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Prototype Development of a Single row Self-Propelled Maize cob picker cum Stalk cutting machine

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ABSTRACT

Maize is one of the vital crops after rice and wheat in India and is a widely produced cereal. Maize contributes only 2.4 percent of total world production. Maize occupied 9.21 Mha, with a production of 25.82 MT in India. The average yield per hectare during 2018-19 was 2804 kg per hectare. Maize is being used in numerous sectors and is consumed mainly in poultry in India. The demand for maize in the developing world would double and to meet the demand, the production must be increased. The small-scale harvesters which can be affordable by Indian farmers are to be developed to make harvesting operations easier. The proposed machine can accomplish three operations at a time: cutting the maize stalk, removing cobs from the stalk, and collecting removed cobs from the plant. The machine will be of great use for small-scale farmers in many ways.

Key words: *Maize Harvester, Snapping rollers, Serrated blade, Stalk cutting, Cob Picking, Productivity*

Introduction

Maize (*Zea mays L.*) is one of the highly adaptable rising crops having wider adaptableness under different agro-climatic conditions. Maize has the highest yield potential among all the cereals, and it is also known as the "**Queen of Cereals**" worldwide. It is cultivated on approximately 150 Mha in almost 160 countries and contributes 36 percent (782 Mt) of the worldwide grain production. The USA is one of the largest producers of maize providing nearly 35 percent of the total production in the world. The other important maize growing countries are China, Brazil, India, Argentina, Ukraine, and Mexico. By 2050, the requirement for maize in the expanding world would double and it is considered as one of the fastest-growing cash crops.

India has 21 percent of corn acreage and provides 2.42 percent of world production in the year 2018. Maize is the third significant food grain in India following wheat and rice and it ranks fourth in total area and seventh in total production and productivity. Maize is the potential crop for doubling farmers' income while providing gainful employment.

The maize landholding is split among distinct farm sizes. Most of the maize farming (60 percent) is done by marginal farmers with less than 1 hectare. In general, specific landholding in India is substantially smaller than the major agri-based countries, and this stands correct in maize farming too.

Based on the past and present trend in maize area, production, and productivity indicates that the demand for maize and its production and productivity would continue to increase in near future. The

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major driving forces of maize demand are poultry and livestock feed and in industries.

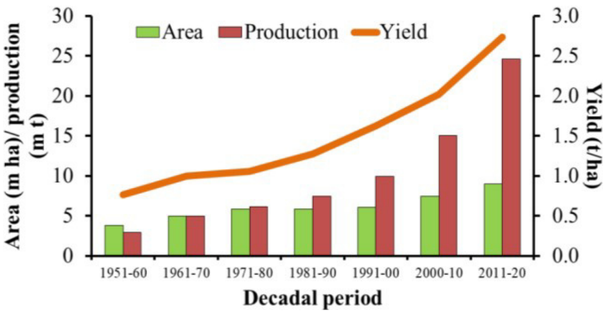


Fig. 1. The trend in maize area, production, and yield in India during 1951-2020

Table 1. Production of Maize during 2018-19 in major producing states of India

S. No	State	Area (Mha)	Production (Mt)	Yield (kg/ha)
1	Madhya Pradesh	1.27	**4.13**	3261
2	Karnataka	**1.34**	3.76	2805
3	Tamil Nadu	0.39	2.83	**7258**
4	Bihar	0.67	2.48	3708
5	Telangana	0.54	2.08	3837
6	Rajasthan	0.84	1.89	2240
7	Maharashtra	0.93	1.77	1906
8	West Bengal	0.26	1.73	4805
9	Andhra Pradesh	0.27	1.56	5875
10	Uttar Pradesh	0.73	1.53	2082
11.	Others	1.78	3.95	2213
	All India	**9.03**	**27.72**	**3070**

Source: Agricultural Statistics at a Glance 2020.

