RESEARCH ARTICLE

Development of Tractor Front Mounted Harvester for Finger Millet

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ABSTRACT

Finger millet crop is important minor millet, which can serve as both food and fodder. Manual harvesting of finger millet involves harvesting earhead and stalk separately which is labor intensive. Hence, the study aimed to design and develop a harvester for finger millet to remove drudgery in harvesting and to achieve a low cost of harvesting. The important crop and machine parameters influencing the harvesting of finger millets were identified for the most prominent variety of CO (Ra) 14 in finger millet. A prototype finger millet harvester was developed and the effect of a machine and operational parameters were evaluated in terms of header loss at different levels of a rotational speed of reel 30, 35 and 40 revolutions per minute (rpm), 35, 40 and 45 cm mounting height of reel and forward speed 1.6, 2.68, and 3.48 km/h. The performance of the harvest was found satisfactory. Comparing the best combinations of machine and operational parameters, the minimum header loss of 1.25 per cent was achieved at the combination of 30 rpm rotational speed of reel, 40 cm mounting height of reel and 2.68 km/h forward speed.

Keywords: *Cutter Bar; Reel; Header Loss; Forward Speed; Reel Mounting Height*

INTRODUCTION

Finger millet, also known as ragi, is valued as a staple food in south India (Karnataka, Tamil Nadu, and Andhra Pradesh) and in hilly regions of the country. Finger millet is often referred to as coarse cereal. Realizing the nutrient richness of millets they are considered as "Nutri-cereals". Finger millet is also known as a dry land crop cultivated in both tropical and sub-tropical regions The high-yielding improved varieties of finger millet are CO-9, CO-13, CO (Ra) - 14, TRY - 1, Paiyur - 1, Paiyur - 2, VL Mandua - 101, 124, 149, 204, 146, 314, 315, H-22, K - 1, Hullubele, Karegidda, Gidda, Jasarilambi, Madayyanagiri- 1,2, Dodda, Jadesange, Jenumudda.

Finger millets can be grown even in poor soil and climatic conditions of low rainfall and intense heat. They have a short growing period and can be very well fitted into multiple cropping systems under irrigated and dry farming conditions. They can provide nutritious grain and fodder within a short period. Millets can be a valuable source of forage because of their rapid growth, high nutritive value, and ability to survive under stressful conditions such as drought. These crops fit well into rotational systems when emergency summer forage is needed. Proper harvest timing is critical in order to achieve maximum feed for animals requiring high nutrition. For classes of livestock with lower nutritional demands, harvests can be delayed to maximize yield.

Wekha *et al.*, (2017) reported that finger millet stover contains up to 61 per cent total digestible nutrients and can be used as good fodder. It provides excellent hay and is used as green forage for cattle, sheep and goats (Chaab *et al.,* 2018). The straw resulting from the grain harvest is valuable and can be grazed directly by the animals or used in cut-and-carry feeding systems. Baath *et al*., (2018) reported that finger millet can generate forage yields ranging from 5.0 to 12.3 Mg/ha.

Manual harvesting of finger millet (whole crop) using sickles involves 25 man-days per hectare. Harvesting of earheads and stalks separately again increases labor. Scarcity of labor and higher wages during harvesting season is a severe problem increasing production costs. Similarly, the lack of appropriate machinery is one of the barriers for increasing the production and productivity of the finger millet crop. To harvest finger millet, small-scale farmers use hand tools, such as scythe or sickle or a combine harvester, which again requires labour for separating the earheads from the stalk. Both the techniques are not suitable for small-scale grain production. Harvesting using a combine harvester is cumbersome and using hand tools is time-consuming and labor intensive. An appropriately scaled machinery is needed to harvest finger millet cultivated by small-scale farmers.

Hence, an attempt was made to develop a suitable tractor front-mounted harvester combining the operation (harvesting earheads and cutting stalks) in a single pass.

MATERIAL AND METHODS

The tractor front mounted finger millet harvester developed consists of two cuts, one at the bottom of earheads and the other at the bottom of the shoot system. Based on the average height of the earhead, the height of the first cut was fixed and the second cut was set at 100 mm from the ground level. The concept of a vertical conveyor reaper was adapted for the development of the finger millet harvester. The main components of the finger millet harvester are shown in figure 1.

