BINDURA UNIVERSITY OF SCIENCE

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

EVALUATION OF STICKING AGENT AND VARIETY ON PELLETED SEED QUALITY, GERMINATION AND SEEDLING VIGOUR IN FLUE CURED TOBACCO (*Nicotiana tabacum*).

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE

(CROP SCIENCE)

JUNE 2025

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DEDICATION

I dedicate this dissertation to my cherished family and friends for their unwavering moral and spiritual support for the entire project duration.

ACKNOWLEDGEMENTS

Firstly, I would like to thank the Almighty for the strength and power he gave me during this whole project period. I am grateful to my family for moral, financial and physical support they gave me. My greatest appreciation goes to my supervisor Mr. J. Chitamba for his tireless support from the initial stages up to the very end of the research. I would like to express my sincere gratitude to Dr. Rukini and Mrs. Muchatibaya for technical support. I am forever grateful to crop science block students who continued to support and encouraging me during this study. I would also want to thank Bindura University of Science Education for granting me this opportunity to put into practice what I have learnt. Lastly, I would like to appreciate myself for great endurance throughout the whole study.

ABSTRACT

This study evaluated the effect of sticking agent and variety on pelleted seed quality, germination, and seedling vigour in flue-cured tobacco (*Nicotiana tabacum*). Pelleting is a critical technique used to enhance seed handling and improve uniformity in germination, yet the effectiveness of different sticking agent's remains under-researched, especially in Zimbabwean tobacco varieties. The experiment was conducted at the Tobacco Research Board's Seed Technology Laboratory using a 2×4 factorial treatment, laid in a completely randomized design (CRD) with eight treatments replicated four times. Two tobacco varieties (KRK 26R and KRK 76) and four sticking agent levels (sugar, polymer, a 50:50 sugar-polymer mix, and raw/uncoated seeds) were used. Data were collected on seed quality using top paper and water tests, germination percentage, seedling emergence, plant height, and stem diameter over a 4-week period. There was no significant variety × sticking agent interaction ($p>0.05$) on all parameters. Variety effects were also not significant ($p>0.05$). However, ticking agents had highly significant effect ($p<0.001$) on germination, emergence, quality and seedling vigour. Seeds treated with polymer alone exhibited the highest germination percentage (95.38%), emergence rate (85.62%), plant height, and stem diameter across all growth stages, followed by sugar-treated seeds. The sugar-polymer mix underperformed in growth parameters, while raw seeds had the poorest overall performance. Based on the research findings, field-based research is recommended to validate these findings under variable environmental conditions and across more tobacco genotypes.

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CHAPTER 1: INTRODUCTION

1.1 Background

Flue-cured tobacco (*Nicotiana tabacum*) is a significant cash crop globally, with over 6 million metric tons produced annually (Food and Agriculture Organization, 2020). The crop is mainly grown in tropical and subtropical regions, with Africa, Asia, and the Americas being the major producers (Tobacco Research Board of Zimbabwe, 2015). In Zimbabwe, tobacco is a major foreign exchange earner, with the crop generating significant revenue for the country (Reserve Bank of Zimbabwe, 2020).

Seed quality and germination rates play critical roles in flue-cured tobacco production. High-quality seeds with improved germination rates can result in better crop establishment, increased yields, and enhanced profitability for farmers (Liu *et al.*, 2019). However, flue-cured tobacco seeds are often characterized by low germination rates and poor seedling vigor, which can lead to reduced crop yields and decreased profitability (Kumar *et al*., 2020) Seed pelleting, is a widely used technique in agriculture to enhance seed performance, improve seed handling, and increase crop yields. The process involves coating seeds with a layer of material, usually a mixture of inert ingredients and sticking agents, to improve seed quality, germination, and seedling emergence (Hartmann & *Kotler*, 2014). Sticking agents play a crucial role in the seed pelleting process, facilitating the adhesion of the pellet material to the seed coat. Sugar and polymer-based sticking agents are commonly used in seed pelleting due to their non-toxic and biodegradable nature (Khan *et al*., 2017; Singh *et al*., 2020). These agents can improve seed quality by reducing seed damage during handling and storage, and enhancing seed germination and seedling emergence (Liu *et al.*, 2019; Kumar *et al.*, 2020). However, there is limited research on the

Effects of sugar and polymer sticking agents on pelleted seed quality, germination, and seedling vigor in flue-cured tobacco.

This study aims to evaluate the impacts of sugar and polymer sticking agents on pelleted seed quality, germination rates, and seedling vigor in flue-cured tobacco. The findings of this research will provide valuable insights for optimizing seed pelleting processes, improving seed quality, and increasing crop yields in flue-cured tobacco production.

1.2 Problem statement

The use of sticking agents in pelleted seeds is crucial for ensuring uniform seed coating and optimal seed germination. However, the effectiveness of sugar and polymer sticking agents on flue-cured tobacco seeds remains unclear. Current methods may result in inconsistent seed germination rates, reduced seedling vigor, and decreased seed quality. Therefore, there is a need to investigate and compare the impacts of sugar and polymer sticking agents on seed quality, germination, and seedling emergence of flue-cured tobacco to identify the most effective sticking agent and optimize seed pelleting processes.

1.3 Justification

This study aims to investigate the suitability of sugar as a sticking agent in seed pelleting. Sugar is a readily available, locally sourced material that can potentially replace or supplement the imported polymer sticking agent. By exploring the effectiveness of sugar as a sticking agent, this research seeks to promote self-sufficiency in the seed pelleting industry and reduce dependence on imported materials.

1.4 Objectives of the study

1.4.1 Main objective

To evaluate the impact of sticking agent and variety on pelleted seed quality, seed germination and seedling emergence and vigor of flue-cured tobacco.

1.4.2 Specific objectives

1. To determine the effect of sugar and polymer sticking agents on seed quality parameters of flue-cured tobacco
2. To compare the impact of sticking agent and variety on pelleted seed germination and emergence of flue-cured tobacco.
3. To assess the effect of sticking agent and variety on seedling vigor of flue-cured tobacco

1.5 Hypothesis's (H_1)

1. There is significant effect of sticking agent and variety on pelleted seed quality parameters of flue-cured tobacco.
2. There is significant effect of sticking agent and variety on pelleted seed germination and emergence of flue-cured tobacco.
3. There is significant effect of sticking agent and variety on seedling vigor of flue-cured tobacco.

CHAPTER 2: LITERATURE REVIEW

2.1. Overview of tobacco production

Tobacco production is a significant agricultural sector globally, contributing to economies through export revenues and job creation. The cultivation and processing of tobacco have deep cultural and economic roots, especially in countries where it is a major cash crop. According to the Food and Agriculture Organization (FAO), global tobacco production reached approximately 5.9 million metric tons in 2020, showcasing its importance in international agriculture (FAO, 2021).Key players in the tobacco industry include China, Brazil, and India, each employing unique agricultural practices tailored to their climatic conditions. China: As the largest producer of tobacco, accounting for about 40% of the world's total production, China utilizes various cultivation techniques that maximize yield. The country predominantly grows flue-cured tobacco, which is favored for its high quality and suitability for cigarette production Brazil: Known for its high-quality tobacco, Brazil is a leading exporter, particularly of burley tobacco. Brazilian farmers often employ sustainable agricultural practices, such as crop rotation and integrated pest management, to maintain soil health and reduce reliance on chemical inputs (World Bank, 2020).India: In India, tobacco is primarily grown in the states of Andhra Pradesh and Karnataka, where the climate is conducive to its growth. Indian farmers often use traditional methods alongside modern techniques, such as mechanized harvesting, to improve efficiency and output (Kumar *et al.*, 2021).

