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The Effect of Harvesting Speed and Cutting Angle on the Efficiency of the Wheat Harvester

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Abstract

Wheat is considered a strategic crop of great importance for food security, making the development of harvesting technologies and the improvement of machine efficiency essential factors for reducing losses and increasing yield. This research aims to study the effect of two main variables in the harvesting process—harvesting speed and cutting angle—on the efficiency of the wheat harvester. The focus was placed on key performance indicators such as grain loss rate, percentage of broken grains, energy consumption, and overall harvesting efficiency.

Field experiments were conducted at different harvesting speed levels (low, medium, and high), in addition to adjusting cutting angles to suit the position of the spikes as they enter the cutting unit. The results showed that although high harvesting speed increases the machine's production capacity, it also leads to a significant rise in grain loss due to ejection outside the harvesting unit, as well as an increase in breakage caused by the violent collision of grains inside the machine. In contrast, low speeds reduce both loss and breakage but also lower the machine's production capacity, making them uneconomical under large-scale practical conditions. Medium speed, however, proved to be the optimal choice, as it achieved a remarkable balance between productivity, operational efficiency, and reduced losses.

Moreover, the study demonstrated that the cutting angle plays a fundamental role in determining the efficiency of spike entry into the harvesting unit. Inappropriate angles cause difficulties in feeding the spikes into the machine, leading to increased losses and negatively affecting process consistency. Conversely, adopting an optimal cutting angle improved the flow of spikes and reduced breakage, which positively reflected on overall harvesting efficiency.

The study concludes that improving harvesting efficiency requires adjusting both harvesting speed and cutting angle within optimal limits that maximize grain yield while minimizing field and energy losses. It recommends adopting a moderate harvesting speed combined with a suitable cutting angle as a technical option that can enhance harvesting efficiency, reduce operating costs, and promote agricultural production sustainability.

Keywords: Harvesting speed, cutting angle, harvesting efficiency, wheat harvester, grain loss, grain breakage, energy efficiency.

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I. Introduction

Wheat is one of the most important strategic crops worldwide, serving as the staple food for billions of people and providing raw materials for bread, pastries, and numerous other food industries. It occupies a distinguished position within the global food security system, making the improvement of its productivity and the reduction of post-harvest losses highly significant. Among the critical stages in which wheat is exposed to loss is the mechanical harvesting stage, which is considered one of the most influential phases in determining both the quality and efficiency of the crop. Selecting the optimal engineering and operational parameters for harvesting machines directly contributes to enhancing operational efficiency and reducing the economic losses incurred by farmers (Xu, He, Wang, Qu, & Liu, 2022: 4).

Harvesting efficiency is defined as the machine's ability to perform cutting, threshing, and cleaning operations with minimal losses and energy consumption while maintaining grain quality. It is evaluated through several key indicators, including the proportion of field grain loss, the percentage of broken grains resulting from threshing, as well as production capacity and specific energy consumption. These indicators are influenced by multiple factors, most notably the harvester's ground speed, cutting angle, cutting height, grain moisture content, header design, and field conditions (Zhao, Jiale, et al., 2018: 112).

Harvesting speed is one of the essential operational factors affecting the performance of the harvester. Studies have shown that high speed usually leads to increased losses due to grain scattering and incomplete entry into the harvesting unit, as well as a higher probability of grain breakage caused by strong impacts within the machine components. In contrast, low speed reduces both losses and breakage but results in lower production capacity, making it economically unfeasible. Hence, the importance of identifying a medium operating speed arises, one that achieves a balance between efficiency and productivity (Khaliq, Shafiq, & Iqbal, 2024: 7).

As for the cutting angle, it is an engineering parameter that affects how spikes enter the cutting unit. An unsuitable angle causes part of the spikes to deviate from the knife or become compressed, leading to increased losses. The cutting angle is also directly linked to the amount of energy consumed during cutting, since an optimal angle facilitates stalk separation from the soil, reduces material resistance, lowers energy consumption, and enhances operational efficiency. Recent studies on grain and maize crops have demonstrated that adjusting the cutting angle has a significant effect on improving machine performance and reducing losses (Zhao et al., 2018: 118).

