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Effect of Snapping Roller Parameters on Maize Harvesting

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The effectiveness of maize harvesting is significantly impacted by the parameters of snapping rollers, which have a crucial function in separating maize ears from the stalks. The present study examines the influence of several snapping roller parameters, such as rotational speed, roller spacing, and surface properties, on the efficiency of maize harvesting. The paper provides a detailed examination of the advancements in snapping roller technology, focusing on improvements that seek to optimize performance and minimize harm to crops. The research highlights significant obstacles, including the need for wear resistance, careful material selection, and the capacity to

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adapt to various maize kinds. The suggested solutions to these difficulties include the use of improved materials, optimal roller designs, and adaptive control systems. Addressing these difficulties may lead to a substantial improvement in the efficiency and sustainability of maize harvesting operations, as shown by the data. This study offers vital insights for the development of more efficient and durable maize harvesting machinery, eventually leading to enhanced agricultural output and food security.

Keywords: Maize harvesting; maize grain; snapping roller; challenges; solutions.

1. INTRODUCTION

Recently, maize acreage has surpassed that of wheat and rice, making it the leading crop in China. Maize is a versatile crop that has several uses in food production, animal feed, industrial processing, and energy generation [1-3]. In China, the percentage of land used for growing maize and the amount of maize produced compared to other grain crops has risen from 17.1% and 19.5% in 1980 to 36.4% and 40.3% in 2022 [4]. Maximizing maize output is crucial for preserving national food security. Maize cultivation in the semi-humid and semi-arid areas of northern China mostly use wide-narrow-row planting patterns. The current harvesting header, designed for large-scale operations, is not suitable for accommodating the wide-narrow-row planting method, which involves varying row spacing [5]. Nevertheless, the current tiny, portable, single-row maize harvester header and double-row maize harvester header encounter issues such as inadequate harvest efficiency and significant grain loss. Hence, the crucial solution to the aforementioned issues lies in the creation of a maize harvesting header that minimizes loss and maximizes efficiency. Nevertheless, the degree of mechanical harvesting for maize is still inadequate, resulting in a significant hindrance to the advancement of maize mechanization. The maize snapping device is a crucial element of the maize harvesting machine that significantly impacts the quality of the harvester.

The primary cause of grain loss and header grain breakage during the harvest process is the collision contact between maize ears and the ear picking gear [6-9]. Studies indicate that the use of a stem-pulling roller and picking plate in combination results in less harm to ear grains [10, 57-59]. Nevertheless, the speed of the stem-pulling roller in the roller-type picking device [11] is greater than that of the stem-pulling roller, leading to a more intense collision between maize ears and the ear picking device. This, in turn, increases the likelihood of grain detachment. Drago GT developed an automated adjustment mechanism for a picking plate to minimize the effect of maize ear collision during ear picking. This device can intelligently modify the spacing between the ear picking plates as needed. It may efficiently decrease both the impact force on maize ears and the loss caused by maize shedding and crushing. The Oxbo 50 series maize header utilizes a conical roller and bending snapping plate combination to decrease the speed at which the ear is pulled during the harvesting process. This effectively reduces the impact force on the maize ear while maintaining efficiency. Although snapping rollers are crucial for maize harvesting, there has been a lack of extensive study on how their individual characteristics impact the overall effectiveness of the process.

Conventional roller designs sometimes struggle to adjust to different field conditions, resulting in problems such as kernel harm, inefficiency in wet circumstances, inadequate stalk retention, and heightened wear and strain. Moreover, the inconsistency in the diameters of maize ears adds complexity to the harvesting procedure, requiring a roller mechanism that is more flexible and sensitive. This paper seeks to thoroughly investigate the impact of various snapping roller settings on the process of maize harvesting. This paper aims to provide practical insights for optimizing harvester design by carefully examining how changes in these parameters affect important performance indicators, such as kernel integrity, operational efficiency in varying moisture conditions, and the mechanical durability of the rollers.

The remaining structure of this paper are followed as: section 2 described the maize grain harvesters, section 3 discussed the related work of this study, section 4 presented snapping roller parameters in maize, section 5 explained the new development and trend, section 6 provided the various challenges and solution for tackle in maize harvesting, and section 7 presented the conclusion of our study.

1.1 Maize Harvesters

The method of harvesting maize is determined by the moisture level of the kernels, which is influenced by variables such as the type of maize, the planting area, and the cropping strategy. If the moisture content surpasses 30%, it is necessary to use a picker. Grain harvester should be used when the moisture content is less than 25%.

1.2 Maize Picker

A maize picker is capable of doing several tasks, such as harvesting ears of corn, removing the husks, gathering the corn, and cutting the stalks. There are two types of pickers based on their power units: tractor-driven and self-propelled [12]. The tractor-driven picker is characterized by inefficiency and a high level of grain loss during field operation, which has led to its progressive replacement by self-propelled alternatives. The self-propelled picker is now popular because to its several benefits, including its professional nature, convenience, attractive effects, high efficiency, and suitability for scaled farming. The primary element of a maize picker is the head. The main purpose of a maize head is to collect, break off, and remove debris. The spacing between the heads is intentionally aligned with the spacing between the planting rows. The collecting unit is situated among the corn rows. It aids in transferring stalks to the snapping unit and prevents the ear from falling out of place. The primary component of the harvest head is the snapping unit [13]. The rolls seize maize stalks and draw them through the snapping bars, whereas maize ears are unable to pass through the gaps between the snapping bars. When maize ears reach the snapping bars, they are forcefully broken off and then transported into the auger by the collecting chains. Typically, snapping rolls consist of rolls with straight flutes [14]. The maize crop is harvested after the husk has reached a golden color and the grains have hardened enough, with a moisture content of no more than 20 percent. The ears are harvested from the standing crop. After being harvested, the ears are dried using solar radiation before the process of shelling. Fig. 1 depict the diagram of maize picker as shown below.

1.3 Spiral-lugged Snapping Rolls

Spiral-lugged rolls are mostly composed of cast iron and include spiral ribs or lugs on their surfaces. The maize head equipped with spiral-lugged snapping rolls has a straightforward design, exhibits a high level of dependability, and demonstrates a robust capacity to accommodate various stalk circumstances. Additionally, the rolls have the capability to draw some husks downwards. The direct contact between the ear and spiral-lugged snapping rolls leads to increased loss and decreased efficiency. Wang and Jia devised an adjustable screw pitch rib snapping roll and a spacing-adaptive differential snapping roll to address the issue of blockage between the snapping rolls and enhance operational efficiency [16-17]. There is a declining tendency in the use of spiral-luger rolls [18].