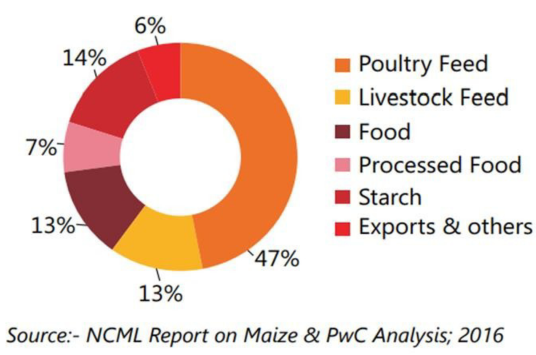


Fig. 2. Consumption of Maize in India Mechanization in Maize Harvesting

FICCI envisages that the productivity level of Maize is supposed to double i.e., almost to 5 MT/ha with a consequent increase in farmers' income by 2022. There is an extensive insight that farm mechanization is vital for increasing yield. Farm mechanization has become essential to ensure timely and proper farm operations that can only be achieved by using efficient and well-adopted machinery and implements.

In maize cultivation, i.e., cob picking, harvesting of stalk, dehusking, and shelling are the operations that require maximum energy of the total energy requirement of the crop production. As for now, there are dehusker cum shellers that are commercially available in markets but cob picking and stalk cutting are the operations where there is a lack of mechanization.

In manual harvesting, different methods or equipment are used by farmers as per their economic background. When the crop is matured and cob moisture is about 25-40 percent, plants are cut by sickle and laid on the side. Later, when the cob moisture is brought down to 15-20 percent, the picking of individual cobs from the plant is done. These operations require about 250-400 man-h/ha. The net cost for manual harvesting with sickle and threshing with conventional maize thresher was 2650/- per hectare. (Ajaib Singh, 2014)

The self-propelled maize combine harvesters are used for harvesting, shelling, and cleaning. The net cost of operation with the combine harvester was 9000/- per hectare but there is a reduction of 100-140 man-h/ha requirement for cob-picking and dehusking of the maize cobs (Ajaib Singh, 2014). Due to high costs and low economic background, farmers cannot afford such costly machines. To mechanize the maize harvesting operation, there is a need for small and compact-sized machines that can best suit small-scale agricultural workers. The developed harvester will also help in drudgery reduction, cost reduction, and time consumption.

The self-propelled single-row maize harvester is not available in the country. To meet the requirements and suitability for maize harvesting, there is a need to develop such a machine by considering different parameters. Therefore, to make picking of cob easier and to overcome the shortage of labour during peak season, mechanical harvesting/cob picking of maize is recommended and there is a need to develop such low-cost harvesters.

Theoretical Calculations for Selection of Power Source for Harvester

The selection of power source depends on the power required for snapping rollers, serrated cutting blade, pneumatic wheels for propelling, etc., The total theoretical power required for cutting of maize stalk with a circular rotating blade can be calculated by the following process:

The total power required for cutting (Tembhukar *et al.*, 2016),

$P_{wt} = (P_{kz} + E_{sc}V_f)W_c$ ... (1)

Where,

P_{wt} is the total power required (kW)

P_{kz} is the idling power (kW/m of cutting width)

E_{sc} is specific cutting energy (kJ/m^2) V_f is forward speed (m/s)

W_c is cutting width (m)

$E_o = F_{max} \times \frac{d}{2}$ .. (2)

Where,

E_o is cutting energy (J)

F_{max} is maximum cutting force (N) & d is the diameter of a stalk (m).

Static cutting forces ranging from 215 N to 570 N for 30 mm diameter (maximum) for corn stalks.

So, F_{max} = 570 N and d = 30 mm

$E_o = 570 \times 30/\ (2 \times 10^{-3})$

= 8.55 J

Specific cutting energy is obtained by dividing cutting energy by the width cross-sectional area of the stem.

$E_{sc} = (8.55 \times 10^{-3})\ /\ \{\pi/4 \times (30 \times 10^{-3})^2\}$

= 12.09 kJ/m^2

Assume,

The forward speed of the harvester is in the range of 1-2 km/h. Taking forward speed as 1.5 km/h

Therefore, V_f = 0.42 m/s

Saw idling power consumption can be expressed as:

$P_k = J\omega^2/2$ ... (3)

Where,

J is the mass moment of inertia for the circular blade (Kgm^2)

ω is blade's angular velocity (rad/s)

Mass moment of inertia for a rigid disc with radius of r, mass of m about axis of rotation z

$J_z = mr^2\ /2$ …………………..….. (4)

$= (0.6 \times 0.125^2)/2$

= 0.0047 kgm^2

Where, m is mass of disc and r is the radius

With due attention to rotary inertia forces for maize stalks rotational speed must be low (900- 1100 rpm).