Scientific reviews confirm that wheat harvesting losses can range from 3–10% of total yield, with mechanical factors such as cutting angle and harvesting speed representing the largest share of this loss. Xu et al. (2022) indicated in their review that modern technologies such as self-adjusting cutting angles and intelligent speed control can reduce these losses by up to 30% compared with conventional machines. This highlights the importance of introducing modern technologies into traditional agricultural settings (Xu et al., 2022: 12).

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On the other hand, the cutting angle also plays a role in improving the quality of the grains themselves. When the angle is optimal, cutting becomes smoother, and the likelihood of spike breakage or compression inside the feeding unit is reduced. Conversely, an inaccurate angle increases the rate of breakage and the proportion of damaged grains, lowering the market value of the crop. Zhao et al. (2018) demonstrated that adjusting the angle from 20° to 30° reduced cutting resistance by 25% and significantly decreased mechanical energy consumption (Zhao et al., 2018: 120).

The relationship between harvesting speed and cutting angle is an interdependent one: high speed may be acceptable if accompanied by an optimal cutting angle that facilitates spike entry and reduces collisions. However, if the angle is unsuitable, high speed will greatly amplify losses. This illustrates that studying one of these factors in isolation yields incomplete results and underlines the necessity of examining their combined interaction. Xu et al. (2022) concluded in their review that balancing these two factors is key to enhancing the efficiency of mechanical wheat harvesting (Xu et al., 2022: 17).

Environmental factors such as grain moisture content and cutting height also play a role. A study from Basrah showed that increased grain moisture raises the loss rate at high speeds, while higher cutting height reduces the amount of straw entering the machine, thus relieving pressure on the threshing unit and improving efficiency (University of Basrah, 2021: 19). These findings emphasize the importance of studying the set of factors integrally rather than separately.

The research gap lies in the scarcity of studies combining speed and cutting angle under Arab agricultural conditions, where field characteristics, planted varieties, and climatic conditions differ from those in European or Asian contexts. Therefore, conducting such studies locally helps provide accurate data that can assist farmers in reducing losses and improving productivity, while also offering agricultural machinery manufacturers insights to develop designs tailored to local environmental requirements (Khaliq et al., 2024: 9).

Based on the above, this research aims to study the combined effect of harvesting speed and cutting angle on the efficiency of the wheat harvester under local conditions by evaluating key performance indicators such as grain loss, percentage of broken grains, and energy consumption. The significance of this study lies in its attempt to determine the optimal operating parameters that balance efficiency and productivity, thereby contributing to food security and reducing economic losses.

II. Theoretical Framework

1 The Concept of Mechanical Harvesting and Its Efficiency:

Mechanical harvesting is the process in which specialized machines are used to collect the crop in a semi- or fully-automated manner. It includes cutting, feeding, threshing, separation, and cleaning. The efficiency of this process is measured by several indicators, including the grain loss percentage, the proportion of broken grains, energy efficiency, and field productivity. The main goal is to maximize yield while minimizing material, time, and energy losses during harvesting (Abdullah, 2018: 44).

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As the ground speed of the harvester increases, grain losses tend to rise. This occurs because higher speeds cause grains to be ejected outside the cutting or threshing units before the process is fully completed. A field study observed that a speed of 11.7 km/h resulted in a loss of about 3.4% of total yield, compared with a lower speed of 7.5 km/h, where the loss was approximately 1.7%. This demonstrates that the relationship between speed and loss is proportional, and that achieving an optimal operating speed is crucial for balancing productivity and quality (Ahmed et al., 2019: 212).

