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Research Article

IMPROVED POTATO DIGGERS IN TERRACE CONDITION OF SIKKIM IN INDIA

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Abstract: Potato digging with improved diggers having high effective field capacities and higher digging efficiency was carried out, ensuring total losses within permissible limit. Light weight, single row animal drawn improved digger was developed and evaluated in terraces for harvesting tubers. The performance of the digger was also compared with power tiller mounted digger and traditional digging methods prevailing in the region. Light weight animal drawn potato digger was tested at average speed of 1.72 km/h at 120 mm depth of operation. Digging efficiency and field efficiency were 93% and 88% respectively. Effective field capacity and cost of operation were 0.030 ha/h and Rs 1250/ha. Labour requirement was 34 man-h/ha excluding 150 h for picking of potato after harvest which showed a saving of 38.25% in labour and 60.93% in cost of digging (including picking of potato) over traditional digging by kudal /spade in terraces. Physical damage to dug out tuber was about 1% as compared to 4.6% in power tiller mounted digger and 0.8% in manual digging. Effective field capacity of power tiller mounted potato digger of 300 mm size was 0.055 ha/h and its field efficiency and digging efficiency were 82% and 89.8% respectively. The cost of operation with improved digger was Rs 1250/ha as compared to Rs 3200/ha by manual method and Rs 1875/ha using power tiller mounted digger.

Keywords: Improved diggers, light weight, digging efficiency, physical damage

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Introduction

Potato (*Solanum tuberosum* L) is an annual, herbaceous, tuber crop of the Solanaceae family. Proper management of various operations in the potato production system and judicious use of inputs can contribute towards reduction of energy input. Mature potato is dug out from the soil and is the main product. Potato digging is a cumbersome process as soil-potato ratio is 31:1 and requires 600 man-h/ha for manual digging [1]. The potato is the third most important food crop in the world. China and India together contribute one-third of total production of potato globally. Potato is cultivated in 1.25% of the total cultivable area in our country. It contributes to 2.42% of agricultural gross domestic product. Among the vegetable segment, the share of potato is estimated to be 25%. India now ranks fourth in potato area (2.02 million ha) and third in production (44.31 million tonnes) in the world with an average yield of 21.97 t/ha. The productivity of potato in India is quite low (18.33 t/ha) as compared to that of Belgium (49 t/ha), New Zealand (45 t/ha), UK (39.7 t/ha) and USA (38.3 t/ha). Uttar Pradesh and West Bengal contribute more than 50% of total potato production in the country. The north eastern region of India produces 1.10 million tonnes of potato from total cultivated area of 0.13 million ha. Of this, about 50,000 ha is in the plains where potato is grown during winter months (November-March) and the rest in the hills where it is grown under longer days of spring, summer and autumn months. In hilly areas, potato is raised as a summer (March-July) and autumn (August-December) crop [2]. The total cultivated area (80,000 ha) of Sikkim state of India is covered using animate power sources. The average area dependent on a pair of bullocks is 3.36 ha in Sikkim. The average annual use of bullocks is 43 days and custom hiring is performed for 28 days in terrace cultivation of Sikkim. The total area under potato in Sikkim is 9400 ha. The average productivity in Sikkim is 4.8 t/ha. In Sikkim, about 90% of the total potato produce is used for seed purpose.

