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Design considerations for development of mechanical ginger harvester-cum-elevator

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Abstract
Manual harvesting of ginger (*Zingiber officinale* Roscoe,) is time consuming, inefficient and full of drudgery hence, mechanization of ginger harvesting is the need of the hour. The harvester should satisfy the basic requirements of achieving maximum harvesting efficiency with minimum damage to the crop and at a lesser cost. Hence an investigation was undertaken to design different components of tractor operated ginger harvester cum elevator. The size of the harvester suitable as per the agro technical features of the crop was taken in to consideration during the design of the ginger harvester-cum elevator. It consists of two components; a digging unit and an elevator unit. Fabrication of inverted V-type blade was made up of M.S. material. The length, width and thickness of the blade designed were 1000, 200 and 10 mm, respectively. The blade was mounted on the machine at an angle that can be varied from 15-25 degree with the horizontal. It was positioned at the front end of the conveyor. Soil-rhizome separating unit consisted of a conveyor having dimensions of 1115x1100 mm. The conveyor unit is made up of MS rods spaced at 30 mm. The angle of the elevator was kept at 20 degrees to the vibration unit. The power to the elevator conveyor was provided through a gear box through a belt and pulley drive system. The power required for harvesting including conveying operation was worked out to be 45-60 hp.

Keywords: Blade, conveyor, elevator, harvester, angle of elevator, digger

1. Introduction

Ginger (*Zingiber officinale* Roscoe,) is one of the most important cash crops and principal spice of India and abroad (Basavaraj and Javan, 2020) [3]. During crop production, harvesting is one of the most critical operations in which rhizomes are digged below the soil surface without damaging, separate them from soil and manually collected from the field. Manual harvesters can be used for harvesting roots and tubers. In the case of ginger harvesting is still done mostly by hand with the use of a garden fork and pick axe to first loosen soil and rhizome the below the surface and take out the rhizome from the soil clump (Kawale 2018) [8]. The lack of suitable mechanical harvester for root crops is due to a number of factors such as the geometry of tubers in the soil at maturity, soil conditions and the high draught requirement of machines (Younus and Jayan, 2015) [17].

By adopting mechanical harvesting manpower requirement was found 60% lower as compared to manual digging, whereas crop damage was less than 2% (Sukhwinder *et al*., 2007) [14]. So there is a need for mechanization in root crop harvesting to reduce human drudgery and to reduce the cost of cultivation by 30-50% with better harvesting efficiency compared to manual harvesting (Vatsa *et al*., 1996) [16]. The design parameters of any root or tuber crop harvester effects the performance of the machine. Generally the root harvester consists of digging blade and a soil separator. The tool geometry of the blade affects the digging efficiency of the harvester and draft.

The tool geometry also governs the blade's rake angle and friction angle of the soil. This allows the design of simple tools on the basis of draft force requirement and improves soil cutting efficiency. The draft increases with the width, depth and rake angle of the digging tool. The cross sectional area of the soil disturbed is not changing appreciably with the rake angle, but significantly increases the draft and remarkably diminishes soil cutting efficiency (Saleh *et al*., 1997) [10]. The tool geometry governs by rake angle of the blade and friction angle of the soil (Agbetoye *et al*., 1998) [1].

The best implemented design for the low draft, high cutting efficiency and superior soil loosening should have a rake angle of about 20° and should be a fairly narrow depth to width ratio of 2 or more (Mckyes and Maswaure, 1997) [9].

The convex type blade with a 20º rake angle performed better than the concave type with a total recovery of 87.60 to 93.44% while it was only 77.47 to 82.14% for later for 200 mm depth for turmeric harvester (Trivedi and Singh, 1975 and Annamalai and Udayakumar, 2007) [15, 2]. Manually harvesting potato crop using spade, Khurpi required man days is about 210 man-day per hectare which results the cost of production of potato become very high because of labor charges for harvesting (Devesh and Ashok, 2017) [6].
Keeping this in the background a need was felt to develop a suitable mechanical harvesting technology for ginger crops. For successful harvest mechanization of ginger, the crop requires a systematic approach and involves an integrated approach of engineers, plant breeders, plant physiologists, food scientists and others for intended output and higher profits.
By considering the above facts and to overcome the problems of harvesting of ginger rhizome and also to reduce the cost of operation, an attempt has been made to design and develop a mechanical ginger harvester-cum-elevator for effective harvesting of the ginger crop.