Fig. 1. Maize picker [15]

1.4 Straight-fluted Rolls

Straight-fluted rolls have a higher level of aggressiveness compared to spiral-lugged rollers. Stripper plates positioned above the rolls serve to avoid direct contact between the maize ears and the rollers. Straight-fluted rollers provide structural benefits that allow for bigger capacity and faster operating speeds. They may be categorized based on their cross-sectional form as quadrangular, five-ribbed, and six-rowed, among others. The use of straight-fluted snapping rollers in maize harvesting is dependable and very effective, resulting in few losses. However, it does result in a significant amount of stalks and husks mixed in with the gathered grain. Currently, straight-fluted snapping rollers are extensively used globally because to their little damage and consistent operational performance under low grain moisture conditions. Many research organizations are extensively studying snapping ways to minimize loss and impurity rates, while also aiming to achieve more effective stalk cutting. The newly developed Oxbo 50 series maize head has tapered ten-knife snapping rollers that are specifically intended to be compatible with stripper plates. The crucial aspect of stripper plates is their design characteristic, which enables the clean removal of the ear from the stalk, therefore minimizing both debris and harm to the ear. The knife with a gradually decreasing width applies a controlled force to the stripper plates, resulting in a significant reduction in both the damage to the corn kernels and the splitting of the corn cobs. The collecting belts of the Oxbo 50 series are constructed from resilient rubber, resulting in less auditory harm, improved conveyance efficiency, and quieter operation [19]. Drago is the first designer in the world who has created stripper plates for maize heads that can be automatically and concurrently changed based on the diameter of the stalks. Additionally, the automation mechanism of each row may function independently. In addition, Drago's stalk rollers have a greater length compared to standard ones, allowing them to delicately break off ears from plants. In order to address the issue of ear bounce and minimize butt-shelling, Drago's maize head is equipped with a knife roll that has the longest length and a smaller diameter, resulting in a reduced tip speed [20]. Fig. 2 depict the drago's series and Oxbo 50 series as shown below.

The Geringhoff maize head is specifically designed to use the Rota Disc mechanism for the purpose of pulling down stalks via the stalk annihilation system as shown in Fig. 3. The Rota Disc can optimize the efficiency of the process, regardless of the ground speed. The Rota Disc technique utilizes an extra unit of power every row in order to effectively chop stalks into smaller fragments [21]. Cui et al. [22,23] created a snapping device that is comparable to the one mentioned. Experimental findings shown that this device can decrease power use by about 60% when compared to traditional spiral-lugged snapping rollers and straw choppers.

(a)

(b)

Fig. 2. (a) Drago's series II head, (b) Oxbo 50 series maize head

Fig. 3. Geringhoff's maize head

(a) Calmer's 12-inch head

(b) Geringhoff's gathering reel head

(c) Geringhoff's narrow-spaced head

Fig. 4. Row independent head for maize harvesting

Calmer's maize head has the capability to remove one side of the gearbox in order to construct the narrow head. The solitary collection chain, equipped with larger paddles, directs stalks into the rolls. In addition, the hydraulic stripper plates are added to enable automated regulation of the head height and row-sensing navigation [24]. The narrow-spaced maize head manufactured by Geringhoff is specifically engineered to penetrate a maize field at any given angle. Additionally, it utilizes the Rota Disc cutting technology and a distinctive slanted two-chain design to efficiently gather maize in various row spacings. The narrow-spaced maize head is more effective in harvesting stuck corn than the reel maize head [25]. Fig. 4 illustrate the row independent head for maize harvesting as shown.

2. MAIZE GRAIN HARVESTER

A maize grain harvester is essentially a modified version of a regular grain combine. It is fitted with an ear picker-head and specifically designed to efficiently harvest maize grain. Due to its cost-effectiveness and efficiency, the ear cleaner is extensively used in suitable regions, resulting in reduced process time and expenses compared to traditional ear picking methods. This kind of grain harvester is versatile, since it can be used for many cereals, including maize. Consequently, these harvesters are cost-effective and user-friendly [26]. A maize grain harvester primarily comprises a maize head, conveying system, threshing mechanism, separation unit, cleaning components, and a grain tank. A maize grain harvester not only streamlines the harvesting process and improves production efficiency, but also minimizes grain loss. The performance of the threshing mechanism, which serves as the central component of a maize grain harvester, has a direct impact on the quality of the harvesting process. The threshing process that takes place between the cylinder and concave is likely a result of both the wedging actions of the kernels and the bending of kernel attachments. At different Post Harvest Handling stages it was tried to analyze the various microbiological parameters [60].

2.1 Tangential Threshing Device

The primary feature of the tangential threshing apparatus is that maize ears are introduced into the threshing cylinder at a tangent angle. Using this particular device results in a reduced threshing time, but it also leads to a higher occurrence of kernel crack age. Augmenting the velocity of the cylinder would enhance the threshing capacity of the rotating maize thresher for all types of maize cobs [27]. As the speed of the cylinder's outer edge rose, the amount of grain lost during threshing reduced. However, the speed also caused an increase in grain damage. Reducing the clearance between the concave and the threshing mechanism will improve the efficiency of threshing and separation. However, this will also result in a greater rate of damage to the grains [28].

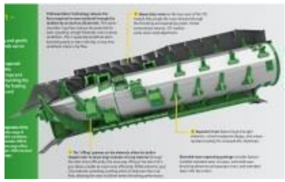
2.2 Longitudinal Axial Flow Threshing Device

The main characteristic of the longitudinal axial flow threshing mechanism is that the maize ears are fed into the threshing cylinder in a straight line, and they move both in the direction of the cylinder's axis and tangentially along it. The device carries out the tasks of threshing and separating, with a longer duration for these processes. Additionally, it has reduced levels of threshing losses and grain damage. Li et al.[29] found that increasing the pace at which maize ears are fed does not have a substantial impact on kernel damage. The damage in the axial device was 50% less than that in the tangential threshing roller [30]. Average bulk density of whole cotton stalk and shredded cotton stalk was found as 29.90 kg/m3 and 147.02 kg/m3 respectively [53].

2.3 Tangential-longitudinal Axial Flow Threshing Device

In order to fully exploit the benefits of the tangential and longitudinal axial flow threshing device, a tangential-longitudinal combination device was created by merging the two aforementioned devices. The machine is fitted with a tangential threshing cylinder positioned in front of the longitudinal axial flow threshing cylinder. This configuration greatly enhances the efficiency of the threshing, separation, and feeding processes, resulting in a large improvement in capacity. Fu et al. [31] developed a tangential-longitudinal axial flow threshing and separation system equipped with soft threshing components. This device successfully reduces the rate of kernel loss and damage. Table 1 displays the five currently prevalent kinds of threshing devices, as in [32-34].