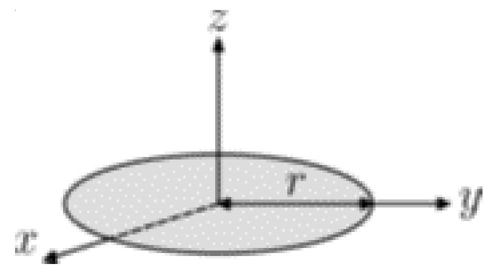


Fig. 3. Rotating disc about Axis of rotation Z

So, we take N=1100 rpm

$\omega = (2\pi N)/60$ .... (5)

$= (2\pi \times 1100)/60$

= 115 rad/sec

Thus, $P_k = (0.0047\times115^2)/2$ watt

= 31.07 watt

= 0.031 kW

$P_{ks} = P_k$/cutting width (cutting width= half of the diameter of the blade =125 mm)

$= (0.031/125 \times 10^{-3})$ kW/m

= 0.248 kW/m

Now, putting the value of P_{ks}, E_{sc}, V_f and W_c in equation given below

$Pwt = (P_{ks} + E_{sc}V_f)W_c$

$= (0.248+ 12.09\times0.42) \times 125\times10^{-3}$

= 0.665 kW (0.89 hp)

The power required to cut the maize stalk with a circular blade having 250 mm diameter and the machine forward speed is 1.5 km/h was found to be 0.665 kW.

So, approximately the power requirement for cutting maize stalk is taken as 1 hp.

A 4-stroke diesel Engine single-cylinder of 5 kW was taken to fulfill the power required for maize harvester for self-propelling of pneumatic wheels, snapping rollers, gearbox losses, etc.,

Conceptual Design

The harvester is developed taking into different considerations such as:

1. Maize Variety
2. Topographical conditions
3. Physical Properties of Maize Stalk
4. Number of cobs per plant
5. Plant density

6. Moisture content at the time of harvesting
7. Force required to cut the stalk

The developed prototype consists of various components like engine, horizontal snapping rollers, guiding unit, holding unit, serrated blade, and gearbox. The machine performs two operations simultaneously i.e., stalk cutting and cob picking. The cobs detached from the stalk are collected in the collection box.

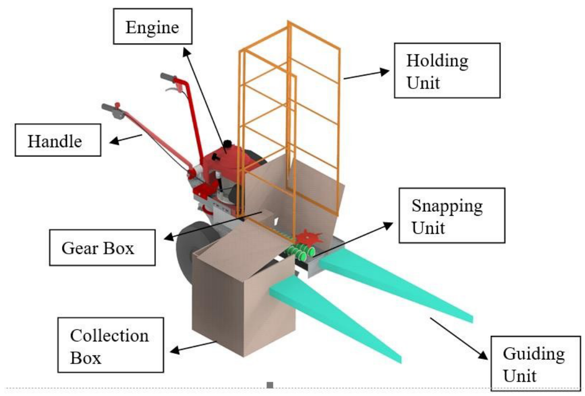


Fig. 4. Components of Maize Stalk cutter cum cob picker machine

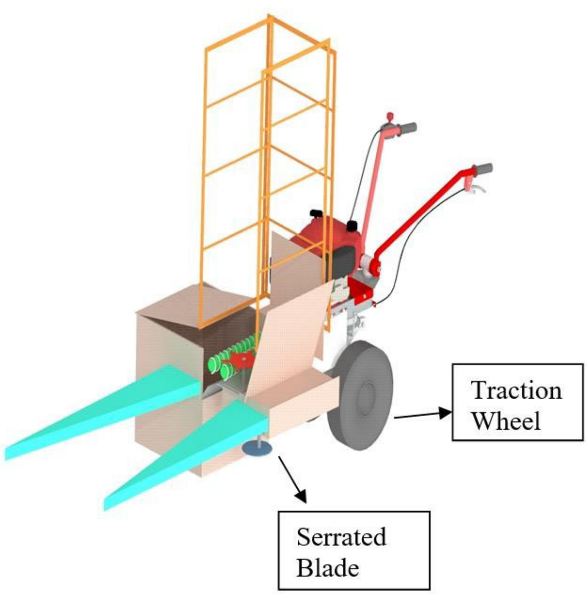
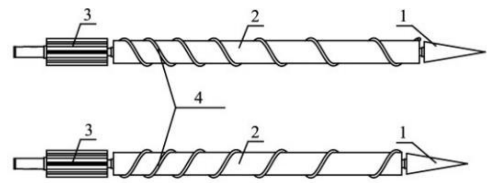


Fig. 5. Maize Stalk cutter cum cob picker machine (Side View)

Working Principle

The proposed machine performs operations i.e., cutting of stalk, cob removal, and cob collection simultaneously. The principle involved here is the standing crop is cut and guided to snapping rollers to snap the cobs from the stalk. The different units of the proposed machine are the guiding unit, cutting blade, snapping unit, and collection chamber.