The seed potatoes were grown in Ribdi, Bhareng, Okhray, Thembong, Tikpur, Buriakhop, Snakhu, Bega, Manebong, Sopakha and Yoksum blocks in west district ; Zaluk, Phademchen, Gnathang and Tokche blocks in the East district; Ravangla and Namthang blocks in the South District and Dechung, Thangu and Lachen blocks in the North district [3]. Central Institute of Agricultural Engineering, Bhopal developed an animal drawn potato digger which consisted of beam, frame, handle, ground wheel, depth adjustment mechanism and V-blade. Effective field capacity and field efficiency were 0.05-0.12 ha/h and 60% respectively. The draft values and labour requirement ranged 600-750 N and 8-20 man-h/ha, respectively [4]. An animal drawn improved single row, V shaped blade potato digger of 18 kg weight was developed at Punjab Agricultural University, Ludhiana. It had an effective field capacity of 0.12 ha/h and field efficiency of 80%. The tuber losses were 1-2%. There were savings of 40-45% in labour and operating time and 35-40% in cost of operation compared to manual method of digging with spade or country plough. An animal drawn improved digger of 8 kg weight was developed at Birsa Agricultural University, Ranchi. The width of cut, effective field capacity and tuber loss were 350 mm, 0.030 ha/h and 3.8%, respectively. The draft value and labour requirement were 460 N and 231 man-h/ha, respectively [5].Tamil Nadu Agricultural University, Coimbatore developed improved potato digger of 120 kg weight and blade length of 575 mm. Effective field capacity, digging efficiency and total losses were 0.10 ha/h, 98.6% and 3% respectively. Labour requirement was 30 man-h/ha. It saved 89% labour and operating time and 71% in cost of operation as compared to conventional method of manual digging using spade. An animal drawn improved digger having dimensions of 1750 x 100 x 570 mm and weight of 10 kg was developed and tested by Maharana Pratap University of Agriculture and Technology, Udaipur in Rajasthan.

Effective field capacity and digging efficiency were 0.06 ha/h and 80-90%, respectively. The draft values, labour requirement and average tuber loss were 500-600 N, 6.70 man-h/ha and 5.7%, respectively. It saved 94% in labour and operating time and 60.5% in cost of operation as compared to traditional practice of digging by country plough [6]. Ahmad, *et al*.,(2014) conducted testing of flat, V shape and hoe type blades on digger and concluded that blade of V shape with a rake angle of 30 degree gave an effective field capacity and digging efficiency of 0.08 ha/h and 93.64%, respectively [7]. Dash, *et al*., (1998) reported on the performance of four different types of bullock drawn diggers, namely, two row riding type, riding type with semi-circular blade, V type and ridger type. The results showed that the average draft for two row riding type, semi-circular blade, V type blade and ridger type were 838.75, 709.26, 655.30 and 559.17 N, respectively. Meanwhile, the digging efficiencies for two row riding type, semi-circular blade, V type blade and ridger type diggers were 74.3, 65.5, 81.9 and 92%, respectively [8]. Amin, *et al*., (2008) tested multi-purpose digger having V blade of 500 mm size and 1500 sweep angle at three levels of forward speeds (1.8, 2 and 2.6 km/h) and three different tilt angles (12°, 18° and 24°). The highest percentage of harvesting efficiency was 93% at forward speed of 2.6 km/h and tilt angle of 18° [9]. Soil type affected draft and moment about the centroidal axis of the digging blade. The draft requirement was consistently higher in the clay loam soil as compared to sandy loam soil. The specific gravity of root crop had significant effect and less dense material was more easily harvested. Translation and rotation of various buried objects did not appear to be affected by their shapes during harvest. A low potato movement/digger travel ratio showed positive effect for efficient harvest. Low ratios were associated with short translation distance of the potato before it reached the soil surface, thus preventing a potato build up in front of the digger. Draft and moment about the centroidal axis of the blade increase with velocity, depth of operation steepness of the approach angle and size of the digger. Draft was directly related to cross sectional area of the soil moved by the digger. Vertical force of digger also increased due to increase in speed of operation but to a lesser degree than draft and moment. The resultant force acted between the lower half and quarter of the blade surface. Greater approach angles increased draft, vertical force, moment and length of the harvest delineation plane [10]. The traditional equipment commonly used in potato cultivation on terraces in Sikkim were traditional plough of 12 kg weight, traditional leveler (Dande) of 20 kg weight and narrow spade used for interculture and digging. The planting and digging operations are performed manually using narrow spade which consumed too much time (450 h) resulting in discomfort to labourers due to prolonged operations. The digging of potato crop in terraces is arduous which needs first cutting of haulms using local sickle which needs average labour requirement of 150 man-h/ha. Next step is potato digging either by Kudal or traditional plough which involves human drudgery. The collection of tubers is same in both traditional and improved digging methods. The difficult terrain and narrow terraces in Sikkim limits the introduction of large size power tillers which are widely used in the plains. Mechanical potato digger especially designed for use with a pair of bullocks is a need of the region. The existing potato digging consumes more labour, time and cost of digging in terrace cultivation. The cost effective improved digger for efficient harvest of tubers with minimum tubers damage was needed in the hilly region. Therefore, the objective of study was to evaluate improved diggers for their suitability on terraces in Sikkim state. It was planned to develop single row, light weight improved digger suiting to terrace width (1.5-2 m).