Harvesting unit

The harvesting unit is the vital part of harvesting the crop with two cuts, collection of earheads, conveying of earheads, windrowing of the stalk etc., takes place. The harvesting unit consists of two cutter bars, reel system, conveying and collection system for earheads, conveying system for stalks and a supporting wheel.

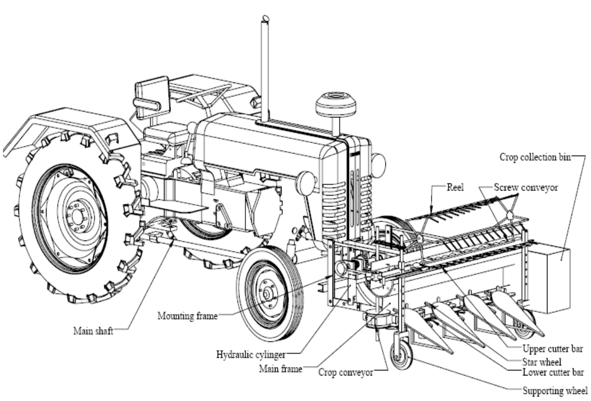


Figure 1: Tractor Front Mounted Finger Millet Harvester

Cutting units

The harvesting unit comprises two cutting stages: an upper cutting unit (A) and a lower cutting unit (B). The height of the upper cutting unit (A) was selected as 460 mm based on the mean value of the lowest height of earhead in the finger millet crop. The height of the lower cutting unit was 100 mm from ground level. The power to the lower cutting unit was obtained from tractor PTO through gear box. A slider crank four bar mechanism was used to convert the rotary motion into reciprocating motion. The total width of the lower cutting unit was 1600 mm.

Reel system

The reel system serves the function of feeding the crop to the upper cutting unit of the harvester. In lodged and tangled crops, the bat reel becomes less effective and the use of the tined pickup reel was considered mandatory. The pickup reel tines enter vertically and retain that orientation resulting in a smoother flow of material to the header and superior cutting. Hence a tined pickup reel was selected.

Increasing the velocity ratio will increase the peripheral speed of the reel and this may increase crop losses due to threshing. Hence, a velocity ratio of 1.2 to 1.5 was selected. The efficiency of the reel was found higher while using 6 tine bars (Choudhuri, 1998).

Conveying and Collection unit for earheads

The prototype finger millet harvester was provided with a screw conveyor to convey the harvested finger millet earheads to the left of the harvester and a collection bin for collecting the conveyed crops.

a. Screw conveyor

A screw conveyor was located below the cutter bar assembly so that the cut earheads fall on the screw conveyor and conveys them to the left end of the finger millet harvester. A collecting bin was provided to collect the conveyed earheads. Based on the space availability the diameter of the screw conveyor selected was 150 mm. The pitch of the screw conveyor plays an important role in conveying the harvested crop. The pitch (P) of the screw conveyor is equal to 0.8 to 1 of the diameter of the screw conveyor (Design data, 2003). The maximum rotational speed recommended for a 150 mm screw conveyor diameter is 150 rpm. The screw conveyor clearance of screw conveyor was 16 mm for better conveyance (Zareiforoush et al., 2010).

b. Earhead collecting bin

The harvested earheads from the upper cutting unit were conveyed by the screw conveyor and collected in a bin of 500 × 500 × 250 mm size.

Conveying unit for stalks

The conveying system for stalks comprises a crop divider and star wheel for gathering the stalks to the lower cutting unit. A flat belt conveyor was provided to convey and windrow the stalks. The angle of star wheel inclination with respect to ground level was 18 to 22 degrees for satisfactory gathering and feeding of plants to the cutter bar. The tip velocity of the star wheel was 1.56 m/s.

Supporting wheel

A supporting wheel was attached on both sides of the harvesting unit to provide necessary support and better balancing during operation.