The production process of tobacco involves several critical stages: land preparation, planting, nurturing, harvesting, and curing. Each step requires specific techniques to ensure high-quality tobacco.

Land Preparation: This initial stage involves clearing the land, plowing, and preparing the soil to create optimal growing conditions. Farmers may test soil pH and nutrient levels to determine the necessary amendments. Planting: Tobacco seeds are usually started in greenhouses and later transplanted to fields. The timing of planting is crucial, as it affects the growth cycle and yield. In Brazil, for instance, farmers often plant tobacco in the spring to align with favorable weather conditions (Brazilian Tobacco Growers Association, 2022). Nurturing: This phase includes regular irrigation, fertilization, and pest management. Harvesting: Tobacco is typically harvested by hand, although mechanical harvesting is becoming more common in some regions. Timing is critical, as leaves should be harvested when they reach the desired maturity level.

Curing the curing process, which involves drying the leaves, significantly influences the flavor and quality of the final product. There are different curing methods, such as air curing, flue curing, and sun curing.

2.2 Tobacco production in Zimbabwe

Zimbabwe is one of the largest tobacco-producing countries in Africa, with the crop being grown mainly in the Mashonaland provinces (Tobacco Industry and Marketing Board, 2020).Tobacco production in Zimbabwe is dominated by small-scale farmers, who account for over 70% of total production. The country's tobacco industry is regulated by the Tobacco Industry and Marketing Board, which oversees the production, processing, and marketing of tobacco (Tobacco Industry and Marketing Board, 2020).

2.2.1 Economic importance

Tobacco is a significant contributor to Zimbabwe's economy, generating substantial foreign exchange earnings and providing employment for thousands of people (Reserve Bank of Zimbabwe, 2020).The industry is one of the largest contributors to Zimbabwe's agricultural Gross Domestic Product, accounting for over 10% of the country's total agricultural output (Zimbabwe National Statistics Agency, 2020). The tobacco industry is a significant employer in Zimbabwe, providing jobs for thousands of people, both directly and indirectly (Tobacco Research Board of Zimbabwe, 2015).It's estimated that the tobacco industry supports the livelihoods of over 100,000 people in Zimbabwe .it provides source of income for many rural households in Zimbabwe, contributing to rural development and poverty reduction . The tobacco industry also provides infrastructure development, such as roads, bridges, and irrigation systems, which benefit rural communities (Tobacco Industry and Marketing Board, 2020).

2.2.2 Main tobacco production areas

Zimbabwe is one of the leading tobacco producers in Africa, with significant contributions to the global tobacco market. The primary tobacco-producing regions in Zimbabwe include Harare, Manicaland, and Midlands's provinces. These areas benefit from favorable climatic conditions, such as warm temperatures and well-drained soils, which are essential for the growth of high-quality tobacco varieties. Harare, the capital city of Zimbabwe, is also an important agricultural hub. The province is characterized by its warm climate, which averages between 15°C to 30°C throughout the year, making it conducive for tobacco cultivation. According to the Zimbabwe Tobacco Association, Harare contributes approximately 20% of the country's total tobacco production (Zimbabwe Tobacco Association, 2021). The proximity to urban markets allows farmers to efficiently sell their produce, often leading to better prices. For example, smallholder farmers in Harare have reported selling their tobacco at a premium due to its quality and the reduced transportation costs to nearby markets (Chikozho *et al.*, 2020). Manicaland is known for its unique microclimates, which provide optimal conditions for high-quality tobacco growth. This province produces about 30% of Zimbabwe's total tobacco, making it a key player in the industry Farmers in Manicaland often adopt modern agricultural practices, such as crop rotation and integrated pest management, to enhance yield and quality. For instance, in 2020, farmers in the region implemented drip irrigation systems that improved water efficiency and significantly increased tobacco yields by up to 40% (Moyo *et al.*, 2021). The high-quality Virginia tobacco produced in Manicaland is sought after in international markets, particularly in Europe and Asia. Midlands Province plays a crucial role in Zimbabwe's tobacco production, benefiting from a warm climate and fertile soils. The province is responsible for about 25% of the country's tobacco farmers in the Midlands are increasingly shifting towards sustainable farming practices, including organic farming methods, to meet international market demands. For example, a study conducted by Ndlovu *et al.* (2022) highlighted that farmers transitioning to organic tobacco farming reported increased market access and higher prices for their produce due to the rising demand for organic products globally. The Midlands region is also known for its commitment to training programs that educate farmers on best practices in tobacco cultivation and sustainable agriculture

2.2.3 Varieties

Several varieties of tobacco are grown in Zimbabwe, including Virginia, Burley, and Oriental (Tobacco Research Board of Zimbabwe, 2015).Virginia tobacco is the most widely grown variety in Zimbabwe, accounting for over 90% of the country's total tobacco production (Tobacco Industry and Marketing Board, 2020).

2.3 Challenges in tobacco production

Rising temperatures, changing rainfall patterns, and increased frequency of extreme weather events affect tobacco yields and quality (IPCC, 2013).Warmer temperatures can lead to increased pest and disease pressure, while changing rainfall patterns can impact irrigation requirements. Intensive tobacco production can lead to soil erosion, nutrient depletion, and soil compaction. Soil degradation can reduce tobacco yields and affect long-term soil fertility. Tobacco is susceptible to various pests and diseases, including the tobacco mosaic virus, tobacco budworm, and hornworm (EPPO, 2020).Pests and diseases can significantly reduce tobacco yields and affect quality. Tobacco prices can fluctuate significantly due to changes in global demand, supply, and trade policies (ITGA, 2020).Market fluctuations can affect the livelihoods of tobacco farmers and the viability of tobacco production.

2.4 Tobacco seed characteristics

Tobacco seeds are remarkably small, typically measuring only 1-2 mm in diameter, which presents unique challenges and opportunities for growers. Despite their diminutive size, these seeds are packed with potential; however, their physiological characteristics play a significant role in their germination and growth. One of the key characteristics of tobacco seeds is their high sensitivity to moisture and temperature. Optimal germination occurs when seeds are exposed to the right conditions, usually between 20°C and 30°C if the temperature fluctuates outside this range, germination rates can be adversely affected. For instance, research by Hossain *et al.* (2020) demonstrated that tobacco seeds exposed to temperatures below 15°C or above 35°C experienced significant reductions in germination rates, highlighting the importance of maintaining ideal conditions during the early stages of seed development.

In addition to temperature sensitivity, tobacco seeds possess a hard seed coat that can impede water absorption. This characteristic often necessitates pre-treatment methods, such as soaking or scarification, to enhance germination rates. For example, a study conducted by Lee and Kim (2019) found that soaking tobacco seeds for 24 hours before planting increased germination rates by 30% compared to untreated seeds. This pre-treatment allows for better water uptake, facilitating the germination process.