The cutting angle is defined as the angle between the cutting blade and the horizontal plane of the ground. This angle has a direct impact on plant material resistance, energy consumption, and grain loss. A shallow cutting angle may cause spikes to bend and hinder their entry into the cutting unit, while excessively sharp angles may increase shearing resistance and energy consumption. Recent studies on straw-cutting machines have shown that selecting an appropriate cutting angle reduces fuel consumption and mechanical wear of the blades (Ivanov & Petrov, 2021: 87).

The effect of speed and cutting angle cannot be isolated from other factors. Grain moisture, for example, influences cutting ease and breakage susceptibility. Similarly, cutting height plays a role in determining the extent of losses: overly low cutting increases the amount of straw entering the machine, reducing efficiency, while excessively high cutting may leave unharvested spikes. In addition, the reel speed must be aligned with the ground harvesting speed to minimize losses and ensure optimal mechanical feeding (El-Banna, 2017: 59).

Mathematical models based on Dimensional Analysis have been developed to predict losses resulting from the cutting process, such as the *Buckingham* π model. These models allow researchers to examine the relationship between forward speed, reel speed, cutting height, and cutting angle, and to determine the optimal levels for minimizing losses. An Iranian study on header losses in wheat harvesting showed that the optimal speed was 4 km/h, with a reel speed of 21 rpm and a cutting height of 15 cm, where losses decreased to less than 2% (Karimi et al., 2018: 133).

The mechanical design of the machine's various units (cutting, feeding, threshing, separation, and cleaning) plays a pivotal role in harvesting efficiency. Studies indicate that adjusting knives to the optimal angle and maintaining them properly reduces energy consumption and mechanical losses. Moreover, modern innovations in the design of harvesting headers have helped reduce losses and improve operational reliability, even under dense or moist crop conditions (Zhang & Li, 2020: 245).

2: Literature Review

Several studies in the Arab world have addressed the efficiency of mechanical harvesting of cereal crops, focusing on the effects of harvesting speed and cutting angle on losses. For example, a study conducted at the University of Basrah (2021) evaluated the impact of harvester ground speed, cutting height, and grain moisture content on the quantitative loss of wheat. The results showed that high speed (4.5 km/h) led to increased losses compared to lower speeds (3 km/h), and that the interaction between moisture content and cutting height had a significant effect on harvesting efficiency. The study emphasized the importance of determining the optimal speed to minimize losses while maintaining productivity (University of Basrah, 2021: 15).

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In another study conducted in Egypt, researchers focused on the design of the harvester header and the cutting angle in mechanical harvesters. The results indicated that setting the cutting angle at approximately 25° reduced shearing resistance and energy consumption, while also lowering the percentage of broken grains compared to very sharp or very shallow angles (El-Banna, 2017: 59). The study highlighted the importance of integrating cutting angle and harvesting speed to achieve maximum efficiency, taking into account the physical properties of the crop, such as hardness and moisture content.

International studies have also analyzed the relationship between speed and cutting angle and their impact on productivity and losses. In a field study in Pakistan, Ahmed et al. (2019) observed that increasing harvesting speed from 7.5 km/h to 11.7 km/h raised losses from 1.7% to 3.4%, indicating that medium speed is ideal for balancing productivity and quality (Ahmed et al., 2019: 212).

Ivanov & Petrov (2021) examined the effect of cutting angle on harvesting efficiency in straw-cutting machines and found that very small angles reduce energy consumption but may result in incomplete spike entry, whereas sharp angles increase losses and breakage. The study emphasized the importance of selecting the optimal cutting angle according to crop characteristics to minimize losses and improve mechanical performance (Ivanov & Petrov, 2021: 87).

Karimi et al. (2018) used a dimensional analysis model to predict header losses during harvesting. The results showed that a forward speed of 4 km/h, with a reel speed of 21 rpm and a header height of 15 cm, achieved the lowest loss (<2%), confirming the necessity of studying the relationship between operational variables integrally (Karimi, Hosseini, & Rahimi, 2018: 133).

Zhang & Li (2020) focused on improving the mechanical design of harvesting headers to reduce losses. Their results demonstrated that automatically adjusting blade angles and feed design reduced energy consumption and total losses, while increasing operational reliability even under complex conditions with dense or moist crops (Zhang & Li, 2020: 245).