Selection of variables

Reel speed (N)

Reel speed is an influencing factor in both harvesting efficiency. The rotational speed of the reel was set between 30 to 34 rpm for harvesting millet (Suning *et al*., 2015). Hence the reel speed selected for the study was 30 (N_1), 35 (N_2), 40 (N_3) rpm.

Reel mounting height (M)

The reel should be mounted at a height such that the height of the tines does not deflect the stalks from the machine and stalks do not fall through the reel tines. Reel height plays a major role in the performance efficiency of harvester (Chaab *et al*., 2018). The reel mounting height was found from the mounting height of reel center, radius of the reel and length of stalk cut by the cutter as 39.7 cm. Hence the reel mounting heights selected for the study were 35 (M_1), 40 (M_2) and 45 (M_3) cm from the upper cutting unit.

Forward speed (S)

Forward speed has a great impact during harvesting in determining the amount of harvest losses because of losses proportionate to the speed of the harvester due to its impact on the operating units and feeding rate (Jalali and Abdi, 2014). The forward speeds selected for the study were 1.6 (S_1), 2.68 (S_2) and 3.48 (S_3) km/h.

Performance evaluation

The performance evaluation was carried out using header loss as an evaluation parameter at selected levels of reel rotational speed, reel mounting height and forward speed

Header losses

Before operating the finger millet harvester in the field, natural losses (B) were measured. A metal frame of size 650 mm × 385 mm was used to determine the natural loss. The frame was placed at ten random places in the field, then the dropped kernals and ears in the frame on the soil were gathered and counted at the laboratory.

For measuring the header loss of the finger millet harvester, at the end of each harvested row the harvester went back along the harvested path about 8 m. Then three 650 mm × 385 mm metal frames put in three places, then kernals and ears were gathered in order to be counted (A). Then header loss was calculated using the following expression(Eqn.1 and 2) (Bawatharani *et al*., 2015).

$$Header\ loss, kg\ ha^{-1} = (A - B) \times 1000\ grain\ weight\ \times 4 \times 10^{-2} \quad (1)$$

(Grain weight for 1000 finger millet grains = 41.53 g)

Where,

A = total grains and ears counted at the head

B = total grains and ears counted in the natural loss section

$$Header\ loss, per\ cent = \frac{Header\ loss}{Total\ yield\ of\ the\ field} \times 100 \quad (2)$$

RESULTS AND DISCUSSION

The developed harvester was evaluated in the field at Agricultural Engineering College and Research Institute, Kumulur. The header loss was measured for each set of variables selected (Figure 2). The data recorded were analyzed using AGRESS software to determine the significance of factors using ANOVA table

Effect of reel rotational speed at selected levels of reel mounting height and forward speed

There observed a minimum and maximum header loss of 4.75 and 16.57 per cent at 30 and 40 rpm reel rotational speed (Figure 3). The increase in reel rotational speed caused an increase in header loss. This is because at low reel rotational speed, the fingers fail to collect and direct the crop to the header. When reel rotational speed was increased fingers beats the earheads strongly and the earheads were thrown behind the harvester, leading to an increase in header loss.

Effect of reel mounting height at selected levels of reel rotational speed and forward speed

It is inferred that 11.4 per cent and 32.9 per cent increase in header loss was observed at 35 cm reel mounting height and 45 cm reel mounting height when compared to 40 cm reel mounting height (Figure 4). This because at high reel mounting height (45 cm), the reel fails to push the plant in to the path of the platform auger which causes the earheads to fall back into the field. This might be because, as the reel mounting height increases, the clearance between the cutter bar and reel increases which causes the earheads to fall down due to vibration.

Effect of forward speed at selected levels of reel rotational speed and reel mounting height

The effect of forward speed on header loss was highly influencing and indicated a maximum header loss of 16.17 per cent at 3.48 km/h forward speed and 40 rpm reel rotational speed (Figure 5). A minimum header loss of 5.01 per cent was observed at 1.6 km/h forward speed and 30 rpm reel rotational speed. It was observed that increasing the forward speed increases vibration in the upper cutting unit, which causes an increase in header loss.