Table 1. Different types of threshing devices for maize harvesting

Threshing Device Type	Picture	Length/mm	Width/mm	Diameter/mm	Feature
Tangential threshing device		/	1560	750	Low threshing speed to reduce vibrations and to protect the drive line
Axial-flow threshing device		2623	/	762	High threshing capacity, less horsepower and less fuel consumption
Axial-flow threshing device		3124	/	762	With a slightly tapered front nose, low growling and high productivity
Twin rotors axial-flow threshing device		2638	/	559	Suitable for damp conditions, offer up to a 10% increase in capacity
Tangential and longitudinal axial		4200	1700	445 (longitudinal	The APS accelerates material

Threshing Device Type	Picture	Length/mm	Width/mm	Diameter/mm	Feature
flow threshing and separation device		(longitudinal axial flow cylinder)	(tangential cylinder)	axial flow cylinder)/ 600 (tangential cylinder)	and pre-separates up to 30% of the grain, the ROTO PLUS system provide optimizing separation performance

3. REVIEW OF LITERATURE

Chen et al. [35] included the construction of a small-scale maize harvester equipped with attitude adjustment capabilities. The purpose of this harvester was to tackle the challenge of harvesting maize in small planting plots and steep terrains seen in hilly and mountainous regions of China. The paper provided an attitude modification, and the accuracy of static attitude modification was verified by an attitude adjustment test. An orthogonal test was conducted to assess the factors influencing the rate of ear loss and bract peeling. The test comprised evaluating the rotational speed of the straw pulling rollers, peeling rollers, and pressure feeding rollers. The mathematical regression model that establishes the relationship between the experimental parameters and indicators was created using Design Expert. The importance of the assessment indicators was confirmed using analysis of variance. The most effective configuration of operating parameters was found to be a rotating speed of 1440 revolutions per minute (r/min) for the straw pulling rollers, 1535 r/min for the peeling rollers, and 406 r/min for the pressure feeding rollers. When the operating parameters were optimized, the ear loss rate was 1.33% and the bract peeling rate was 93.98%. The design characteristics of the compact maize harvester adhere to the relevant national standards and effectively meet the needs of mechanical maize harvesting in China's hilly and mountainous areas. Various engineering properties helps significantly for designing of equipment, enhance plant production, developing new technologies in which agricultural residues are used as raw material [50].

Mu et al.[36] studied that the bond model of corn kernel and straw was built based on mechanical tests such as shear test and compression test. This model aimed to investigate the rolling and crushing effects of various crushing rollers. An examination of the crushing process shows that the disc crushing roller (DCR) has a significant kneading area per unit length, while the spiral-notched serrated crushing roller (SNSCR) exerts a transverse shearing effect on the material. These characteristics have an impact on the effectiveness of the material's crushing. The data is carefully analyzed using the discrete element technique and simulation test, as well as the multiple regression method and variance analysis method. The crushing impact was assessed using a Binzhou screen and a corn silage grain-crushing score screen. The crushed materials obtained from corn kernels can be categorized into three groups based on their size: broken grains that pass through a 2 mm sieve, broken grains that pass through a 4.75 mm sieve, and broken grains that are unable to pass through a 4.75 mm sieve. Similarly, the crushed materials obtained from corn stalks can be divided into four groups based on their size and thickness: broken straw that passes through a 4 mm sieve, broken straw that passes through an 8 mm sieve, broken straw that passes through a 19 mm sieve, and broken straw that is unable to pass through a 19 mm sieve. The crushing effect and crushing categorization of the simulation test and bench test exhibited a high degree of congruence. The findings indicated that the disc crushing roller group had the highest overall score, with a straw rolling rate of 89.1% and a grain crushing rate of 87.7%. This group was deemed the best suited for harvesting whole-plant silage maize (WSM).

Chen et al. [37] studied that the primary components of a silage maize harvester are horizontal feeding devices and plate hob cutting equipment. In order to address the issues of obstruction in the feeding process, high energy consumption, and subpar chopping quality, a horizontal different diameter five-rollers device (HDDFD) was developed. Additionally, the plate hob chopping device was adjusted and examined in parallel. The feeding conveying speed was found to be 2.0-4.5 m/s by dynamic analysis. The equation for the distance between the actual and predicted cutting-edge curves and the location of the fixed blade was ultimately derived. At the bench site, we conducted single factor and response surface orthogonal tests to analyze the impact of feeding speed, rotating speed of the chopping cylinder, feeding amount, and feeding direction on the standard grass length rate (SGLR) and energy consumption per unit mass (ECPUM). The ideal operational parameters for achieving best chopping performance are as follows: a feeding speed of 3.39 m/s, a rotation speed of the chopping cylinder of 1016.17 r/min, a feeding quantity of 8.04 kg/s, and a feeding direction of 52.2°. Furthermore, the SGLR (Specific Gas Liquid Ratio) and ECPUM (Effective Calorific Power of the Upper Mantle) were determined to be 95.35% and 37.63 kJ/kg, respectively. The relative error between the experimental findings obtained using the specific combination of parameters and the projected value was confirmed to be below 5%. The dependability of the modified feeding and chopping gear was confirmed by field testing. It is evident that the HDDFD and improved plate hob chopping device can fulfill the demands of automated silage harvesting, resulting in a noticeable improvement in working quality and a reduction in energy consumption during chopping.

Chen et al. [38] aimed to analyze the mechanical motion process between the peeling device and the corn ear in order to address the issues of low working efficiency and high damage rate of high and low roller peeling equipment used in fresh corn harvesting in China. As a solution, a high-low roll peeling structure is proposed. This construction utilizes elastomeric rubber material, a roller segmentation design, and an adjustable spiral frame, with the selection of appropriate parameters provided. A three-factor, three-level orthogonal test was done utilizing the Box-Behnken central grouping approach in Design-Expert 12 software to establish the most effective operating settings for the fresh-corn-peeling apparatus. The variables under consideration were the speed of the peeling roller, the tilt angle of the peeling roller, and the frequency of the vibrating plate. The assessment criteria taken into account were the bract peeling rate (BPR) and the grain breaking rate (GBR). Using the findings from the theoretical study, a test bench was created for the fresh-corn-ear-peeling device. The parameter combination that would result in the best peeling quality was found based on the real-life working conditions. The findings indicate that the influence on the BPR (Back Pressure Ratio) and GBR (Ground Bearing Ratio), ranked from highest to lowest, follows the sequence: peeling roller speed, peeling roller tilt angle, and frequency vibration plate. The optimization module was used to optimize the operating parameters and employed the following integers to get the ideal combination of operating parameters: The speed of the peeling roller was 480 revolutions per minute ($r \cdot min^{-1}$), the tilt angle of the peeling roller was 8 degrees (°), the frequency of the vibrating plate was 260 times per minute ($times \cdot min^{-1}$). The associated BPR was 91.75%, which was 0.66% points lower than the ideal value. The GBR was 1.55%, which was 0.08% points higher than the best value. This fresh-corn-peeling equipment demonstrated exceptional performance in terms of peeling fracture outcomes when compared to regular peeling equipment. Hence, this research offers significant technical assistance for the efficient design and choice of fresh-corn-peeling machinery.

Garudik et al. [39] examined that maize is a significant crop in India, ranking third in importance after rice and wheat. It is a widely cultivated grain. Maize accounts for a mere 2.4 percent of global agricultural output. In India, maize was cultivated on 22.98 lakh hectares of land, resulting in a yield of 36.61 million metric tons. The average yield per hectare in the 2020-21 year was 2804 kg per hectare. The performance of the maize cob harvester was evaluated to determine the impact of three independent variables: forward speed of operation (1.7 km/h, 1.9 km/h, 2.1 km/h), snipper speed (55 m/min, 62 m/min, 68 m/min), and variety of maize crop (Dhania-9965, Sartaj-765, D-9081) on various dependent variables such as stripping loss, ratio of stem length before and after harvesting, and machine parameters like actual field capacity and field efficiency. Additionally, it was noted that the machines performed well while moving at a speed of 1.9 km/h in the forward direction and at a snipper speed of 62 m/min. The crop experiences a stripping loss of 0.197%. The ratio of the length of the stem before and after harvesting is 825 mm and 113.33 mm respectively. The machine's actual field capacity is 0.081 ha/h, with a field efficiency of 75.7%. The machine's operational cost was determined to be Rs.337.65 per hour. The breakeven point was calculated to be 149.64 hours, and the payback time was around 2.5 years. The machine's overall production is 75 quintals per hectare.