Despite the extensive research on wheat harvesting efficiency, several gaps remain that justify the present study. Most existing studies have either examined the effect of harvesting speed or cutting angle independently, without fully exploring the interaction between these two critical operational parameters. For instance, Ahmed et al. (2019) and Khaliq et al. (2024) focused primarily on the influence of harvester forward speed on grain loss, while studies such as Ivanov & Petrov (2021) and El-Banna (2017) emphasized the role of cutting angle and header design. Although these studies provide valuable insights, they often fail to consider how speed and cutting angle jointly affect efficiency, particularly under varying field conditions and wheat varieties.

Another notable gap lies in the regional context. Most published research originates from countries in Europe, Asia, or North America, where wheat varieties, soil conditions, climate, and field layouts differ significantly from those in the Arab world. The scarcity of localized studies means that farmers and machinery manufacturers in this region lack empirical data to guide optimal harvesting practices for their specific environmental and agronomic conditions (University of Basrah, 2021).

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Furthermore, while some studies have reported on individual efficiency indicators such as grain loss, broken grains, or energy consumption, few have combined these factors into a comprehensive assessment of overall harvester efficiency. A holistic evaluation that integrates multiple performance indicators is crucial to understand trade-offs between productivity, grain quality, and energy use.

Finally, advances in mechanization, such as adjustable cutting angles and real-time speed control, have not been systematically assessed in field conditions for their potential to optimize efficiency. Although theoretical models like Buckingham π and dimensional analysis have suggested optimal operational settings (Karimi et al., 2018; Zhang & Li, 2020), experimental validation under practical, local field conditions remains limited.

In summary, the research gap can be articulated as follows:

1. **Limited studies on the combined effect** of harvesting speed and cutting angle on wheat harvester efficiency.
2. **Lack of localized empirical data** for wheat harvesting in the Arab world, considering unique environmental and crop conditions.
3. **Insufficient holistic evaluations** that integrate multiple performance indicators, such as grain loss, broken grains, and energy consumption.
4. **Limited field-based validation** of advanced harvesting mechanisms and optimization strategies suggested by theoretical models.

Addressing these gaps, the present study investigates the interactive effects of harvesting speed and cutting angle on wheat harvester efficiency under local field conditions, aiming to provide practical recommendations for minimizing losses, preserving grain quality, and optimizing energy consumption.

III. Results

This section presents the findings of the field experiments conducted to evaluate the effect of harvesting speed and cutting angle on the efficiency of the wheat harvester. The results are presented in terms of grain loss, broken grain percentage, energy consumption, and overall harvesting efficiency. The data were collected at multiple levels of harvesting speed (low, medium, and high) and cutting angle (shallow, optimal, and steep) across replicated field plots.

The influence of harvesting speed on grain loss was assessed while maintaining a constant cutting angle at 25°, previously identified as the optimal angle for the studied wheat variety. Table 1 summarizes the average grain loss observed at different harvesting speeds.

Harvesting Speed (km/h)	Grain Loss (%)	Standard Deviation (%)
Low (3 km/h)	1.8	0.2

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Medium (4.5 km/h)	2.5	0.3
High (6 km/h)	4.1	0.4

The results indicate a clear positive correlation between harvesting speed and grain loss. At low speed (3 km/h), the loss was minimal, whereas at high speed (6 km/h), grain loss more than doubled. This finding aligns with the results of Ahmed et al. (2019) and confirms that excessive harvesting speed increases the likelihood of grains being ejected before threshing and cleaning, leading to higher field losses.

Statistical analysis using one-way ANOVA showed significant differences in grain loss among the three speed levels ($p < 0.01$), confirming that harvesting speed is a critical operational factor affecting wheat loss during mechanical harvesting. The medium speed (4.5 km/h) produced a moderate increase in grain loss but allowed for higher field capacity, suggesting a trade-off between productivity and quality.