The test results were statistically analyzed for header loss (Table 1). The analysis of factor means revealed that minimum header loss was observed in the combination of $N_1M_2S_2$ after comparing all possible combinations of interactions of factors considered. The selected best combinations of parameters are 30 rpm reel rotational speed, 40 cm reel mounting height and 2.68 km/h forward speed.

Table 1. Analysis of variance for header loss

SV	DF	SS	MS	F
Treatment	26	1201.31	46.20	81.13**
Reel rotational speed (N)	2	619.87	309.93	544.22**
Reel mounting height (M)	2	305.47	152.73	268.19**
Forward speed (S)	2	232.29	116.14	203.94**
N × M	4	18.77	4.69	8.24**
M × S	4	5.50	1.37	2.41NS
N × S	4	10.14	2.53	4.45**
N × M × S	8	9.24	1.15	2.02NS
Error	54	30.75	0.56	
Total	80	1232.07	15.40	

C.V = 7.5 per cent, ** = Significant at 5 per cent level, NS= Non- significant

Figure 2. Performance evaluation of the tractor front mounted finger millet harvester

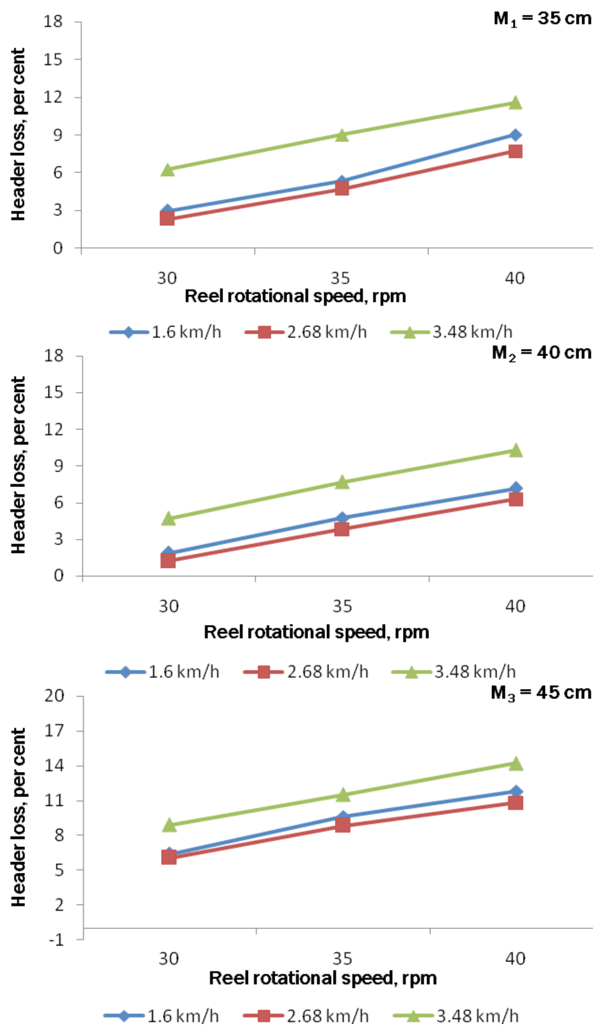


Figure 3. Effect of reel speed at selected levels of reel mounting height and forward speed on header loss