2. Material and Methods

2.1 Agro-technical requirements

The tractor drawn ginger harvester cum elevator designed and development at College of Agricultural Engineering, Raichur, University of Agricultural Sciences, Raichur and performance evaluation of developed machine is conducted in the experimental plot Chitta village of Bidar district in lateritic soil. The machine developed by considering biometric and physical characteristics of the ginger crop which have a direct influence on the design of harvester-cum-elevator *viz.*, plant height, no. of leaves, depth of rhizome, rhizome spread, the weight of ginger with soil mass, bulk density of rhizome were studied as per the standard procedure at the time of crop harvesting. The observations were recorded in a plantation with a spacing of 30 cm x 30 cm and the size of the raised bed is 90 cm.

2.2 Design parameters considered for the development of Ginger harvester-cum-elevator:

The tractor mounted ginger harvester-cum elevator was developed based on soil-crop machine parameters. The desired functions of the ginger harvester are to dig the rhizome, detaching soil from ginger, separate soil mass and finally windrowing the harvested crop. The main objective of the design and development of harvester-cum elevator was to minimize the damage to the ginger crop, maximize the soil separation and all operations are completed at a minimum cost including a lower power requirement. Thus, the basic components of tractor drawn ginger harvester cum elevator considered were frame, gear box housing, power transmission system, depth gauge wheel, digging unit, vibrating unit, ground wheel, separation unit and windrower. The details of the working components of the harvester cum elevators are explained as follows.

2.2.1 Frame

The dimensions of the supporting frame for the harvester-cum elevator were fixed by considering the plant height, width of bed and tractor width. Accordingly, the frame made out of mild steel having overall dimensions of 1640 mm x 1200 mm was considered for mounting all necessary machine components viz., digging blade, vibration unit, power transmission unit and conveyor unit.

2.2.2 Digging blade

The digging blade is to dig the rhizome in the soil sub-surface to a depth of about 15-30 cm. The digging blade was fabricated using mild steel material. The length, width and thickness of the blade considered were 1000, 200 mm and 10 mm, respectively. The blade was mounted at the base of the machine and provision was made to vary its angle from 15 - 25 degrees with the horizontal as per the requirement. The minimum draft, maximum pulverization of soil and high harvesting performance, the rake angle of recommended being 15-25 degree (Dessye B., 2021) [5].
The draft exerted by the blade was calculated using the general soil mechanics equation for a blade deforming the soil into two dimensions (Hettiarachi *et al*., 1966) [7] by considering the following different soil properties and tool geometry parameters:

$$P_p = \gamma Z_1^2 N\gamma + CZ_1 Nc + CaZ_1 Nca + qZ_1 Nq$$

Where,
P_p = Passive resistance of soil acting at an angle of soil-metal friction with the normal to the interface, kg per meter width,
γ = Bulk density of soil, kg. m^{-3}
Z_1 = Depth of operation, m,
C = Cohesion of soil, kg.m^{-2},
Ca= Soil-interaction adhesion, kg. m^{-2} and
q = Surcharge pressure on soil from the surface above the failure plane, kg. m^{-2}.

Nγ, Nc, Nq and Nca are dimensionless N- factors, which describe the shape of soil surface failure and thus, the function of angle of shearing resistance of soil (Φ), angle of soil metal friction (δ) and geometry of loaded interface *i.e.* rake angle (α).
For the determination of the draft, the assumptions were made as per the suggestion by Shirwal, 2010 [12], on design parameters for mechanical harvesting of carrots hence, the above equation could be reduced as follows

$$P_p = \gamma Z_1^2 N\gamma + CZ_1 Nc$$

According to Hettiarachi *et al*. (1966) [7], the interface was taken from a graph that could be interpolated using the following equation:

$$N_\delta = N_{\delta=0}\left[\frac{N_{\delta=0}}{N_{\delta=\varphi}}\right]^{\frac{\delta}{\varphi}}$$

Where,
N = Required value of the appropriate N-factors (N_δ or Nc)
$N_{\delta=0}$ and $N_{\delta=\Phi}$ = Corresponding value of the N-factor at δ =0 and
δ = Φ, respectively, obtained from the appropriate chart

Following values for the different parameters in the equation were used for determination of passive resistance of the blade:
were used for determination of passive resistance of the blade:

γ = 1450 kg.m^{-3}, C = 710 kg.m^{-2}, Φ = 25.58°, δ = 25.31°, α = 15°, Z_1 = 0.2 m

Using the relationship, the value of N-factors were calculated as follows:

$N\gamma = 1.83$, $Nc = 1.68$

Substituting the values of $N\gamma$ and Nc, the passive resistance (P_p) per unit width of the blade was obtained as:

$P_p = 1450x(0.2)^2x1.83+710x0.2x1.68$

$= 344.70$ kg. m^{-1}

Therefore, P_p for an effective width of cut of 0.90 m blade is 310.23 kg.