2.4.1 Factors quality affecting tobacco seed

The quality of tobacco seeds is influenced by a plethora of factors, including environmental conditions, genetic makeup, and handling practices.

Environmental conditions

Environmental conditions during seed development and storage are critical in determining seed viability. Temperature and humidity levels are particularly important; excessive humidity can lead to seed mold and decay, while low humidity can result in desiccation. For instance, during the seed maturation phase, maintaining relative humidity levels between 50-70% is ideal for preventing seed deterioration (Gonzalez *et al.*, 2021). Furthermore, the storage environment post- harvest plays a vital role; seeds stored in cool, dry conditions typically exhibit higher viability rates than those kept in warm, humid environments.

Genetic factors

The genetic composition of tobacco seeds significantly influences their resilience and adaptability to various growing conditions. Hybrid varieties, which are often bred for specific traits such as disease resistance or drought tolerance, tend to have enhanced performance compared to traditional varieties. For example, research by Smith *et al*. (2018) revealed that hybrid tobacco seeds demonstrated a 20% increase in yield under drought conditions compared to non-hybrid counterparts. This genetic diversity enables farmers to select seed varieties that are best suited for their specific climate and soil conditions, ultimately leading to improved crop outcomes.

Handling factors

Lastly, handling practices during harvesting and storage can profoundly impact seed quality. Improper handling can lead to physical damage, which not only affects seed viability but also germination rates. For example, rough handling during the harvesting process can cause bruising or cracking of seeds, making them more susceptible to diseases and reducing their ability to germinate. A study by Choudhury *et al.* (2020) found that seeds subjected to harsh handling conditions exhibited a 15% decrease in germination rates compared to those handled with care. Proper training for farmers and workers on best practices for harvesting and storing seeds is crucial in preserving seed integrity and enhancing overall quality.

2.5 Seed coating and pelleting

Seed coating and pelleting are innovative agricultural practices that enhance the quality and performance of seeds. These processes aim to improve seed viability, protect against environmental stresses, and facilitate planting. Understanding the principles and types of seed coatings is essential for optimizing seed production and crop outcomes.

2.5.1 Principles of seed coating

Seed coating refers to the application of a protective layer of material onto the seed surface. This practice serves multiple purposes. Coatings can contain fungicides and insecticides that shield seeds from pathogens and pests during the early stages of growth. For instance, a study by Flessa *et al*. (2019) demonstrated that seeds coated with a fungicide had a significantly lower incidence of seedling diseases compared to untreated seeds the coating can improve seed flow ability and reduce dust during planting, making the process smoother. This is particularly beneficial in large-scale agricultural operations where efficiency is crucial by providing a controlled environment for the seed, coatings can enhance germination rates. For example, coatings can help retain moisture around the seed, creating optimal conditions for sprouting. Coatings can also be formulated to include nutrients and growth stimulants, providing seeds with essential resources at the start of their growth. This can be particularly advantageous in nutrient-poor soils, giving the seedlings a better chance of establishing themselves.

2.5.2 Types of seed coatings

Film Coatings: This type of coating involves applying a thin layer of material that enhances seed uniformity and provides a protective barrier against pathogens. Film coatings are usually made from polymers and can include active ingredients to promote plant health. Encrustations are thicker coatings that can incorporate fertilizers or pesticides, offering additional benefits. This approach allows for the simultaneous delivery of growth nutrients and protection against pests and diseases during the critical early growth phase. A study by Wang *et al*. (2018) indicated that encrusted soybean seeds resulted in higher yields compared to uncoated seeds, attributed to the added nutrients and protection. Pelleting is a more advanced process that results in larger, more uniform seeds that are easier to plant. This method involves forming a pellet around the seed using various materials, often including clay, which provides weight and size uniformity. Pelleted seeds are particularly useful for precision planting, as they facilitate accurate seed placement.

2.5.3 Pelleting process

Pelleting is a sophisticated agricultural technique that involves creating a solid, rounded mass around seeds to enhance their performance during planting and growth. This process typically includes the addition of binders and various materials that contribute to the overall structure and efficacy of the pellets. Seed preparation: The first step in the pelleting process involves selecting and preparing the seeds. This may include cleaning the seeds to remove any impurities and ensuring they are dry. Optimal moisture content is crucial, as it affects the binding process.

Binder addition: Binders are materials added to facilitate the formation of pellets and ensure that the seeds remain intact. Common binders include clay, starch, and various natural polymers. The choice of binder can significantly influence the pellet's strength and durability

Mixing and conditioning: The seeds, along with the binder and any additional materials (such as nutrients or pesticides), are thoroughly mixed. This step often involves conditioning, where heat and moisture are applied to improve the binding properties of the materials. Conditioning helps to soften the binder, making it easier to form uniform pellets.

Pellet formation: The actual formation of pellets occurs in a pellet mill or granulator. The mixture is forced through a die, shaping it into round pellets. The size and shape of the die determine the final pellet dimensions. Research by Wang *et al*. (2021) indicated that using a die with specific hole diameters can optimize pellet size for various crop types, improving planting efficiency.

Drying and cooling: After formation, the pellets are often subjected to drying and cooling processes to remove excess moisture and enhance shelf stability. Proper drying is essential to prevent mold and decay during storage.

Quality control: The final step involves quality control checks to ensure that the pellets meet specific standards for size, weight, and integrity. This may include tests for hardness, disintegration time, and nutrient release rates. Quality assurance is crucial for maintaining the effectiveness of the pelleted seeds during planting and growth.

Advantages of pelleting Improved seed handling: Pelleted seeds are generally easier to handle and plant, reducing the risk of damage during transportation and sowing. Their uniform size allows for better flow through planting equipment, minimizing clogs and breakdowns

Reduced seed loss during planting: The round shape and cohesive structure of pellets help prevent seed loss during planting. Unlike bare seeds, which may bounce or roll away, pellets tend to stay in place during the planting process, ensuring more accurate placement in the soil. This can lead to higher planting success rates.

2.6 Sticking agents in seed coating

Sticking agents play a crucial role in the seed coating process, ensuring that the various materials applied to seeds adhere effectively. This adherence is vital for protecting seeds during handling and planting while enhancing their overall performance in the field..

2.6.1 Definition and purpose of sticking agents

Definition: Sticking agents are substances specifically designed to enhance the adhesion between seed coatings and the seeds themselves. These agents facilitate the binding of the coating materials, ensuring they do not peel off during processing, transportation, or planting. The primary purpose of sticking agents is to maintain the integrity of the seed coating throughout its lifecycle. By ensuring that the coating remains intact, sticking agents help protect the seed from environmental stressors, pests, and diseases. Furthermore, they can enhance the seed's performance by providing nutrients or promoting moisture retention

2.6.2 Types of sticking agents

Sticking agents can be categorized into several types based on their composition and functionality. Common types Include: Natural sugars, such as sucrose and glucose, are frequently used as sticking agents. These substances not only enhance adhesion but also serve as a source of energy for the seeds. For instance, research by Singh *et al*. (2020) showed that the addition of glucose in the seed coating improved germination rates and early seedling growth by providing readily available energy, which is particularly beneficial in the early stages of development.