1. Tapering section 2. Picking/Body section,
3. Cut Section, 4. Variable screw pitch ribs

Fig. 6. Variable Snapping rollers

Guiding unit: It is a relatively simple matter for gathering device controls stalks and feeding them into the snapping unit when the stalks are standing. The guiding unit consists of guiding arms that divide the plant row-wise and a star wheel that revolves continuously in a horizontal plane through gear drive to guide the maize plant straight into the snapping rollers. The lodged stalks are lifted by the gathering assembly and are guided into the snapping unit without damage to cobs.

Cutting blade: A circular rotating blade of 250 mm diameter having serrated teeth on the periphery is used for cutting the stalk. The blades will be made up of carbon steel with 2.5 mm thickness teeth. It will be fixed on bevel gear casing by holders and reverse screws.

Snapping unit: The spiral ribbed rollers are used to remove the cobs from the stalk which revolve in an inward direction. It will have tapered and spiral ribbed points to facilitate stalk entry and pull the maize stalks downward between the two rolls. The cobs are snapped off from the stalk when the cobs contact the close space rolls.

The snapping roller unit consists of a pair of reversed and inwardly rotating rollers. The tapering portion at the face end of the picking roller is smoothed out and mainly guides the stem into the picking/body section. The picking portion is cylindrical, and the two parallel rollers have opposite threads with variable threads. The ears are separated from the plants by pinching the corn plants. The rear part of the rollers is a solid pulling section also known as the cut section. The primary function is to forcefully discharge the stem part and the straw on the ground.

Collection chamber: The cobs removed will be collected directly in the collection chamber which is provided adjacent to the snapping unit. When the chamber is full, the cobs will be removed.

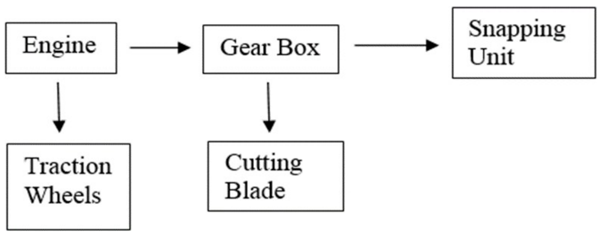


Fig. 7. Flowchart of Power Transmission of Maize Harvester

Advantagaes

a. The proposed machine reduces the human effort in cutting the maize stalk manually using sickles and cob picking.
b. It reduces the time consumed in cutting the stalk and cob picking
c. It enhances the agricultural productivity of maize by decreasing the cost of cultivation.
d. It cuts the number of labor as well as labor hours to cut down the stalk.
e. Many of the machine parts are simple and is portable.
f. Cost of operation and maintenance is extremely low due to inexpensive and easily accessible parts.
g. Unskilled workers can also operate the machine and its maintenance is quite easier.

Conclusion

Maize is one of the vital crops in the world and it has the potential to double the farmer's income. In India, much of the maize growing farmers are small-medium scale farmers who cannot afford costly huge machines for harvesting. Presently, the manual harvesting of maize is tedious and time-consuming. The harvesting of maize needs to be done at the right moisture content to ensure the quality of maize grains. Manual harvesting also increases the cost of operation which in turn decreases the profit of farmers.

The proposed machine performs the cutting of maize stalk and cob picking operations simultaneously so that the man-hours required to perform these operations can be drastically decreased. The development of this machine will ensure the convenience, availability, and easiest way to remove the cobs from a plant which can also enhance the income of maize growing farmers especially small-medium scale farmers. It can also be helpful to overcome the shortage of labor during peak season and a single unskilled worker can operate/maintain the machine.

The specific cutting energy for cutting maize stalks is 12.09 kJ/m^2. The forward speed is taken as 0.42 m/s (1.5 km/h) and the power required to cut the stalk is taken as 1 hp and the overall 5 kW engine is selected for the necessary operations in a harvester.

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