The passive resistance (P_p) was acting at an angle of friction (δ) with a normal to the interface, hence the component parallel to the blade face (P_{p1}) was given as:

$P_{p1} = 310.23 \text{ x Cos } 70°$

$= 106.10$ kg

The component perpendicular to the blade face (P_{p2}) was given as

$P_{p2} = 310.23 \text{ x Cos } 20°$

$= 291.52$ kg

The obtained value of P_{p1} and P_{p2} were used to determine the bending moment of the digging blade. It was assumed that the average soil resistance of the blade acting at a distance of 0.2 z_1 measured from the cutting edge (Bernacki *et al*., 1972) [4]. Therefore, the distance between the centre of resistance and point of support could be determined as:

250 – 50 = 200 mm

Therefore, the bending moment (B.M.) due to P_{p2} is:

B.M. = 291.52 x 200 = 58304 kg.mm

Bending stress (σ_b) is represented as: $\sigma_b = \frac{B.M}{\frac{1}{6}bt^2}$

Where,
B.M = Bending moment, kg. mm
b = Width of the blade at its point of mounting, mm,
t = Thickness of the blade, mm.

Bending stress was calculated as: $\sigma_b = \frac{58304}{\frac{1}{6}200.t^2} = \frac{349824}{200.t^2}$

And, direct stress (σ_d) due to P_{p1} was calculated as: $\sigma_d = \frac{P_{p1}}{b.t}$
Hence,

Total stress = $\sigma = \sigma_b + \sigma_d$

$$\sigma = \frac{349824}{200.t^2} + \frac{106.10}{200.t}$$

By taking the factor of safety as 1.2 and equating the total stress (σ) with safe stress 600 kg.mm^{-2} of mild steel, the thickness of blade (t) was determined as:

$$600 = \left(\frac{349824}{200.t^2} + \frac{106.10}{200.t}\right) 1.2$$

t = 10 mm

Hence, the thickness of the blade was kept as 10 mm and the total width of the blade was kept as 1000 mm as per the requirement of digging operation.

2.2.3 Selection of prime mover

For the selection of a suitable prime mover, the total power required for harvesting operation was worked out. The total power required is the sum of power required for digging the rhizome, dropping it back on the conveyor, elevator functioning and power required for pulling the machine. The total power required for the harvester cum elevator was 19.23 kW, but the commercially available tractors are having above 28 kW. Drawbar power obtained by more than 35 hp tractor as predicted by Zoz (1974) [18] was considered for selection of prime mover. Therefore, the power required to operate the machine will be adequately provided from the drawbar and PTO of a 28 kW tractor. For maximum reduction in rhizome damage and increase in speed of operation, the power required for harvesting and conveying operation of the ginger crop was worked out to be 45-60 hp.

2.2.4 Separating unit

The soil-rhizome separating unit consisted of a conveyor having dimensions 1115x1100 mm. The conveyor consists of mild steel rods of 10 mm diameter and 1100 mm length. As per the width of the unit, the number of rods fixed were 98 with a spacing of
30 mm. The ends of the rod were flattened by hammering and two holes were drilled at the flat sheet. The ends and centre of these rods were riveted on a canvas belts of width 75 mm and thickness 10 mm. To determine the size of the conveyor, the width of the conveyor was selected as 1.10 m on the basis of the tread width of the tractor. The tractor drawn P.T.O. operated harvester designed and developed for harvesting turmeric crop which comprises digging unit and soil separator by considering soil, biometric and machine parameters (Shailaja, *et al*., 2019) [11].

The determination of the length of the conveyor is given below.
Forward speed of tractor = 0.833 m.s^{-1} (3.0 km h^{-1})
Weight of soil =124.70 kg.s^{-1}
Weight of rhizome = Number of plants per square meter x weight of rhizome per plant x area covered per second

= 7.10 kg. m^{-2}x(1x0.83) m^2. s^{-1}
= 5.90 kg. s^{-1}
Total mass of material = 240.70+5.90
= 246.60 kg

At least 50 percent of soil mass has to fall down at the time of conveying, the net mass to be conveyed
Total material to be handled =123.30 kg. s^{-1}

Now equating the volume of material flowing with the volume of the conveyor by assuming the material would spread uniformly on the conveyor with a thickness of 10 cm layer, the length of conveyor required was obtained as follows.

