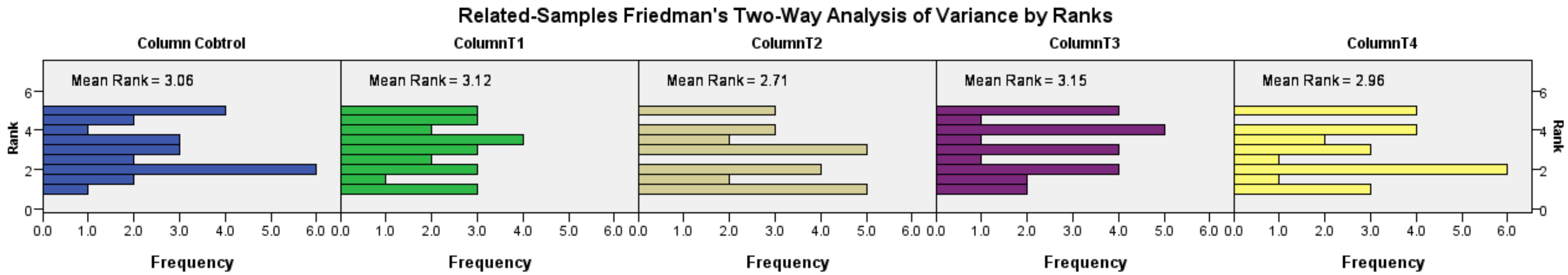
Figure D3. Friedman test results showing the effects of fertilizer types on the number of kernels per row of corn ($p < 0.05$).



Total N	24
Test Statistic	2.421
Degrees of Freedom	4
Asymptotic Sig. (2-sided test)	.659

1. Multiple comparisons are not performed because the overall test retained the null hypothesis of no differences.

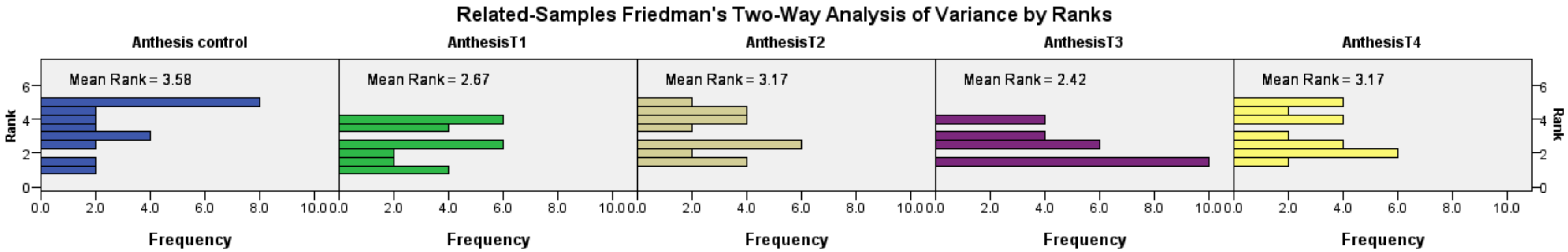
Figure D4. Friedman test results showing the effects of fertilizer types on the number of kernels per column of corn ($p < 0.05$).



Total N	24
Test Statistic	1.455
Degrees of Freedom	4
Asymptotic Sig. (2-sided test)	.835

1. Multiple comparisons are not performed because the overall test retained the null hypothesis of no differences.

Figure D5. Friedman test results showing the effects of fertilizer types on the anthesis timing of corn ($p < 0.05$).



Total N	24
Test Statistic	10.785
Degrees of Freedom	4
Asymptotic Sig. (2-sided test)	.029

Appendix E. The result of Turkey's HSD test on 100-kernel weight (*p* < 0.05*)*.

100 kernel weight

Tukey HSD[a,b]

Fertilzier	N	Subset	
		1	2
Control	24	20.8348	
T4	24	22.0592	22.0592
T3	24	22.7500	22.7500
T2	24	23.9870	23.9870
T1	24		24.6249
Sig.		.060	.188

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 16.354.

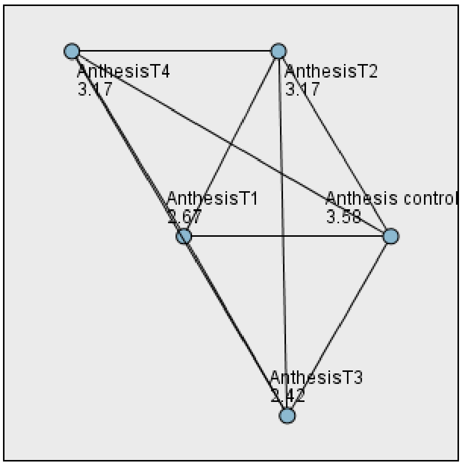
a. Uses Harmonic Mean Sample Size = 24.000.

b. Alpha = .05.

Figure E1. Turkey's HSD test showing the effects of fertilizer types on the 100 kernels weight of corn (*p* < 0.05).

Appendix F. The results of pairwise comparison on the duration form germination to anthesis of corn ($p < 0.05$).

Pairwise Comparisons



Each node shows the sample average rank.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
AnthesisT3-AnthesisT1	.250	.456	.548	.584	1.000
AnthesisT3-AnthesisT2	.750	.456	1.643	.100	1.000
AnthesisT3-AnthesisT4	-.750	.456	-1.643	.100	1.000
AnthesisT3-Anthesis control	1.167	.456	2.556	.011	.106
AnthesisT1-AnthesisT2	-.500	.456	-1.095	.273	1.000
AnthesisT1-AnthesisT4	-.500	.456	-1.095	.273	1.000
AnthesisT1-Anthesis control	.917	.456	2.008	.045	.446
AnthesisT2-AnthesisT4	.000	.456	.000	1.000	1.000
AnthesisT2-Anthesis control	.417	.456	.913	.361	1.000
AnthesisT4-Anthesis control	.417	.456	.913	.361	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure F1. Pairwise comparison showing the effects of fertilizer types on the duration from germination to anthesis of corn ($p < 0.05$).

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