Polymers: Sticking agents can also be polymers, which may be either natural or synthetic. Natural polymers, such as starch, are commonly used due to their biodegradability and effectiveness in promoting adhesion. Synthetic polymers, like polyvinyl alcohol (PVA), are favored for their durability and water

Waxes are another category of sticking agents utilized in seed coatings to form a water-resistant barrier around the seed. This barrier helps to reduce moisture loss and protects the seed from various environmental factors. For example, a study conducted by Tiwari *et al.* (2022) found that using a wax coating significantly reduced water loss in seeds during storage, leading to better seed viability and germination rates.

2.6.3 Effects of sticking agents on seed quality

The selection of sticking agents plays a pivotal role in determining seed quality, influencing various factors such as germination rates, seedling vigor, and overall plant health. Effective sticking agents contribute positively to seed performance by ensuring that the protective coatings remain intact and functional throughout the seed’s lifecycle. One significant effect of high- quality sticking agents is the improvement in seed germination rates. Enhancement is largely due to the protective barrier formed by the sticking agents, which helps to prevent damage during handling and planting, as well as reducing the risk of seed-borne diseases. Moreover, sticking agents also play a crucial role in promoting seedling vigor

Is important to note that if sticking agents are not properly formulated, they can have adverse effects on seed quality. For instance, excessive use of certain sticking agents may create a barrier that restricts gas exchange and water absorption, leading to poor germination and weak seedlings.

2.7 Sugar sticking agents

Sugar sticking agents are a specific category of sticking agents that utilize various types of sugars to enhance adhesion and support seed performance. These agents are valued for their ability to provide both adhesive qualities and nutritional benefits to seed

2.7.1 Types of sugar sticking agents

Sucrose is one of the most commonly used sugar sticking agents due to its excellent adhesive properties. It not only helps in binding the coating materials to the seeds but also serves as an energy source Glucose Known for its high solubility and rapid absorption by seeds, glucose is another effective sugar sticking agent. Its quick uptake allows for immediate energy availability, which is crucial for seed germination. Research by Martin *et al.* (2020) indicated that glucose-coated seeds germinated faster and produced healthier seedlings compared to those with other types of sticking agents. This rapid absorption can be particularly beneficial in environments where quick establishment is necessary.

Fructose is often utilized in seed coatings for its ability to enhance seedling vigor. Its unique biochemical properties can stimulate growth and development in young plants

2.7.2 Effects of sugar sticking agents on seed quality

The use of sugar sticking agents in seed coatings has been shown to significantly enhance seed quality, particularly in terms of germination speed and seedling strength. These benefits are essential for optimizing crop establishment and overall agricultural Furthermore, the benefits of sugar sticking agents extend beyond germination rates to include improved seedling vigor. A study conducted by Thompson and Johnson (2020) highlighted that seedlings from glucose- coated seeds exhibited stronger root systems and healthier foliage than those from untreated seeds. The research indicated that the presence of glucose not only provided an immediate source of energy during the early stages of growth but also stimulated physiological processes that enhance root development and nutrient. In addition to sucrose and glucose, fructose also plays a significant role in enhancing seed quality. A study by Patel *et al.* (2022) demonstrated that seeds coated with fructose showed improved seedling performance, with increased biomass and resilience against environmental stresses. These findings suggest that fructose can enhance the metabolic activities of seedlings, leading to stronger plants that can better withstand unfavorable conditions.

2.8 Gaps in Current Knowledge

2.8.1 Limitations of Current Research

Current research on sticking agents in tobacco seed production presents several notable limitations, particularly concerning the long-term effects of these agents on seed performance. While there has been a significant amount of research devoted to the immediate outcomes associated with the use of various sticking agents, a comprehensive understanding of their impact over extended periods remains largely unaddressed

2.8.2 Need for Further Research.

There is a pressing need for further research to explore the effects of sugar and polymer sticking agents on pelleted seed quality, germination, and seedling vigor in flue-cured tobacco. As the tobacco industry seeks to enhance production efficiency and sustainability, understanding the interactions between these sticking agents and seed performance becomes increasingly critical.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Study site

The study was conducted in the Seed Technology Laboratory at Tobacco Research Board Kutsaga Harare, Zimbabwe (17.8551°S 31.0464° E).At an altitude of 1.470 above sea level. It falls under natural region 2 with annual rainfall of 700 to 1050mm.The laboratory is equipped with state-of-the-art facilities and equipment, including seed pelleting machines, germination chambers, and growth rooms. The laboratory provides a controlled environment with precise temperature of +/- 20 degrees Celsius, humidity, and light control, allowing for accurate and reliable experimentation. The seed pelleting process was conducted using a specialized machine, and the pelleted seeds was germinated and grown in controlled environment chambers.

3.2 Experimental design

The research was conducted as a 2×4 factorial treatment structure, laid in a completely randomized design (CRD) with 8 treatments replicated 4 times to give 32 experimental units (petri dishes)

The 8 treatments were as follows:

Polymer × K RK 26R (A)

Polymer × K RK 76 (B)

Sugar × K RK26R (C)

Sugar × K RK 76 (D)

Raw seed × K RK 26R (E)

Raw seed × K RK76 (F)

50% sugar 50% polymer × K RK 26R (G)

Half sugar half polymer × K RK 76 (H)

Table 3.1 Experimental Layout

REP 1	REP 2	REP 3	REP 4
G	H	E	F
D	B	D	G
A	E	H	E
H	C	A	A
F	D	B	D
B	F	F	H
C	A	G	C
E	G	C	B

3.3 Preparation of pelleting

To ensure the drum was clean and free of any unwanted seeds, I thoroughly cleaned it with a cloth and blew it out to remove any debris. This was crucial to prevent mixing seeds from different varieties. After cleaning the drum I make sure the water pipes where clean and I filled the water tank with clean water For the polymer treatment, I mixed it at 1:2 ratio, combining 200ml of concentrated polymer with 400ml of water to make 600ml of solution for pelleting then I weigh 5 grams apron star (insecticide) and 40 grams (food color blue) I started pelleting K RK26 R short season variety first, followed by the KRK 76 long season variety on a separate day to avoid any potential contamination.

Sugar Treatment

For the sugar treatment, I dissolved 500 grams of brown sugar in water to make 1 litre of solution, aiming for a similar consistency to the polymer solution. I tested the concentration by hand until I achieved the desired thickness.

Combination Treatment

For the 50%sugar and 50 %polymer treatment, I mixed 250ml of dilute polymer with 250ml of dilute sugar and used this solution for pelleting.