Chandel et al. [40] in order to examine how operational parameters impact the performance of a maize combine with a snap roll header, we conducted tests at several feed rate levels: 69.94 Mg h-1, 85.48 Mg h-1, and 124.33 Mg h-1. Additionally, we tested the combine at different moisture content levels: 24.45%, 26.03%, and 28.90%. The pre-harvest losses rose from 1 to 4% due to the sun drying of the maize crop, which caused the grain moisture level to decline from 28.90% to 24.45%. This reduction in moisture content weakened the ear shank. The shelling efficiency ranged from 96.81% to 98.13%, while the cleaning efficiency ranged from 95.20% to 95.80%. The lowest level of grain damage seen was 2.1%, and the smallest overall loss recorded was 9.96%. The optimal values for the feed rate and moisture content (w.b.) were determined to be 85.48 Mg h-1 (with a forward speed of 1.10 km h-1) and 26.03%, respectively. The shelling efficiency, cleaning efficiency, grain damage, and total loss by the combine were recorded as 98.13%, 95.80%, 2.10%, and

10.23%, respectively. The energy required for maize harvesting using a maize dehusker cum sheller was 2152.26 MJ ha-1, whereas the energy required for maize harvesting using a maize combine with snap roll header was 2633.25 MJ ha-1. Solar energy is essential for achieving optimal moisture levels for maize cultivation and minimizing losses. Maize with a low global warming potential is a feasible energy crop. Additionally, residual maize stover may serve as a viable substitute for fossil fuels, suitable for applications such as bioethanol production, silage production, and residential fuel usage in rural, mountainous regions. Ensuring the ideal stage of harvesting is essential in order to decrease the energy required for maize harvesting, grain storage, and other potential applications.

Zhang et al. [41] examined that the primary method of maize harvest in China is maize picking. The loss of maize during the picking process contributes significantly to the overall loss of maize throughout the harvest. A study was conducted to investigate the elements and principles that affect the loss of maize during picking. The study included both experimental research and theoretical analysis. Initially, the boundary conditions were defined by evaluating the mechanism of maize picking. These circumstances then evaluated the effects of maize picking loss. Subsequently, the researchers used single-factor tests using a central composite design (CCD) approach to ascertain the impact of different components and their interactions on the loss of corn during picking. Ultimately, the models for kernel loss and ear loss were established in order to identify the most effective parameter combination for maize harvesting. A field experiment verification was performed. The findings revealed that the most effective parameters for harvesting maize were a rotating speed of 1120 revolutions per minute for the pulling rollers, an operating speed of 1.94 meters per second, an inclination of the header at an angle of 18 degrees, and a clearance of 30 millimeters between the picking plates. By determining these ideal conditions, the rate of kernel loss was 0.065%, and there was no loss of ears. The experimental findings and regression models generated may be used to forecast the performance of maize picking harvest, direct the modification of header operating parameters, and provide a theoretical foundation for minimizing mechanical loss during maize harvesting.

Parson [42] To transition the United States' energy consumption to renewable sources, the use of whole-plant maize harvest may be a very beneficial method for obtaining feedstock for the manufacturing of cellulosic and lignocellulosic ethanol. repeated studies have investigated the practice of harvesting whole-plant maize by making repeated runs over the field or by employing a mix of agricultural equipment components at the same time to finish the task. This project aimed to create a specialized maize harvester that can be towed by a powerful tractor with a big frame (>300 horsepower) in order to efficiently chop and bale the grain. To accomplish this objective, an NH 450SFI omni-directional forage header was combined with an NH 340S+ baler. Furthermore, several adjustments were made, such as redesigning the undercarriage, implementing a swing-style hitch, and adding a PTO driveline. The implemented hitch enabled the placement of the whole-plant harvester in an offset configuration from the baler, guaranteeing that the maize crop may be harvested without being crushed by the tractor. The harvester needed an average power of 130 horsepower, however there were instances of peak loads reaching as high as 310 horsepower. The whole-plant harvester generated bales that had an average density of 21.5 lbs/ft3, which exceeded the required density of 13.5 lbs/ft3 to overload semi-trailers. The harvest rates varied between 14.8 and 15.4 tons per acre, as determined by the standard variation of bale weight. This research designed a harvester that streamlines the logistics of harvesting whole-plant maize in the field and generates tightly packed bales, which improves the feasibility of transporting the grain for the farmer.

Qin et al. [43] stated that the efficiency and quality of maize harvesting are directly impacted by the performance of the mechanisms used for picking. Several field trials have been conducted to enhance picking performance, but they have been limited by variables such as exorbitant expenses, the diverse types of maize used, and fluctuating harvesting seasons. The proposal suggests using virtual simulation analysis as a substitute for field tests in order to provide a precise benchmark for optimizing the choosing mechanism. A finite element model of a maize plant and picking mechanism was created using trial findings and relevant data from academic literature. The correctness and rationality of the simulation findings were confirmed by comparing them to the data collected from an experiment conducted with a high-speed camera. The simulations studied the coupling impact of three primary factors: the rotating speed of the picking roller, the edge angle of the picking board, and the feed-in speed. The findings indicated that decreasing the rotating speed of the picking roller resulted in less harm to the maize during the picking procedure, while yet maintaining high efficiency in harvesting. Additionally, it was determined that the most favorable picking board edge angles were within the range of 13°–15°. While decreasing the feed-in speed may mitigate harm to the maize, it was not the primary contributing factor. In addition, power consumption studies were conducted to determine the ideal rotating speed of the picking roller for maximum operating efficiency. The findings of this research will serve as a valuable point of reference for the design, development, and optimization of the maize picking mechanism.

Zhang et al. [44] examined that the driving responsibilities of a maize harvester are physically demanding because to the unpredictable soil conditions, variable states of the maize crop, and the extended duration of labor. Operators are required to fine-tune and optimize the internal configurations of the harvester in order to change the operational parameters and minimize the amount of harvest loss. This study explored an intelligent control system designed to automate the adjustment and minimize the losses associated with maize picking during harvest. An experimental data-based prediction model was used to forecast the rate of maize picking loss. The rotational speed of the pulling rollers, operating speed, and header height were then tuned to reduce the aforementioned loss. The intelligent control system enables the use of both manual and automated controls. In automatic mode, the controller regulates the rotational speed of the pulling rollers, the operating speed, and the header height depending on the measured picking losses. The automated control system is composed of quicker and slower loops. The fuzzy proportional–integral–derivative (PID) approach is used to optimize the rotational speed of pulling rollers and the operating speed in the quicker loop, while the PID method is utilized to control the header height in the slower loop. The system's efficacy and stability were assessed via field experiments. The system test results indicated that all functional components exhibited rapid responsiveness, with little overshoot and steady-state faults. The developed control approach may optimize each operational parameter of the maize harvester, regardless of the load state. The studies yielded maize picking loss rates of 1.676% and 1.386%, which satisfy the criteria for maize harvesting.