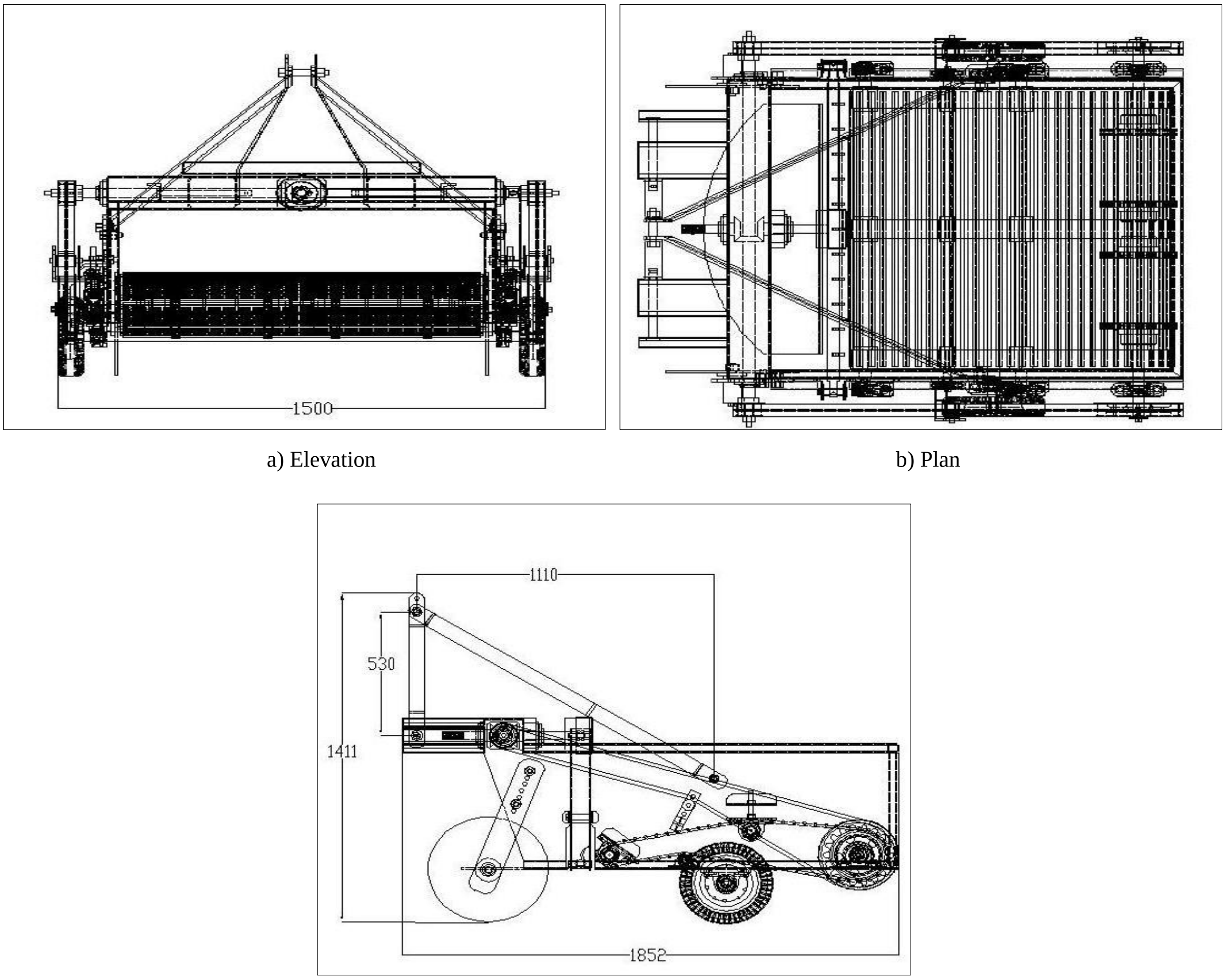
Q_{out} = γ x length of conveyor x thickness of material spread x speed of conveyor

123.30=1450x Lx0.10 x 0.83

L= 1.02 ≈1.1 m

Therefore, the conveyor of 1.1 m length was fabricated using M.S. rods of 10 mm diameter and placed at 30 mm spacing keeping in view the minimum size of the rhizome to be retained on the conveyor. This gave an opening of 60 per cent perforated area for sieving the soil. The percentage of carrot damaged increased with increase in length of soil separator and decreased with increase in rake angle and soil separator angle (Shirwal *et al*., 2015) [13].