3.3.1 Pelleting Procedure

20 grams of seeds was used for each treatment. The pelleting process involve spraying water to moisten the seeds, followed by adding powder and alternating with water until the seeds reached a diameter of 1 millimeter. Apron star was then added when the seed is covered with powder, Seed was removed from the pelleting drum to the calibrating machine. The calibration machine is used to separate seeds based on their size. It works by directing seeds into two different dishes. Seeds that are less than 1.8 millimeters in size fall into the first dish, while seeds that have reached the desired size of 1.8 millimeters fall into the second dish. Seeds that fall into the first dish (undersized) are recirculating back into the pelleting drum for further coating until they reach the desired size. This continuous process ensures that all seeds meet the required size standard, with the calibration process considered complete when all seeds have been sorted into the second dish. The final pelleted seed size is 1.8milimetre so after reaching the size we then add food color after all the seed is mixed with color we then start spraying polymer at this stage, we add polymer to the seeds for about 10 minutes to achieve the desired outcome. The polymer, sugar concentration and half sugar half polymer coating gives the seeds a shiny appearance and helps bind the powder

Raw Seed

Seed was put in pelleting drum and moisten the seed by spraying water .Once the seed is moist different coating treatments are applied. Polymer, sugar and half sugar half polymer treatment each treatment is applied to a separate batch of 20grams, allowing for comparison of different coating effect

3.2.2 Drying Process

Seed is labeled and put in a dryer for 1 hour to remove excess moisture. After this drying period, the seeds are fully dried and ready for planting.

Seeds are removed from the dryer and packaged in separate pockets for each variety, with clear labeling. Quality testing is then conducted using two methods Water Test. Half fill sampling spoon with pelleted seed with then drop at once into the petri dish with water and observe the seconds taken for pellets to disintegrate Maximum duration is 15sec and minimum is 6sec for water test For top of paper we use filter paper that we use to plant pelleted seed. We use the same method and maximum is 60sec and minimum is 30sec

3.3.3 Planting Procedure

Seeds that pass the quality test are then planted in Petri dishes. The planting process involves .Surfaces is cleaned, and Petri dishes are disinfected with methylated spirit and cleaned with cotton wool. Let them dry for 5 minutes .Afterwards cotton wool is placed is petri dish which is neatly cut with the shape of the petri dish. Then potassium nitrate (KNO3) solution used to break dormancy is sprayed to moisten the cotton wool .Excess solution should be drained. Then filter paper with 100 cells is placed on top of the cotton wool written variety, date of planting and treatment method besides the cells .Pellets are planted on each cell. Each treatment is represented with 4 petri dishes. After planting Petri dishes are placed in incubators 1-4with controlled temperature ±20°C.

3.3.4 Seed bed preparation and planting

Cleaned and disinfect the float trays to prevent any potential contamination. Moisten the growing medium before planting to ensure it's at the optimal moisture level for seed germination. Label each float tray according to the treatment allocation, including the replication number, treatment number, and variety (K RK 26R or K RK 76).Allocate the coated and raw seeds to the designated cells in each float tray according to the treatment specifications. Planted one seed per cell, by gently pressing the seed into the growing medium to ensure good contact. Made sure the seeds are planted at the correct depth, usually about 0.5-1 cm. Then watering the seeds gently but thoroughly after planting to settle the growing medium and provide adequate moisture.

Greenhouse Conditions

Maintain a consistent temperature between 20-25°C to promote optimal seed germination and seedling growth. Ensure adequate lighting for the seedlings

3.4 Data collection

3.4.1 Quality parameter

Data was captured using two method top of filter paper and water test. In the water test, pellets were sprinkled into a petri dish filled with water using a sampling spoon to measure the time taken in seconds for the seeds to disintegrate. The same method was used for the top of filter paper test, where seeds were sprinkled onto filter paper using a sampling spoon to record the time taken in seconds for the seeds to disintegrate. These tests were conducted to assess the quality parameter of the seeds. Water test maximum duration is 15sec and minimum is 6sec .Top of paper maximum is 60sec and minimum is 30sec

3.4.2 Seed germination

Seeds was planted in petri dishes and placed in an incubator with a controlled temperature of plus or minus twenty degrees Celsius. The first count was taken on the seventh day, where seeds that had germinated with a clear root, leaves and stem were counted and recorded on a germination test form. Seeds that had not yet germinated were left in the petri dish for the second count, which was done on the sixteenth day (final count). During the final count, the remaining seeds that had germinated were counted and recorded, and the total number of germinated seeds was calculated by adding the first and second counts. Abnormal seeds and dead seeds were also recorded. The germination percentage was calculated by adding all the numbers, dividing by the total number of seeds, and then multiplying by one hundred to determine the germination percentage for each variety.

3.4.3 Seedling vigour

Seedling vigor parameters were evaluated in a greenhouse experiment. Seeds were sown in 200-cell float trays, with each tray representing a treatment, and maintained under controlled temperature conditions. Days to first emergence was recorded on the seventh day and percentage emergence was calculated by dividing the number of germinated seeds over the total number of seeds planted multiplying by 100. Subsequently, plant height and stem diameter were measured weekly from week two to week four to assess seedling vigor.

3.5 Data analysis

Data collected from seed quality tests, germination percentages, and seedling vigor measurements were analyzed using Analysis of Variance (ANOVA) to determine the significance of treatment effects. The analysis was conducted using a Completely Randomized Design (CRD) with 8 treatments replicated 4 times. Statistical significance was tested at a 5% level ($p<0.05$) to compare differences among treatment means. GenStat helped identify which sticking agent treatments produced the best seed quality and seedling performance.

CHAPTER 4: RESULTS

4.1 Effect of sticking agent and variety on pelleted seed quality parameters of flue-cured tobacco

4.1.1 Top of paper test

Sticking agent had highly significant effects ($p>0.001$) on top paper test values. Sugar treatment had the best quality (31.75 sec) followed by polymer (35.88 sec) lastly 50% sugar 50% polymer which took (55.5 sec). Raw seed treatment had also poor quality as its top of paper test score was 0 (Fig. 4.1). Variety had no significant effect ($p=0.716$) on seed quality through the top of paper test. There was no significant interaction between sticking agent and variety.