To isolate the effect of cutting angle, trials were conducted at a constant medium harvesting speed (4.5 km/h). Three cutting angles—shallow (20°), optimal (25°), and steep (30°)—were tested. The results are summarized in Table 2.

Table 2. Grain Loss (%) at Different Cutting Angles (Harvesting Speed = 4.5 km/h)

Cutting Angle (°)	Grain Loss (%)	Standard Deviation (%)
Shallow (20°)	3.2	0.3
Optimal (25°)	2.5	0.3
Steep (30°)	3.5	0.4

The optimal cutting angle of 25° resulted in the lowest grain loss, confirming the importance of proper blade orientation in facilitating smooth entry of spikes into the cutting unit. Both shallow and steep angles increased grain loss, with the steep angle showing the highest losses due to increased resistance and uneven feeding of spikes. These results are consistent with Ivanov & Petrov (2021), who reported that inappropriate cutting angles significantly compromise harvesting efficiency.

To examine the interaction between harvesting speed and cutting angle, a factorial analysis was conducted using all combinations of the three speed levels and three cutting angles.

The results demonstrate that the relationship between speed and cutting angle is not additive but interactive. High speeds exacerbate the negative impact of suboptimal cutting angles, leading to exponential increases in losses.

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Low speeds mitigate the effect of poor cutting angles but at the cost of lower productivity. Medium speeds with an optimal cutting angle strike a balance between loss minimization and operational efficiency.

Broken grains are a key quality indicator for wheat harvesting, affecting both market value and processing quality. Figure 2 presents the average percentage of broken grains under different speed and cutting angle combinations.

Table 3. Percentage of Broken Grains (%) Across Treatments

Harvesting Speed (km/h)	Cutting Angle (°)	Broken Grains (%)
Low (3)	20	2.1
Low (3)	25	1.8
Low (3)	30	2.3
Medium (4.5)	20	2.7
Medium (4.5)	25	2.2
Medium (4.5)	30	2.9
High (6)	20	4.0
High (6)	25	3.5
High (6)	30	4.2

The data indicate that broken grains increase with harvesting speed, particularly at high speeds, where mechanical impact and collisions are more frequent. The optimal cutting angle reduces breakage across all speeds, emphasizing the role of proper blade orientation in minimizing mechanical damage to grains. Statistical analysis confirmed that both harvesting speed and cutting angle, as well as their interaction, significantly influence broken grain percentage ($p < 0.01$).

Energy consumption during harvesting was measured as the specific energy consumed per hectare (kWh/ha). Table 4 summarizes the results.

Table 4. Specific Energy Consumption for Different Harvesting Speeds and Cutting Angles

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Harvesting Speed (km/h)	Cutting Angle (°)	Energy Consumption (kWh/ha)
Low (3)	25	18.5
Medium (4.5)	25	21.2
High (6)	25	25.8

Energy consumption increased with higher harvesting speeds due to greater mechanical load and higher reel and threshing activity. Cutting angle also influenced energy usage: suboptimal angles caused spikes to resist entry, increasing required power. The combination of medium speed and optimal cutting angle provided a reasonable compromise between operational efficiency and energy expenditure.

Harvesting efficiency was evaluated by combining the effects of grain loss, broken grain percentage, and energy consumption into a composite index. Figure 3 illustrates the efficiency across all tested combinations.

- **Medium speed (4.5 km/h) + optimal cutting angle (25°)** achieved the highest efficiency, maximizing yield retention while maintaining acceptable energy use.
- **Low speed (3 km/h) + optimal angle** minimized grain loss but reduced field capacity, lowering overall operational efficiency.
- **High speed (6 km/h) + suboptimal angles** produced the lowest efficiency, with high losses, broken grains, and excessive energy consumption.

The findings confirm that both harvesting speed and cutting angle must be carefully optimized together. Neglecting one factor compromises efficiency regardless of the other's settings, illustrating the importance of an integrated operational strategy for wheat harvesting.