Vodounnou et al. [45] studied a specialized corn harvester was purposefully developed and built for use in economically disadvantaged countries. The system comprises a harvester header, a chain conveyor, a driving power unit, and a five-wheel tricycle. The manufacturing of the components was finished, and the devices were put together onto the tricycle. The evaluation of the small-scale maize harvester's performance was carried out using maize kernels with a moisture content of 15% on a wet basis. The engine was run at three distinct rotational speeds: 1347, 1521, and 1937 revolutions per minute (rpm). The harvester maintained a consistent forward velocity of around 0.617 kilometers per hour. The testing experiment showed a statistically significant effect on the physical characteristics of maize ($p<0.05$). The machine reached its peak capacity, operating at a pace of 0.05 hectares per hour. In addition, the driving efficiency reached a peak of 97.30%, while the picking and carrying efficiencies achieved the greatest levels of 84.11% and 98.21% respectively. However, it was observed that the machine's noise level decreased as the engine speed rose. Moreover, the velocity of the engine had a direct influence on both the effectiveness of the selection process and the transportation process. The equipment has been deemed suitable for the majority of small-scale farms.

Wang et al. [46] examined that the maize stalk is a significant biomass resource in China. The extent to which stalks are cut has a significant influence on following activities in the field. Field experiments were carried out to examine the impact of cutting on various parts of the stems for different types of corn, operating speeds of the combine harvester, and moisture levels of the stems. Before conducting the experiments, the stalks were separated into four pieces, starting from the bottom and going up. Each segment was then painted with a distinct color to distinguish them from one another throughout the chopping process. The findings indicated a steady drop in the percentage of the qualifying length of stalk chopped (PQLSC) and an initial rise followed by a decrease in the percentage of the stalk broken (PSB) as the sections of maize stalk moved from lower to higher, while maintaining the same rotating speed of blades.

When the moisture content of the stalk was kept constant, an increase in stalk diameter led to a greater PQLSC (plant quality and leaf surface conductance) and PSB (photosynthetic biomass). The PQLSC exhibited the maximum value of 34.1% for the lower regions of the stalks, while the PSB reached its lowest value of 44.8% at a rotating speed of 915 rpm for the blades. This study offers guidance for determining the optimal operating speed and rotating speed of the blades for a harvester in order to produce the lowest particle size.

Fu et al.[47] explained the influence of impact factors and moisture content on kernel detachment. Additionally, the physical parameter of dissipated momentum is included into the data analysis procedure. Experiments were conducted on a drop-testing platform, using an accelerometer attached to corn ears to ascertain the impact characteristics. With an increase in impact velocity from 3.5 to 6.0 m/s at a moisture content of 18.5%, there was a concomitant rise in peak acceleration, the integral of acceleration, and rebound velocity. However, the impact duration exhibited a downward trend. The mass of the separated kernels rose from 5.13 to 13.70 g per corn ear. When the moisture content of the kernels rose from 11.8 to 30.6% at an impact velocity of 5.0 m s-1, the mass of the detached kernels reduced from 12.61 to 7.56 g per corn ear. The dissipated momentum exhibited similar patterns to those of the detached kernel mass. In addition, a comprehensive analysis was conducted using complete factorial testing to build a model that examines the combined effects of velocity and moisture content on the mass of the detached kernel. The methodology and data may provide theoretical assistance for designing and optimizing deck plates on maize heads, hence reducing the occurrence of kernel separation.

Li et al. [48] stated that the majority of rural regions in our nation have successfully completed the corn harvest, and the technology for harvesting spikes has reached a high level of maturity. However, in order to fully accomplish the ultimate grain harvest, it is necessary to include an additional procedure. The operational procedure is arduous, time-consuming, and labor-intensive. The corn threshing system is designed with a cut flow and horizontal axis flow construction. The machine utilizes a dual drum configuration; however it deviates from the conventional dual roller series mechanism in which the cutting roller's length is much less than that of the axial drum. The primary component responsible for threshing in the maize threshing system design is an axial drum. The design of the harvester is shown using Solid works engineering drawings, specifically focusing on the structural design of the corn grain harvesting system along the horizontal axis. Furthermore, the maize threshing system yield was determined based on the planting pattern of the Huanghuaihai area. The rate of fragmentation and the variability of corn kernels were determined by several maize threshing tests conducted at varying speeds and moisture levels. To enhance the performance of the corn grain threshing system, a comparative analysis of the test data was conducted and reported. Laboratory analysis of manual seeder as seed rate (2.85 kg/ha and 2.88 kg/ha), seed damage (7.84% and 7.74%), and seed uniformity (62 cm and 64 cm) of cotton and castor crop respectively [57].

4. SNAPPING ROLLER PARAMETER IN MAIZE HARVESTING

In maize harvesting, the snapping rollers are crucial components of the combine harvester or corn picker. They are responsible for effectively stripping the ears of corn from the stalks. The key parameters of snapping rollers include:

Roller speed: This refers to the rotational speed of the snapping rollers. Proper speed is critical to ensure the rollers can strip the ears from the stalks without causing excessive damage to the corn or the plant. Optimal speed balances efficiency and minimal crop loss.

Roller clearance: This is the gap between the two snapping rollers. The clearance must be set correctly to accommodate the size of the corn stalks. If the gap is too wide, smaller stalks may not be gripped effectively, resulting in incomplete harvesting. If too narrow, larger stalks may be crushed, leading to increased losses and potential damage to the equipment.

Roller profile: The design or shape of the snapping rollers' surface impacts how they interact with the corn stalks. Some rollers have a smooth surface, while others have ridges or flutes. The profile is designed to improve the grip and feeding action, ensuring the stalks are pulled down efficiently while minimizing kernel loss and stalk damage.

Material and durability: The materials used for the snapping rollers affect their longevity and performance. Rollers are typically made from durable metals or reinforced polymers to withstand the mechanical stresses during operation. High-quality materials reduce wear and tear, ensuring consistent performance over multiple harvesting seasons.

Angle and orientation: The angle at which the snapping rollers are set can influence the efficiency of corn ear removal. Proper alignment ensures that the stalks are fed smoothly between the rollers. Incorrect angles can cause jamming or inefficient feeding, leading to higher rates of unharvested corn or damage.

Adjustment mechanism: This parameter refers to the ease with which the snapping rollers can be adjusted for different crop conditions. Harvesters should be able to quickly modify roller speed, clearance, and angle to adapt to varying stalk sizes and field conditions, ensuring optimal harvesting efficiency. Each of these parameters plays a critical role in the effectiveness of snapping rollers during maize harvesting. Proper adjustment and maintenance of these parameters ensure maximum yield, minimal crop damage, and prolonged equipment life.