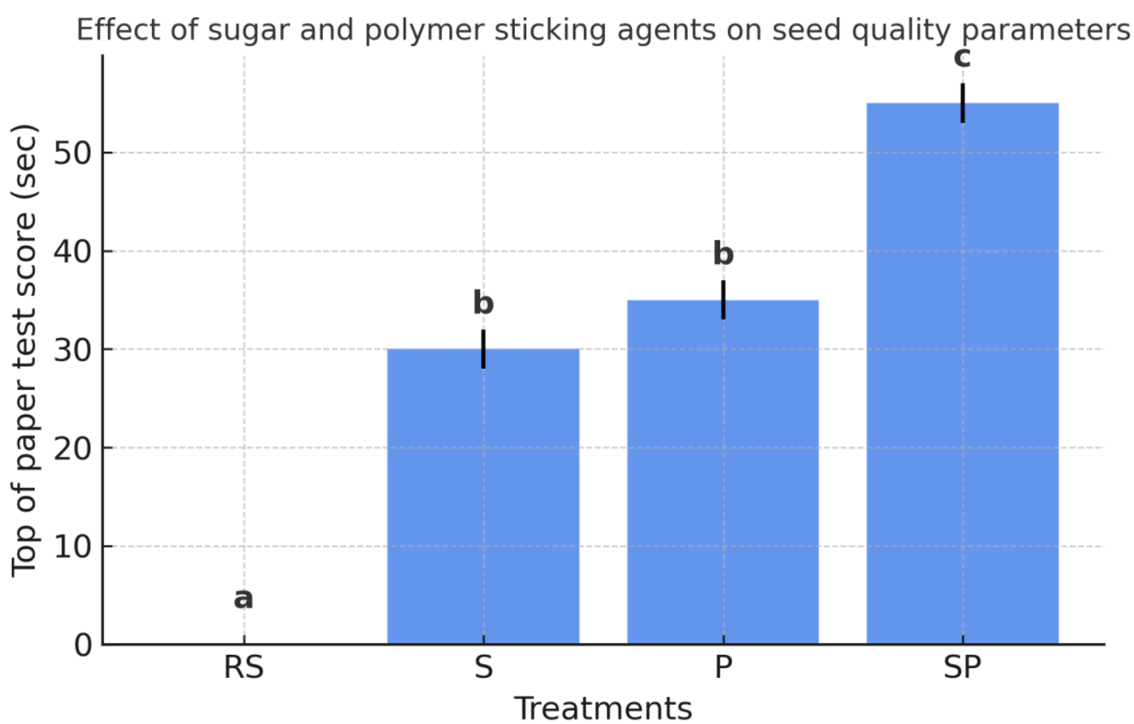

Fig 4.1: Effect of sugar and polymer sticking agents on seed quality parameters on top of paper test

4.1.2 Water test

Sticking agent had highly significant effect (p>0.001) on water test values. Sugar treatment had the best (6.00sec) followed by polymer (6.88sec) lastly50% sugar 50% polymer which took (16.62sec). Raw seed treatment had also poor quality as its water test score was 0.75sec (Fig. 4.2). Variety had no significant effect (p=0.549) on seed quality through the water test. There was also no significant interaction between sticking agents and variety p=0.3 on seed quality through the water test

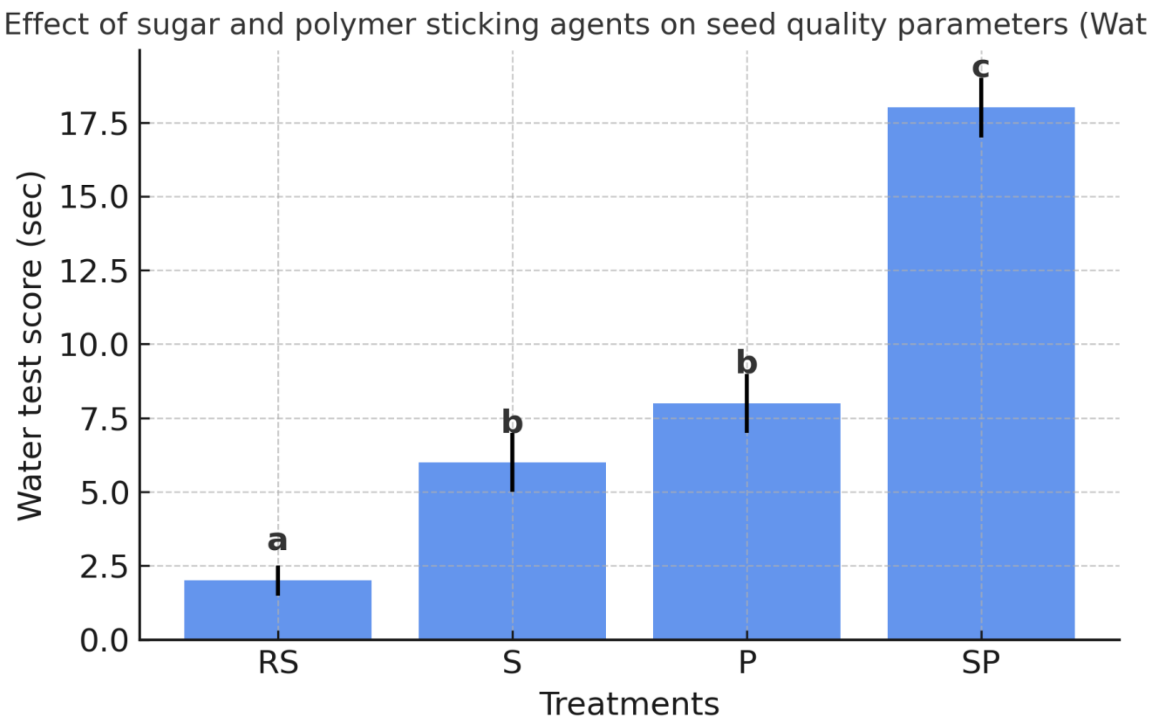

Fig 4.2: Effect of sugar and polymer sticking agents on seed quality parameters on water tests

4.2 Effect of sticking agent and variety on pelleted seed germination and emergence of flue-cured tobacco.

Sticking agent had highly significant effects ($p>0.001$) on seed germination and emergence .Polymer treatment had the highest germination and emergence (95.38 and 85.62 respectively) .while raw seed treatment had the lowest seed germination and emergence (73.5 and 64.23% respectively). This is shown on Fig 4.3. Variety had no significant effect ($p <0.05$) on seed germination and emergence. There was no significant interaction between sticking agent and variety ($p < 0.05$) on seed germination and emergence.