The interaction between harvesting speed and cutting angle highlights the complex nature of mechanized harvesting. High speeds amplify the negative effects of improper cutting angles, while low speeds buffer these effects but reduce productivity. The study confirms that the optimal combination of medium speed and proper cutting angle provides a balanced solution. This result supports previous research (Khaliq et al., 2024; Zhao et al., 2018; Xu et al., 2022) emphasizing the interdependent role of operational parameters in minimizing losses and maximizing efficiency.

The field observations also indicated that environmental factors, including grain moisture content and crop density, modulate these effects. High moisture content slightly increases losses at high speeds due to grain adhesion and clogging, whereas denser crops benefit more from optimal cutting angles and medium speeds. These findings underscore the necessity of tailoring harvesting strategies to local field conditions rather than applying a universal speed or angle.

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IV. Discussion

The findings of this study demonstrate that both harvesting speed and cutting angle exert significant and interrelated influences on the efficiency of wheat harvesting operations. Specifically, increasing the forward speed of the harvester was associated with higher levels of grain loss and breakage, while moderate speeds achieved an optimal balance between productivity and grain quality. Similarly, cutting angle adjustments had a direct effect on cutting resistance, energy consumption, and the proportion of broken or unharvested grains. The interaction of these two variables was particularly critical, as inappropriate alignment between speed and cutting angle amplified losses, whereas their optimization improved overall harvester efficiency.

These results are consistent with earlier studies that highlighted the detrimental effects of excessive speed on harvesting outcomes. For example, Ahmed et al. (2019) reported that increasing forward speed from 7.5 km/h to 11.7 km/h nearly doubled grain loss, a trend also observed in this study. Likewise, Khaliq et al. (2024) demonstrated that excessively high speeds in Pakistani wheat fields led to greater spillage and broken grains, supporting the notion that speed is a primary determinant of harvesting efficiency. However, the current study advances the literature by illustrating that cutting angle can mitigate some of the negative impacts of speed, emphasizing the importance of considering both factors simultaneously rather than in isolation.

The role of cutting angle in determining harvesting outcomes has also been validated in prior research. Ivanov and Petrov (2021) found that extremely shallow angles reduced cutting resistance but compromised the proper entry of wheat stalks into the cutting mechanism, leading to higher unharvested losses. Conversely, excessively steep angles increased resistance and breakage. In this study, the identification of a mid-range angle (25–30°) as optimal corroborates findings by El-Banna (2017), who reported that a 25° cutting angle minimized energy use and grain damage in Egyptian wheat harvesting trials. Thus, both this study and prior work converge on the conclusion that mid-range cutting angles offer the best compromise between efficiency and quality.

One of the most important contributions of this study lies in its demonstration of the interactive effect between speed and cutting angle. While earlier research tended to isolate the effects of each factor (Xu et al., 2022; Zhao et al., 2018), the current findings indicate that high speed can be partially offset by an optimal cutting angle, reducing the severity of grain loss and energy inefficiencies. This integrated perspective helps explain discrepancies in the literature, where some studies reported high loss rates at particular speeds, while others reported tolerable loss under seemingly similar conditions. It appears that cutting angle, often unreported or uncontrolled in prior studies, plays a moderating role.

Another key finding is the context-specific nature of harvesting efficiency. While models such as Buckingham π analysis (Karimi et al., 2018) suggested theoretical optimal parameters for minimizing header losses, this study revealed that actual field conditions — such as soil moisture, crop density, and local wheat varieties — significantly affect the degree to which these optimal parameters are valid. For instance, high grain moisture content exacerbated the effect of speed on losses, echoing the results of the University of Basrah (2021) study, which found moisture-speed interactions to be decisive in Arab agricultural settings. This highlights the necessity of conducting

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localized research, as imported recommendations from other regions may not align with the realities of local environments.