5. DEVELOPMENT TREND OF MAIZE HARVESTER

While the fundamental operations of maize harvesters have remained mostly unchanged for many years, there has been a growing number of advancements and sophisticated technologies in mechanical harvesting. The current developments in maize harvesters may be summarized as.

More versatility and adaptability: A harvester may be fitted with several specialized cutting heads to accommodate the harvesting of different types of crops. Additionally, a harvester may be fitted with cutting heads of varying widths to meet the demands of various levels of productivity. Harvesters use tires of varying widths and employ a crawler-type walking mechanism to enhance their versatility in diverse field situations.

Greater capacity and productivity: Currently, the primary characteristics of sophisticated maize harvesters are their high speed, wide cutting breadth, and fast feeding rate. The largest maize harvester, equipped with a cutting head width of 18 meters and an engine power of 600 kilowatts, has the capacity to harvest 24 rows in a single pass. The newly developed forage harvester, equipped with a cutting head that spans 9 meters in width, has exceptional production efficiency and is specifically designed for use on expansive areas and large-scale farms. The developed implement was operated by the mini-tractor using three-point hitch, it performs both the operations of installation and retrieval of drip line [51]. That functions at forward speeds ranging from 0.7-9.7 kmph (0.43-6.0 miles/hour) and depths between 1 and 2 cm (0.39 and.78 inch)[52].

Automation and intelligentization: Harvesters often use mechanical and electrical technology to minimize harvest loss, enhance operational efficiency, and decrease labor effort. For instance, sensors are created and mounted on harvesters to detect the rows and heights of cutting heads. These sensors aid in adjusting the driving direction and cutting head heights. Consequently, drivers do not need to be vigilant when driving. In addition, sensors and control systems are used to quantify grain mass-flow, moisture content, and yield. The settings of the harvester may be dynamically modified based on the detected information to get the most optimum outcome. The control system of current maize harvesters may provide technical services and comprehensive solutions to farmers by integrating information technologies like GPS and GIS. This enables them to plan their next steps more effectively. The physical, chemical and mechanical properties ofbio-chars depend on the feedstock type and pyrolysis operating conditions [55].

6. CHALLENGES AND SOLUTIONS IN MAIZE HARVESTING DUE TO SNAPPING ROLLER

When investigating the impact of snapping roller environments on maize harvesting, there might be several difficulties that may develop. Here, we've enumerated a few of these difficulties with possible resolutions:

Kernel Damage: A major difficulty in maize harvesting is the potential for kernel damage when snapping rollers are used. Snapping rollers are specifically designed to remove maize ears from the stalks. However, during this process, they may apply an excessive amount of pressure on the kernels, resulting in bruising, cracking, or full detachment from the cob. This not only diminishes the commercial quality of the maize but also impacts its storage and processing attributes, resulting in substantial economic losses for farmers. In order to reduce kernel damage, producers have the option to enhance the design of snapping rollers by using materials and technical processes that provide a gentler hold on the maize ears. In addition, modifying the roller speed and spacing may effectively decrease the impact force on the kernels. Consistent upkeep and calibration of the harvesting machinery guarantee peak efficiency, reducing harm to the maize crop.

Efficiency in Wet Conditions: Rollers that snap often have reduced efficiency when exposed to damp circumstances. If the maize stalks and leaves are moist, the rollers may have difficulty in efficiently separating the ears from the stalks, resulting in blockages and longer periods of downtime required to remove the jams. This lack of efficiency might impede the speed of the harvesting process and result in higher operating expenses. In order to tackle this issue, producers have the option to create rollers that possess improved traction capabilities and self-cleaning characteristics, specifically designed to handle damp and slippery maize stalks. Efficiency may be enhanced by using adaptive control systems that modify the roller pressure and speed in accordance with changing moisture levels. Agricultural workers have the ability to plan the timing of their harvests to coincide with the most favorable weather conditions, whenever possible. Additionally, they may use various drying methods to decrease the moisture levels in their corn fields. The percentage of blown pods, un threshed pods, broken pods and spilled pods were observed as 14.51, 18.92, 0.126, 1.04% and 6.07, 14.59, 0.361, 0.99% for GG-22 and GG-20 varieties, respectively [49]. The factors namely spool rotation (35-53, 53-71 and 71-89 rpm) and forward speed (2.03.0, 3.0-4.0 and 4.0-5.0 kmph) were taken for an experiment [54].

Stalk Retention: An difficulty often seen with snapping rollers is the inadequate retention of stalks, resulting in insufficient removal of ears and excessive attachment of stalk debris to the harvested maize. This issue has the potential to complicate following processing stages and diminish the quality of the collected product. Improving the accuracy of snapping roller mechanisms may enhance the efficiency of stripping. Advanced technical solutions, such as variable-speed rollers and changing roller angles, may be used to accomplish this. These technologies are capable of adapting to various stalk thicknesses and strengths. Consistently upgrading the harvesting equipment to include the most recent technical breakthroughs and making field-specific modifications may assist in reducing stalk retention problems [56].

Wear and Tear: Snapping rollers experience substantial degradation as a result of their mechanical operation and the abrasive properties of maize stalks. This wear may result in decreased productivity and higher maintenance expenses over time, which can have a negative influence on the overall profitability of maize harvesting operations. Employing high-durability materials, such as wear-resistant alloys and coatings, may effectively prolong the lifetime of snapping rollers. By implementing a comprehensive maintenance program that incorporates frequent inspections, lubrication, and prompt replacement of worn-out parts, one may effectively avoid equipment failures and guarantee continuous operational efficiency. Furthermore, allocating resources towards acquiring sophisticated roller designs that provide uniform wear distribution may effectively extend the lifespan of the equipment.

Non-uniform Ear Size: Maize plants have variability in ear sizes, which presents a difficulty for snapping rollers that are usually calibrated to accommodate a conventional ear size. Unequal ear sizes might result in variable harvesting efficiency, as tiny ears may pass through the rollers unnoticed while bigger ears may sustain harm. Creating adjustable snapping rollers that can adapt to various ear sizes has the potential to greatly enhance harvesting efficiency. Advanced technologies, including as sensors and automatic adjustment mechanisms, have the capability to accurately determine the size of each ear and make real-time changes to the roller settings. Rollers that may be customized and have changeable settings, allowing for manual calibration before to harvesting, can assist in managing variations in ear size.

To effectively deal with the difficulties caused by snapping rollers during maize harvesting, it is necessary to use a mix of sophisticated technical solutions, consistent maintenance, and adaptable technologies. Enhancing the design and performance of snapping rollers enables farmers to attain more efficiency, minimize crop damage, and secure a more lucrative harvest.