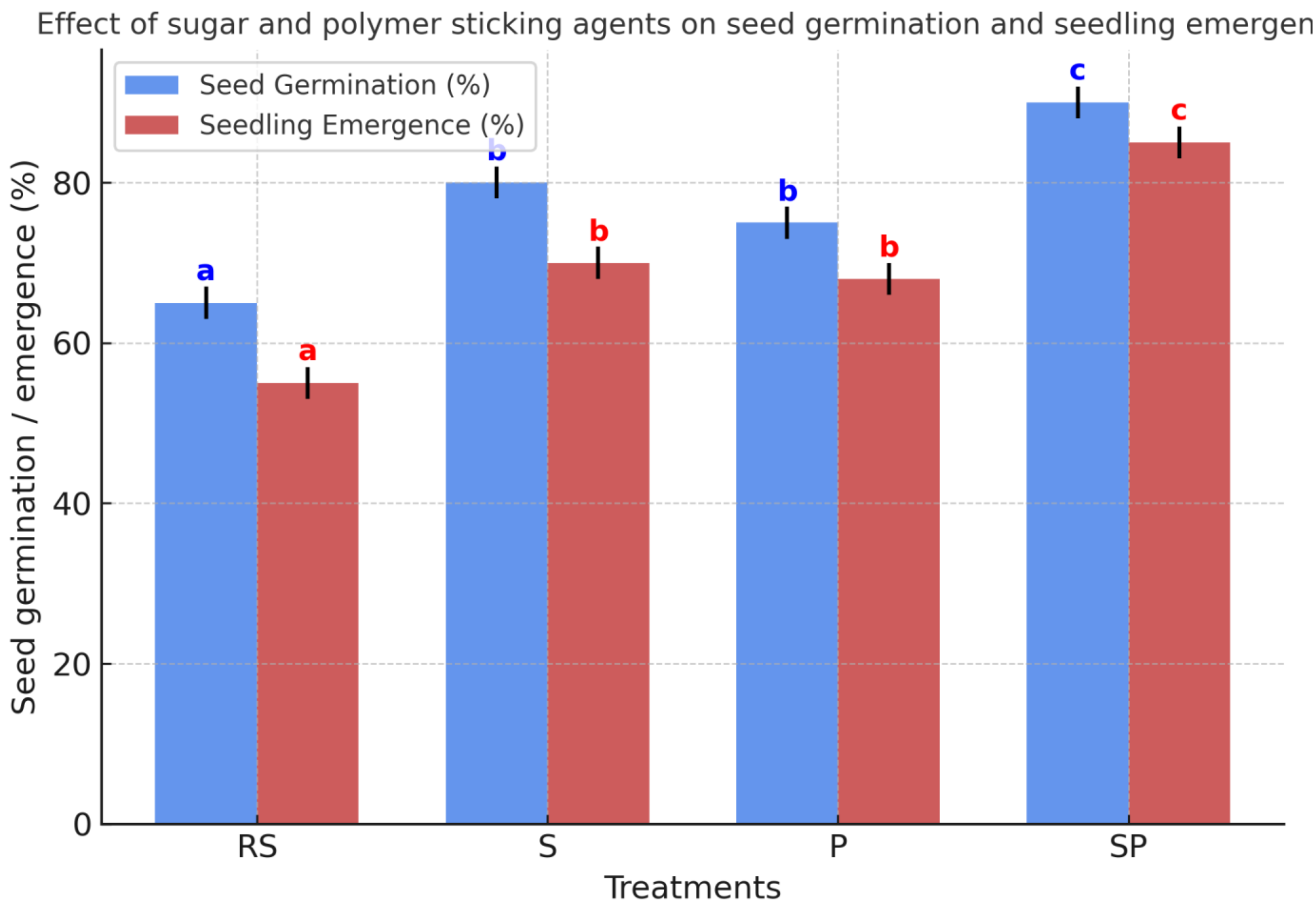

Fig 4.3; Effect of sugar and polymer sticking agents on seed germination and emergence

4.3 Effect of sticking agent and variety on seedling vigour of flue-cured tobacco

4.3.1 Plant height

Sticking agent had highly significant effect ($p>0.001$) on plant height at week 2, 3, and 4 after planting. The polymer treatment and sugar treatment produced taller plants across all weeks consistently whereas 50% sugar and 50% polymer resulted in the shortest plants. (Table 4.1). Variety had no significant effect ($p <0.05$) on plant height. There was no significant interaction between sticking agent and variety ($p < 0.05$) on plant height.

Table 4.1 Effect of sugar and polymer sticking agents on plant height

Treatment	2 WAP	3 WAP	4 WAP
P	6.112a	9.575b	11.65b
RS	3.675c	8.238c	10.30c
S	5.338b	9.925a	11.06b
SP	2.500d	7.238d	9.24d
P-value	<0.001	<0.001	<0.001
LSD (5%)	0.2824	0.5526	0.592
CV%	2.93	3.21	2.89

4.3.2 Stem diameter

Sticking agent had highly significant effect ($p>0.001$) on stem diameter at week 2, 3, and 4 after planting. The polymer treatment and sugar treatment produced thicker stem across all weeks consistently whereas 50% sugar and 50% polymer resulted in thinner plants (Table 4.2) .Variety had no significant effect ($p <0.05$) on stem diameter. There was no significant interaction between sticking agent and variety ($p < 0.05$) on stem diameter

Table 4.2 Effect of sugar and polymer sticking agents on stem diameter

Treatment	2 WAP	3 WAP	4 WAP
P	2.012a	3.188a	4.062a
RS	1.887a	2.963b	3.812b
S	1.950a	3.025ab	3.875ab
SP	1.688b	2.438c	3.000c
P-value	0.002	<0.001	<0.001
LSD (5%)	0.1225	0.1995	0.2226
CV%	4.96	5.15	4.74

CHAPTER 5: DISCUSSION

5.1 Effect of sticking agent and variety on pelleted seed quality parameters (top of paper and water tests)

The water test results showed significant treatment effects with treatment 50% sugar 50% polymer showing the highest values (16.62) while raw seed treatment had the least values (0.75). This indicates varying coating solubility and dissolution rates amount the different treatments. Likewise the top paper test showed 50% sugar 50% treatment superiority (52.75) indicating better moisture retention as well as distribution properties these outcomes are consistent with smith *et al*. (2018) conclusions about the importance of coating material selection for optimal seed moisture interactions

5.2 Effect of sugar and polymer sticking agents on seed germination and emergence of flue-cured tobacco

Seed germination showed strongly significant treatment effects with polymer treatment having the highest germination rate (95.38%) followed by sugar treatment (89.25%). The results are consistent with Choudhury *et al.* (2020) who reported that appropriate seed coating treatments can improve germination by up to 30%. The germination rates in raw seed treatment (73.50%) indicate possible inhibitory effects potentially as a result of coat thickness or composition affecting moisture penetration.

5.3 Effect of sugar and polymer sticking agents on seedling vigor of flue-cured tobacco

5.3.1 Plant height

Plant height measurements showed strong treatment effects across all-time points with polymer treatment and sugar treatment generally outperforming raw seed treatments and 50% sugar 50%. The temporal pattern showed shifting treatment advantages with polymer treatment dominating at two weeks after planting (6.112 cm), sugar leading at three weeks after planting (9.925 cm) and polymer regaining its upper hand at four weeks after planting (11.65 cm). This dynamic response pattern is consistent with research by Hossain *et al*. (2020) who discovered that seed treatment benefits can change throughout the growth cycle due to changing plant requirements and environmental interactions.

The minimal variety effects at two weeks after planting followed by non-significant variety differences at later stages suggest that genetic influences on height are most pronounced during the early stages of growth. The significant variety sticking agents interactions at two weeks after planting as noted by Lee and Kim (2019) show that optimal treatment selection should consider genetic background more so for early stage growth management.

5.3.2 Stem diameter

The research showed significant temporal changes in stem diameter response to sticking agent treatments across the growing period. At two weeks after planting and three weeks after planting while variety effects were non-significant polymer consistently produced the greatest stem diameter showing superior early stage growth promotion. This is consistent with findings by Flessa *et al.* (2019) who reported enhanced stem-growth parameters in treated seeds when compared to untreated controls. By four weeks after planting there was a significant variety effect which emerged with KRK26R showing better performance suggesting genetic influence on stem development became more pronounced with lapse of time.

The insignificant variety by sticking agents interactions at 2 , 3 and 4 weeks after planting shows that genetic factors did not affect treatment response as plants mature. This is inconsistent with Wang *et al.* (2018) who had different observations where seed treatment effects varied by genotype during growth stages. Polymer treatment consistently gave superior results throughout the study period indicating consistent growth promotion benefits while treatment50% sugar 50% consistently gave the smallest stem diameter possibly due to interactions between coating components affecting nutrient availability or uptake.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The research showed that sugar and polymer-based sticking agents influenced seed quality, germination, emergence, and early seedling vigour in flue cured tobacco significantly. Treatment P recorded the best germination and emergence rates as well as superior seedling height and stem diameter .however the sugar treatment had best quality under the top of paper and water test. 50% sugar 50% treatment had subpar performance in germination and growth. Treatment RS had the weakest performance of all the treatments investigated. Variety effects were generally minimal except at the later stages of growth were interactions became apparent.