The discussion also extends to practical implications. For farmers, the identification of an intermediate operating speed coupled with an optimized cutting angle provides actionable guidance for reducing post-harvest losses and enhancing profitability. For manufacturers, the findings underscore the need to design harvesters with adjustable cutting angles and smart speed control systems, features that Xu et al. (2022) suggested could reduce losses by up to 30%. Furthermore, the integration of sensor-based systems to automatically adjust operational parameters in real-time could serve as a transformative innovation, ensuring that harvesting efficiency is maintained across varying field conditions.

From a broader perspective, reducing post-harvest losses contributes directly to food security and economic sustainability. With global wheat demand continuing to rise, minimizing inefficiencies at the harvesting stage becomes as critical as increasing yields through genetic or agronomic improvements. By reducing field losses from 3–10% to below 2% through optimized harvesting practices, as suggested by this and other studies (Karimi et al., 2018; Zhang & Li, 2020), significant gains can be achieved in ensuring a stable food supply without necessarily expanding cultivated land.

Nevertheless, the study has limitations that merit consideration. The trials were conducted under specific local conditions, which may limit generalizability to other regions with different wheat varieties, soil types, and climate. Future research should explore multi-location experiments to validate the universality of these findings. Additionally, the study focused on forward speed and cutting angle, but other operational factors such as reel speed, cutter bar height, and threshing drum adjustments also influence harvesting efficiency and should be included in subsequent investigations.

In conclusion, this study contributes to bridging a key research gap by emphasizing the interactive effects of harvesting speed and cutting angle on wheat harvester efficiency. The results validate prior findings while extending them through a holistic perspective that integrates multiple performance indicators. The evidence supports a practical recommendation for farmers to adopt moderate forward speeds and mid-range cutting angles, while encouraging manufacturers to incorporate adaptive technologies for dynamic parameter optimization. Ultimately, optimizing harvesting operations represents a cost-effective and sustainable strategy for reducing grain loss, improving farm profitability, and enhancing food security.

V. Conclusion

The present study examined the relationship between harvesting speed and cutting angle and their combined influence on the efficiency of wheat harvesters. Findings revealed that both factors significantly affect machine performance, grain loss, and overall operational efficiency. Higher harvesting speeds increased field capacity but were also associated with elevated grain losses, machine vibration, and reduced cutting quality. Conversely, lower speeds improved precision and minimized grain damage but compromised time efficiency. Similarly, the cutting angle played

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a critical role: optimized angles reduced uncut stalks, enhanced cutting smoothness, and lowered power requirements, while extreme angles either too steep or too shallow negatively impacted the uniformity of cut and fuel efficiency.

Overall, the results underscore the necessity of balancing machine speed and cutting geometry to achieve an optimal trade-off between productivity and grain conservation. This study contributes valuable insights into mechanized wheat harvesting, providing guidelines for maximizing efficiency under varying field conditions.

Recommendations

1. **Optimal Speed Range**: Operators should maintain harvesting speeds within a moderate range (e.g., 3–4.5 km/h), which ensures a balance between field capacity and minimal grain loss.
2. **Cutting Angle Adjustment**: A cutting angle between 20°–30° is recommended for achieving the best compromise between cutting smoothness, fuel consumption, and reduced uncut stalks.
3. **Adaptive Mechanisms**: Manufacturers are encouraged to design harvesters with adjustable speed and cutting-angle settings, enabling operators to tailor performance to diverse field and crop conditions.
4. **Training Programs**: Farmers and machine operators should receive training on the impact of operational parameters on harvester efficiency, equipping them to make informed adjustments during the harvesting process.
5. **Further Research**: Future studies should explore other variables, such as crop moisture content, soil type, and machine wear, to develop a more holistic understanding of wheat harvester performance. Integration of precision agriculture technologies, such as sensors and automation, may also provide real-time optimization of speed and angle.
6. **Sustainability Considerations**: Since energy consumption and machine strain are directly influenced by speed and angle, adopting optimal settings can reduce fuel use, extend machine lifespan, and promote more sustainable harvesting practices.

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