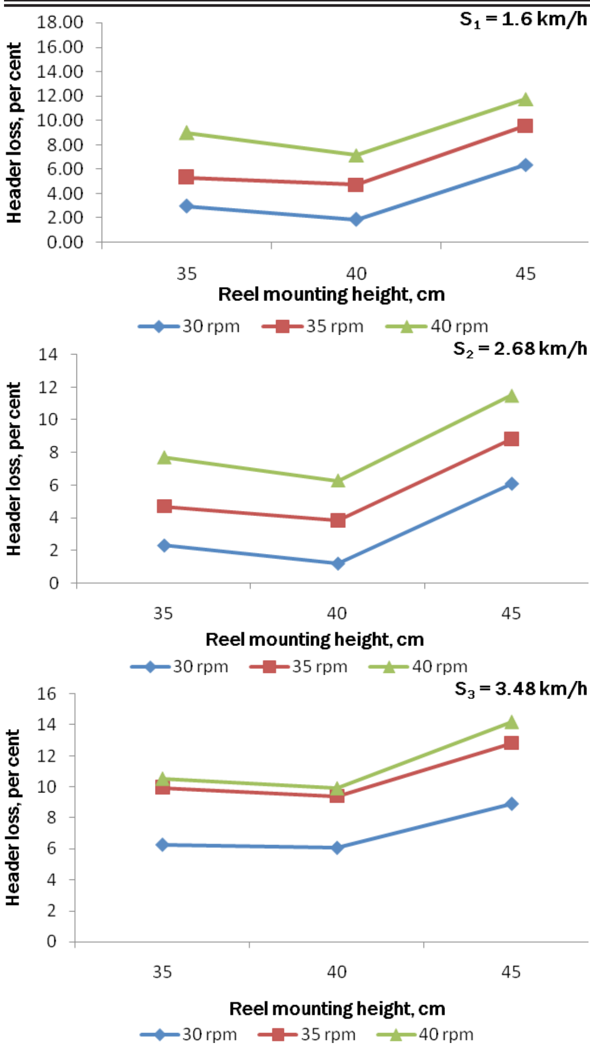
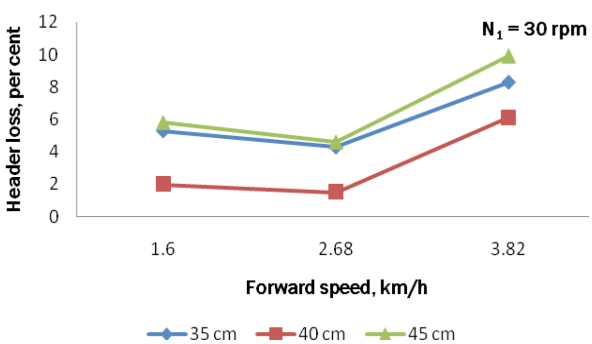


Figure 4. Effect of reel mounting height at selected levels of reel speed and forward speed on header loss



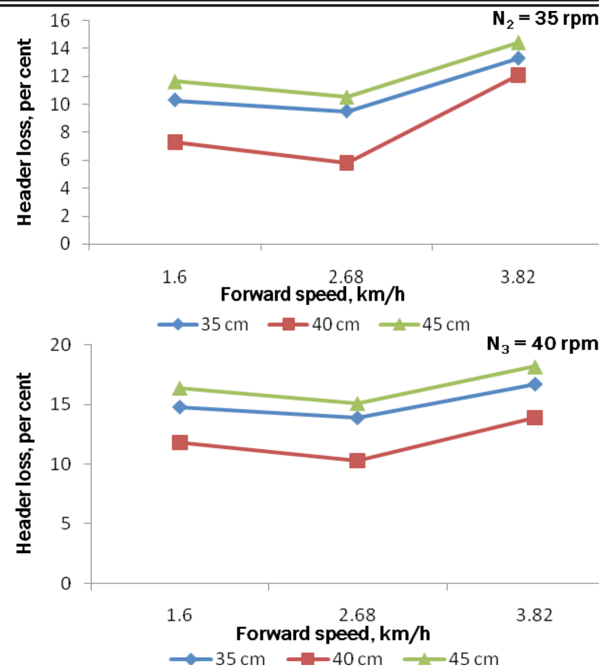


Figure 5. Effect of forward speed at selected levels of reel speed and reel mounting height on header loss

CONCLUSION

The developed harvester worked satisfactorily during the field evaluation. It is concluded that the header loss was significantly affected by the reel rotational speed, mounting height of reel and forward speed and forward speed has major effect on header loss. The minimum header loss of 1.25 per cent was achieved at the combination of 30 rpm reel rotational speed, 40 cm mounting height of reel and 2.68 km/h forward speed with 1.25 percent header loss hence they were considered optimum. Further research is necessary to reduce header loss by modifying the harvesting unit.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

The article written is entirely an original research work and free of plagiarism. The references used were cited appropriately.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding mail; nisha34agri@gmail.com

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