6.2 Recommendations

Based on the research findings seed analyst are recommended to use polymer as a sticking agent for flue cured tobacco seed. However where polymer is unavailable use of sugar as sticking agent is equally recommended as it had highest quality and good seed germination, emergence and vigour.

The research needs to be undertaken in field conditions to validate laboratory findings and to determine treatment performance under environmental variability.

Further investigations are recommended in order to assess long-term yield effects and test additional flue cured tobacco cultivars for genotype specific responses to coating treatments.

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APPENDICES

Appendix 1.1: Analysis of variance for top of paper

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	11640.8	3880.28	1871.89	<.001
Variety	1	0.281	0.281	0.14	0.716
Sticking agent	3	1.844	0.0615	0.3	0.828
Residual	24	49.75	2.073		
Total	31	11692			

Appendix 1.2: Analysis of variance for water test

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	1051.63	350.542	258.86	<.001
Variety	1	0.5	0.5	0.37	0.549
Sticking agent	3	5.25	1.75	1.29	0.3
Residual	24	32.5			
Total	31	1089.88			

Appendix 2.1: Analysis of variance for seed germination

Source of variation	d.f.	s.s.	m.s.	v.r	F pr.
Sticking agent	3	2080.25	693.42	57.99	<.001
Variety	1	3.12	3.12	0.26	0.614
Sticking agent	3	25.12	8.38	0.7	0.561
Residual	24	287	11.96		
Total	31	2395.5			

Appendix 2.2: Analysis of variance for seedling emergence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	1949.25	649.75	71.37	<.001
Variety	1	0.125	0.125	0.01	0.908
Sticking agent	3	34.125	11.375	1.25	0.314
Residual	24	218.5	9.104		
Total	31	2202			

Appendix 3.1: Analysis of variance for plant height 2WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	63.5763	21.1921	316.89	<.001
Variety	1	0.28125	0.28125	4.21	0.051
Sticking agent	3	0.87623	0.29208	4.37	0.014
Residual	24	1.605	0.06688		
Total	31	66.3388			

Appendix 3.2: Analysis of variance for plant height 3WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	36.8912	12.2971	39.27	<.001
Variety	1	0.3612	0.3612	1.15	0.293
Sticking agent	3	0.1913	0.0638	0.2	0.893
Residual	24	7.515	0.3131		
Total	31	44.9588			

Appendix 3.3: Analysis of variance for plant height 4WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	26.0575	8.6858	26.66	<.001
Variety	1	0.605	0.605	1.86	0.186
Sticking agent	3	0.4725	0.1575	0.48	0.697
Residual	24	7.82	0.3258		
Total	31	34.955			

Appendix 3.4: Analysis of variance for stem diameter 2WAP

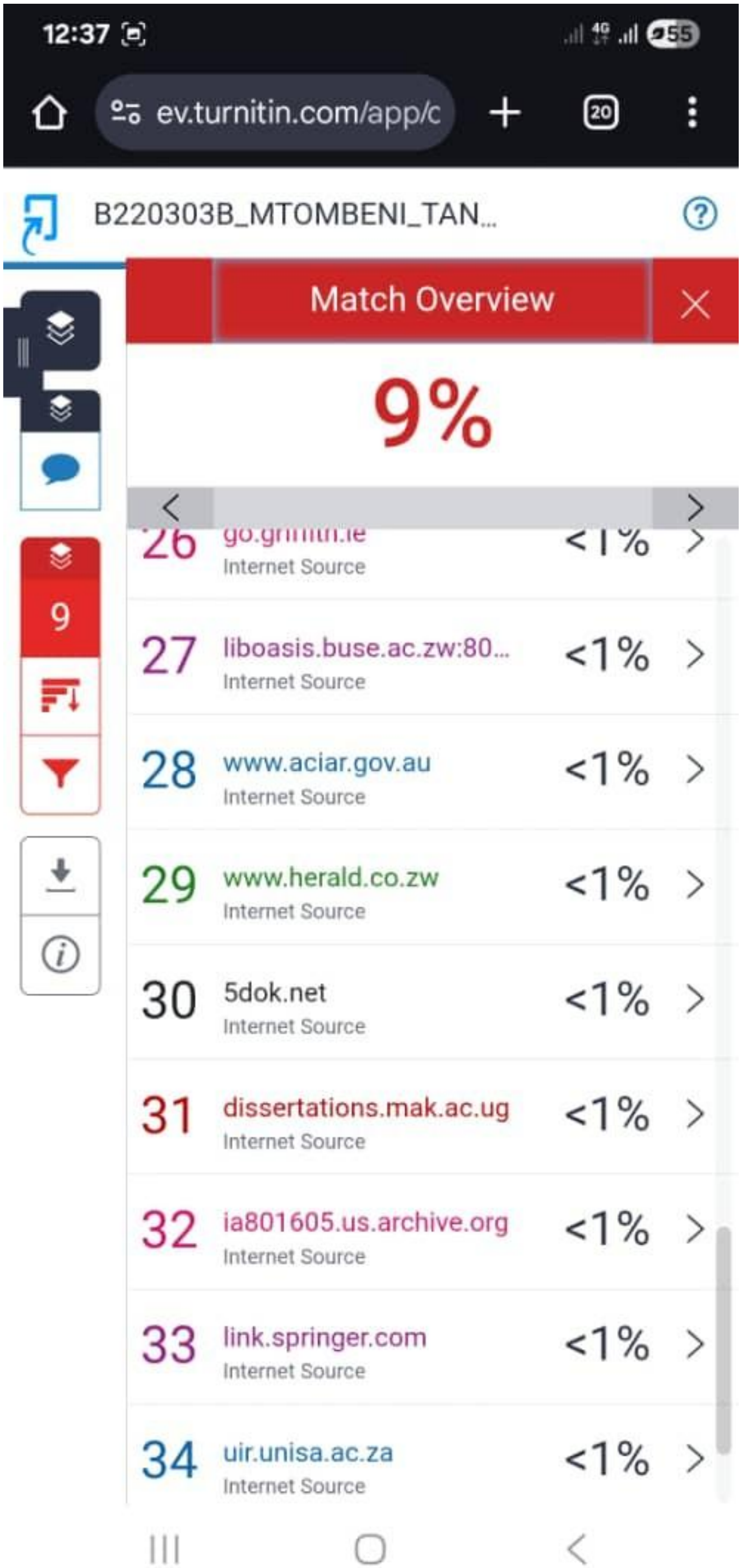
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	1.94344	0.64781	36.8	<.001
Variety	1	0.00781	0.00781	0.44	0.512
Sticking agent	3	0.03844	0.01281	0.73	0.545
Residual	24	0.4225	0.0176		
Total	31	2.41219			

Appendix 3.5: Analysis of variance for stem diameter 3WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	4.96625	1.65542	49.35	<.001
Variety	1	0.00125	0.00125	0.04	0.849
Sticking agent	3	0.03625	0.01208	0.36	0.782
Residual	24	0.805	0.03354		
Total	31	5.80875			

Appendix 3.6: Analysis of variance for stem diameter 4WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sticking agent	3	5.0525	1.68417	65.19	<.001
Variety	1	0.125	0.125	4.84	0.038
Sticking agent	3	0.2025	0.0675	2.61	0.075
Residual	24	0.62	0.002583		
Total	31	6			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