Similarly, a provision was made to change the angle of the soil separator between 15º- 25º from the horizontal towards the ground surface. The digging blade and soil separator were attached to the side supporting flats and then the whole assembly was attached to main frame. Thus, a complete unit of compact ginger harvester cum elevator was developed as shown in the orthographic multi-view projection (Fig.1) and fabrication of tractor drawn ginger harvester cum elevator (Plate1). As per the standard procedure, the cost of the development of the prototype ginger harvester cum elevator was worked out to be Rs. 78,325 which includes the cost of material used and fabrication charges pictorial view (Plate 2).



a) Elevation

b) Plan

c) Side view

Fig 1: Orthographic multi-view drawings of ginger harvester cum- elevator

Plate 1: Fabrication of tractor drawn ginger harvester cum elevator

Plate 2: Pictorial view of developed tractor drawn ginger harvester-cum elevator

Conclusion
The developed ginger harvester cum elevator noticed minimum draft, maximum pulverization of soil, high harvesting efficiency and better soil separation. It was also observed power required for digging and conveying ginger crop using this harvester-cum-elevator is 45 hp - 60 hp. The total cost for development of the prototype was Rs 78,325. The overall developed ginger harvester cum elevator was found efficient and highly economically, time saving, reducing labour charges with minimum damage.

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References
1. Agbetoye LAS, Kilgour J, Dyson J. Performance evaluation of three pre-lift soil loosening devices for cassava root harvesting devices for cassava root harvesting. Soil and Tillage Research. 1998;48:297-302.
2. Annamalai SJK, Udayakumar R. Optimization of operational parameters of digger cum elevator type turmeric harvester, Proceedings of the International Agricultural Engineering Conference, Bangkok, Thailand, 2007.
3. Basavaraj, Javan PR. Biometric and engineering properties of ginger rhizome towards the development of root crop harvester. International Journal of Chemical Studies. 2020;8(3):725-730.
4. Bernacki H, Haman J, Kanafojski CZ. Agricultural Machines, theory and construction. Scientific Publications Foreign Cooperation Center, Warsaw. 1972;(1):513.
5. Dessye Belay. Design, Construction and Performance Evaluation of Potato Harvesters: A Review. International Research Journal of Engineering and Technology. 2021;8(4):2747-2771.
6. Devesh K, Ashok T. Performance evaluation of tractor drawn potato digger cum-elevator. International Journal of Agricultural Science Research. 2017;7(2):433-448.
7. Hettiaratchi DRP, Whitny BD, Reece AR. The calculation of passive pressure in two-dimensional soil failure. Journal of Agricultural Engineering Research. 1966;11(2):89-107.
8. Kawale Nagendra. Development and evaluation of ginger harvester cum elevator, PhD thesis, University of Agricultural Sciences, Raichur, 2018.
9. Mckyes E, Maswaure J. Effect of design parameters of flat tillage tools on loosening of a clay soil. Soil and Tillage Res. 1997;43(3-4):195-204.
10. Saleh, AL-Suhaibani A, Abdulrahman, AL-Janobi. Draft requirement of tillage implements operating on sandy-loam soil. Journal of Agricultural Engineering Research. 1997;66(2):177-182.
11. Shailaja D, Ramteke RT, Solanki SN. Development and Performance Evaluation of Tractor Drawn Turmeric Digger cum Separator. International Journal of Current Microbiology and Applied Sciences. 2019;8(2):1053-1061.
12. Shirwal S. Studies on design parameters for mechanical harvesting of carrots. Unpublished M.Sc. Thesis in Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi, 2010.
13. Shirwal S, Indra Mani, Sirohi NPS, Adarsh Kumar. Development and Evaluation of Carrot Harvester. Agricultural Mechanization in Asia, Africa and Latin America. 2015;46(1):28-34.
14. Sukhwinder S, Sanjay R, Manjit S. Design and development of offset type digger for sugarcane plus potato Intercropping, Potato Journal. 2007;34(3-4):227-230.
15. Trivedi SK, Singh RK. Design and development of two row tractor drawn potato digger. Unpublished B.Tech. Thesis in Agricultural Engineering Department. G. B. Pant University of Agricultural and Technology, Pantnagar, Nainital, 1975.
16. Vatsa DK, Singh SP, Verma MK. Comparative studies on performance of power tiller operated potato diggers in hills. Journal of the Indian Potato Association. 1996;23(3-4):121-129.
17. Younus A, Jayan PR. Performance evaluation of root crop harvesters. International Journal of Engineering Research and Development. 2015;11(6):38-52.
18. Zoz FM. Optimum width and speed for least cost tillage operations. Transaction Journal of American Society of Agricultural Engineers. 1974;17(3):845-850.