7. CONCLUSION

Ultimately, the fine-tuning of snapping roller environments is crucial in improving the efficiency of maize harvesting. Optimally calibrated snapping rollers result in less grain loss and damage, leading to increased yield both in terms of quality and quantity. The current trend in maize harvesting equipment is centered on precision agriculture, which involves the integration of modern materials and smart technology to accommodate different field conditions and maize types. Notwithstanding these progressions, obstacles such as ensuring consistent performance in various conditions and minimizing equipment deterioration persist. Possible approaches to address these difficulties are continuous investigation into resilient materials, real-time monitoring systems for adjusting parameters, and the use of machine learning algorithms to forecast and respond to dynamic circumstances. Future advancements in snapping roller technology have the potential to greatly enhance the sustainability and productivity of maize harvesting operations by effectively tackling these difficulties.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gao, Liwei, Shiwei Xu, Zhemin Li, Shengkui Cheng, Wen Yu, Yongen Zhang, Denghua Li, Yu Wang, and Chen Wu. Main grain crop postharvest losses and its reducing potential in China. Transactions of the Chinese Society of Agricultural Engineering. 2016;32(23):1-11.
2. Cheng, Shangkun, Huayu Han, Jian Qi, Qianglong Ma, Jinghui Liu, Dong An, Yang Yang. Design and Experiment of Real-Time Grain Yield Monitoring System for Corn Kernel Harvester. Agriculture. 2023;13(2):294.
3. Oglesby, Camden, Amelia AA Fox, Gurbir Singh, Jagmandeep Dhillon. Predicting In-Season Corn Grain Yield Using Optical Sensors. Agronomy. 2022;12(10):2402.
4. National Bureau of Statistics PRC. China Statistical Yearbook 2002 (Chinese-English Edition). China statistics press; 2002.
5. Geng, Aijun, Xiaolong Hu, Jiazhen Liu, Zhiyong Mei, Zhilong Zhang, Wenyong Yu. Development and Testing of Automatic Row Alignment System for Corn Harvesters. Applied Sciences. 2022; 12(12):6221.
6. Liu YC, Li MX, Wang JZ, Feng L, Wang FZ, He XN. Design and test of entrainment loss detection system for corn kernel direct harvester. Trans. Chin. Soc. Agric. Mach. 2023;54:140-149.
7. DU, Yuefeng, Lirong Zhang, Enrong MAO, Li XY, Wang HJ. Design and experiment of corn combine harvester grain loss monitoring sensor based on EMD [J]. Transactions of the Chinese Society for Agricultural Machinery. 2022;53: 158-165.
8. Zhendong WANG, Tao CUI, Dongxing ZHANG, Li YANG, Xiantao HE, Zepeng ZHANG. Design and experiment of rasp bar threshing element of corn combine harvester. Nongye Jixie Xuebao/Transactions of the Chinese Society of Agricultural Machinery. 2021;52(9).
9. Zhendong Wang, Tao CUI, Dongxing Zhang, Li Yang, Xiantao HE, Zepeng Zhang. Design and experiment of low damage corn threshing drum with gradually changing diameter. Nongye Jixie Xuebao/Transactions of the Chinese Society of Agricultural Machinery. 2021;52(8).
10. Tang Z, Liu S, Zhou F, Li T, Wang J, Li C. Design and experiment of ear harvester for seed corn. *Trans.* CSAM. 2021;52:102-112.
11. Fang HM, Niu MM, Shi S, Liu H, Zhou J. Effect of harvesting methods and grain moisture content on maize harvesting quality. Transactions of the CSAE. 2019;35(18):11-18.
12. Chen Z. Maize full value harvest key technology and equipment. 2014; 1-181.
13. Navas, Eduardo, Roemi Fernández, Delia Sepúlveda, Manuel Armada, Pablo Gonzalez-de-Santos. Soft grippers for automatic crop harvesting: A review. Sensors. 2021;21(8):2689.

14. Baker C, John, Keith E, Saxton WR, Ritchie WCT, Chamen DC, Reicosky MFS, Ribeiro Scott E Justice, Hobbs PR. No-tillage seeding in conservation agriculture; 2006.
15. Available:http://ecoursesonline.iasri.res.in/ mod/page/view.php?id=2250
16. Wang Gang, Wang Gang, Jia HongLei Jia HongLei, Tang Lie Tang Lie, Zhuang Jian Zhuang Jian, Jiang XinMing Jiang XinMing, and Guo MingZhuo Guo MingZhuo. Design of variable screw pitch rib snapping roller and residue cutter for corn harvesters. 2016;27-34.
17. Honglei, Jia, Wang Gang, Zhao Jiale, Li Changying, Wang Yu, Guo Hui. Design and experiment of spacing-adaptive differential snapping rollers for corn harvester. Nongye Jixie Xuebao/Transactions of the Chinese Society of Agricultural Machinery. 2015;46(3).
18. Nagendra M, Ravindra K, Kumar R, Upendra K, Meena SS. Development and evaluation of a portable forage harvester for maize crop. SKUAST Journal of Research. 2020;22(2):68-77.
19. Oxbo 50 series maize head. Available:http://www. oxbocorp.com/Products/FieldMaize.aspx. Accessed [2016-01-28]
20. A comparison of maize head harvest performance 2008- 2009-2010. Available:http://www.oxbocorp.com/Portals /0/ Oxbo/Report_2010.pdf. Accessed on [2016-01-28]
21. Geringhoff. Available:http://geringhoff.de/rota-disc.html. Accessed on [2016-01-28]
22. Cui Tao, Cui Tao, Liu Jia Liu Jia, Zhang DongXing Zhang DongXing, Yang Li Yang Li. Design and experiment of cob-picking and stalk-chopping united mechanism. 2012;95-100.
23. Cui, Tao, Jia Liu, Dongxing Zhang, Shi S. Flexible body simulation for corn stem based on ANSYS and ADAMS. Trans. Chin. Soc. Agric. Mach. 2012;43:112-115.
24. Maize head eats narrow rows for breakfast. Available:http://www.agweb.com/article/tail gatetalk. Accessed [2016-01-29]
25. Geringhoff. Available:https://geringhoff.com/products/ freedom/. Accessed on [2016-01-29]
26. Zinn RA, Barreras A, Corona L, Owens FN, Plascencia A. Comparative effects of processing methods on the feeding value of maize in feedlot cattle. Nutrition Research Reviews. 2011;24(2):183-190.
27. Tiwari PS, Pandey MM, Gite LP, Shrivastava AK. Effect of operating speed and cob size on performance of a rotary maize sheller. Journal of Agricultural Engineering. 2010;47(2):1-8.
28. Mümken, Philipp, Joachim Baumgarten, Stefan Böttinger. Basics for tangential threshing devices-mathematical description of the curve characteristic of the concave clearance. Landtechnik 67, no. 1 (2012): 26-30.
29. Li, Xinping, Wantong Zhang, Shendi Xu, Zhe Du, Yidong Ma, Fuli Ma, Jing Liu. Low-Damage Corn Threshing Technology and Corn Threshing Devices: A Review of Recent Developments. Agriculture. 2023;13(5):1006.
30. Zhe QU, Dongxing ZHANG, Li YANG, Tianliang ZHANG, Zhendong WANG, Tao CUI. Experiment on feed rate and cylinder speed of longitudinal axial flow threshing and separating device for maize. Nongye Jixie Xuebao/Transactions of the Chinese Society of Agricultural Machinery. 2018;49(2).
31. Fu, Jun, Zhi Chen, Lujia Han, Luquan Ren. Review of grain threshing theory and technology. International Journal of Agricultural and Biological Engineering. 2018;11(3):12-20.
32. Products combine harvesters. Available:http://agriculture1. newholland.com/eu/en-uk?market=uk. Accessed [2016-02-21]
33. Harvesting. Available:http://www.caseih.com/northamer ica/ en-us/products/harvesting. Accessed on [2016-02-21]
34. Grain harvesting. Available:http://www.deere.com/en_US/pro ducts/equipment/grain_harvesting/grain_h arvesting.page. Accessed on [2016-02-21]
35. Chen, Meizhou, Guangfei Xu, Yuanzhen Wei, Yinping Zhang, Peisong Diao, Huanxiao Pang. Design and experiment analysis of the small maize harvester with attitude adjustment in the hilly and mountainous areas of China. International Journal of Agricultural and Biological Engineering. 2024;17(1):118-127.
36. Mu, Xiaodong, Huabiao Li, Zongyuan Wang, Qihuan Wang, Duanyang Geng, Junke Zhu. Comparison of crushing effect of differently shaped crushing rollers on

whole-plant silage maize. Agriculture. 2023;13(7):1276.
37. Chen, Meizhou, Guangfei Xu, Maojian Wei, Xiaowei Li, Yuanzhen Wei, Peisong Diao, Peide Cui, Shaomin Teng. Optimization design and experiment on feeding and chopping device of silage maize harvester. International Journal of Agricultural and Biological Engineering. 2023;16(3):64-77.
38. Chen, Shun, Xinwei Zhang, Chunxia Jiang, Kechuan Yi, Qingqing Wang, Xuemeng Sha, Xiaolong Zhang. Experimental Study on the Peeling Fracture Effect of Fresh Corn Ear Based on High and Low Roller Peeling Equipment. Agriculture. 2023;13(8):1585.
39. Garudik, Shalini RK, Naik, Kanhaiya Thakur, Geeta Patel. Performance evaluation of maize cob harvester in Chhattisgarh, India. International Journal of Plant and Soil Science. 2023; 35(24):191-201.
40. Chandel, Rupinder, Surinder Singh Thakur. Optimizing field performance of axial flow rotary combine with single rotor and snap roll header for maize harvesting. Journal of Agricultural Science. 2022;14(3):211.
41. Zhang, Zhen, Ruijuan Chi, Yuefeng Du, Xiang Pan, Naixi Dong, Bin Xie. Experiments and modeling of mechanism analysis of maize picking loss. International Journal of Agricultural and Biological Engineering. 2021;14(1):11-19.
42. Parsons, Larry N. Machinery conversion for single-pass harvest and baling of a whole-plant maize crop. Master's thesis, The Ohio State University; 2021.
43. Qin, Jiahao, Yuepeng Yin, Zhigang Liu, Yuefeng Du, Guoye Wang, Zhongxiang Zhu, Zhen Li. Optimisation of maize picking mechanism by simulation analysis and high-speed video experiments. Biosystems Engineering. 2020;189: 84-98.
44. Zhang, Zhen, Ruijuan Chi, Naixi Dong, Yuefeng Du, Xiaoyu Li, Bin Xie. Design and testing of an intelligent control system for maize picking harvest. Applied Sciences. 2020;10(24):8888.
45. Vodounnou, Julus H, Emmanuel A Ajav, Gontrand C Bagan, Victorin K Chegnimonhan. Devel- opment and performance evaluation of a small-scale maize harvester for developing countries. Journal of Experimental Agriculture International. 2020;42(8):144-156.
46. Wang, Lijun, Yongbao Wan, Zhiheng Zhang, Yongtao Yu, Tianhua Liu. Performance evaluation of a Maize Stalk Chopping device based on field tests. Applied Engineering in Agriculture. 2019;35(6):997-1008.
47. Fu, Qiankun, Jun Fu, Zhi Chen, Lujia Han, Luquan Ren. Effect of impact parameters and moisture content on kernel loss during corn snapping. International Agrophysics. 2019;33(4).
48. Li, Yanfang, Zhiqin Wang, Decheng Wang, Kaili Han, Zhifei Gu, Chen Cai, Yalei Wu, Yan Li. Structural Design and Experimental Analysis of Maize Threshing System1 The progress of grain threshing technology. In *2018* ASABE Annual International Meeting, p. 1. American Society of Agricultural and Biological Engineers; 2018.
49. Amrutiya MD, Makavana JM, Kachhot AR, Chauhan PM, Tiwari VK. Performance evaluation of tractor operated groundnut thresher. Current Journal of Applied Science and Technology. 2020;38(6): 1-15.
50. Makavana JM, Agravat VV, Balas PR, Makawana PJ, Vyas VG. Engineering properties of various agricultural residue. International Journal of Current Microbiology and Applied Sciences. 2018;7(6):2362-2367.
51. Balas PR, Jhala KB, Makavana JM, Agravat VV. Design and development of mini tractor operated installer and retriever of drip line. International Journal of Current Microbiology and Applied Sciences. 2018 A;7(8):1566-1577.
52. Balas PR, Makavana JM, Mohnot P, Jhala KB, Yadav R. Inter and intra row Weeders: A review. Current Journal of Applied Science and Technology. 2022;41(28):1-9.
53. Makavana JM, Sarsavadia PN, Chauhan PM. Effect of pyrolysis temperature and residence time on bio-char obtained from pyrolysis of shredded cotton stalk. International Research Journal of Pure and Applied Chemistry. 2020;21 (13):10-28.
54. Balas PR, Makavana JM, Jhala KB, Chauhan PM, Yadav R. Economically comparison of mini tractor operated installer and retriever of drip line. Indian Journal of Agriculture and Allied Sciences. 2022 A;8(1):2395-1109.
55. Makavana JM, Chauhan PM, Sarsavadia PN, Yadav R. A review of sustainable

technologies for bio char production from biomass any waste Material. International Journal of Environmental Sciences and Natural Resources. 2020;25(1):24-36.
56. Balas PR, Lakhani AL, Pargi SJ, Mehta TD, Makavana JM. Performance evaluation of manual seeder machine for precision farming. Journal of Experimental Agriculture International. 2024;46(2):68-77.
57. Kumar M, Bej G, Pandey HS. Status and Scope of Automated Coconut Harvester in India: A Review. J. Exp. Agric. Int. 2023;45(5):1-15. Available:https://journaljeai.com/index.php/JEAI/article/view/2115
58. Ashraf MT, Victor VM, Naik RK. Mechanizing Sugarcane Harvesting in India: A Review. Curr. J. Appl. Sci. Technol. 2023;42(47):80-5. Available:https://journalcjast.com/index.php/CJAST/article/view/4318
59. Corredo LD, Canata TF, Maldaner LF, de Lima JD, Molin JP. Sugarcane harvester for in-field data collection: State of the art, its applicability and future perspectives. Sugar Tech. 2021;23(1):1-4.
60. Makavana JM, Makwana PJ, Kukadiya VD, Joshi AM. Post-harvest losses of lemon fruits: An assessment of microbial floral strength during post-harvest handling. International Journal of Current Microbiology and Applied Sciences. 2018;7(5):1184-1188.

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