Materials and Methods

The development of improved digger after studying traditional digging on terraces was performed suiting to the local breeds of hilly region and considering root zone depth in potato crop in sandy loam soil. The performance of light weight digger was compared with power tiller attached digger and traditional manual digging method in hilly region under animal-based farming system. The design criteria of digger include sufficient strength for withstanding the load, simple in construction, materials of construction and workmanship, light weight, small size, maneuverability, ease in operation, adjustment and turning at headlands. The developed equipment can be fabricated by local blacksmiths in hilly region for large scale popularization as per design considerations. Soil type, range of soil moisture content, size and weight of tubers, speed of operation, were taken in consideration for design as per feedback of farmers in four districts of Sikkim. The improved digger should be able to operate at proper depth (100-120 mm) to dig the maximum possible potatoes. The transverse dimensions of cutting was kept in such a way that the all the tubers of plant were dug. The exposure of dug tuber had minimum cutting, bruising and injures. The proper arrangement of lifting rods resulted in avoiding clogging of soil clods and haulms.

Prototype of potato digger of total 10.2 kg weight was developed using mild steel sheet as blade material. Fabrication of components was done using fixtures and computer aided drawing of components were used for manufacturing digging unit employing standard production unit. The CAD drawing of improved digger is given in [Fig-1]. The main components of animal drawn potato digger consisted of main frame, digging blade, shank, lifter rods, beam, handle and clamp [Fig-2a, b]. The main frame was of round galvanized iron pipe of 65 mm diameter which had weight of 2.60 kg. Eight Lifter rods of round mild steel bar (weight: 0.80 kg) of 115 mm length and 7.85 mm diameter were provided which were welded at 18 mm interval in the rear of V shape blade of 1.75 kg weight and overall dimensions of 277 x 210 x 6 mm. Two L shape clamps of mild steel flat (size 40 x 5 mm) and 1.25 kg weight were provided and shank of 320 mm length and 1.20 kg weight were fabricated using mild steel flat of size 40 x 5 mm. The galvanized iron handle (weight: 0.75 kg) of 600 mm length and diameter of 25 mm was provided and clevis of mild steel flat of size 40 x 10 mm was welded on main frame. After completion of manufacturing work, the components of the digger were free from pits, burrs, cracks and other visual defects. The digger was symmetrical on both the sides along the longitudinal central axis of the digger bottom. The bearing points were touching the ground and the digger was well balanced when the unit was set at its working position and placed on a plain surface. Single row improved digger performance was tested under laboratory and field conditions and its performance was compared with digging unit attached to power tiller and existing traditional digging method under All India Coordinated Research Project on Utilization of Animal Energy located at College of Agricultural Engineering and Post Harvest Technology, Ranipool. The weight, size and material quality of components were checked in the laboratory test. The size of experimental plots were 2000 sq. m each for trials of animal drawn digger, power tiller mounted diggers and traditional digging method for potato tubers. The visible and invisible damage on harvested potato tubers of local Beta variety were noted and average of 100 readings were taken.100 samples of harvested potato tubers were randomly selected for determining their size, weight, numbers of eye (bud), shape and moisture content (wet basis) under laboratory test. The size of harvested potato varied from 18.3 to 57.9 mm and buds were 3-6 on the harvested potato and weight of tubers varied from 17.5 to 46 g. The average moisture content (wet basis) of freshly harvested potato was 81%. The soil moisture content (dry basis), bulk density and cone index were determined at harvest stage. The observations recorded related to soil, tuber, equipment and other operational parameters are given in [Table-1]. The draft measurement was determined using spring type dynamometer and samples of soil were tested for moisture determination by oven dry method keeping them for 24 h at 105 0C. The weight, size and damage of harvested tubers were determined using precision weighing balance, micrometer and through microscopic analysis. As per IS : 11033-1984 , potato digger was made of weight less than 20 kg including beam and exposed potatoes were more than 70% with maximum permissible tubers damage less than 5%. The blade was run below the tuber zone. In 10 m, potatoes exposed, damaged potatoes and total potatoes (including manual digging/picking) were considered and following relations were used for calculations:

Exposed percentage by mass = 100 x (Mass of potatoes exposed/Mass of total potatoes)

Damaged percentage by mass = 100 x (Mass of damaged potatoes/Mass of total potatoes) Results and Discussion

The light weight animal drawn improved digger was tested at average speed of 1.72 km/h and depth of operation of 120 mm for digging Holland variety of potato in an area of 1200 sq.m [Fig-3]. Size of harvested tubers ranged from 40 to 60 mm. Digging and field efficiency of the digger were 93% and 88%, respectively. Draft required for digging was 334 N.

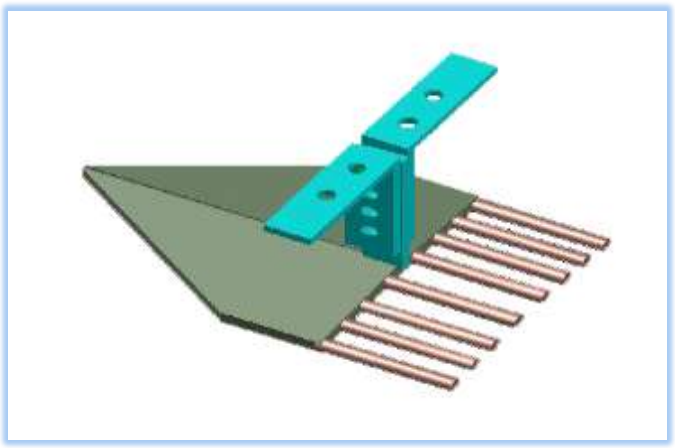
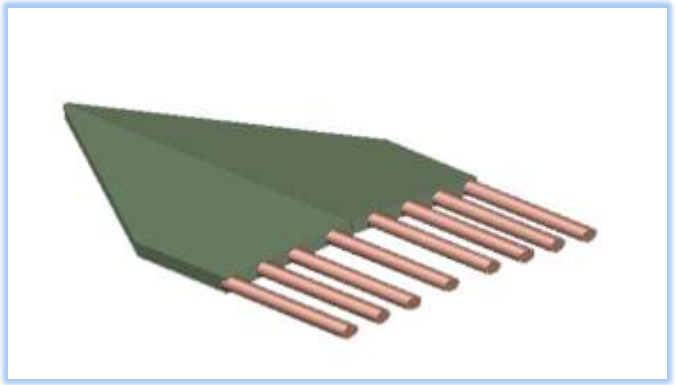
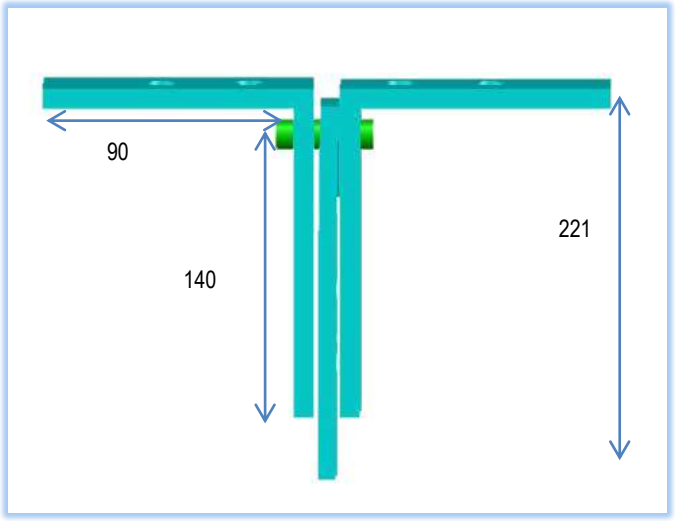


Fig-1 CAD drawing of refined potato digger



Thickness = 6 mm, Diameter of lifter rod =7.85mm
Fig-2a. Digger blade with lifter rods



Diameter of hole = 10mm, Thickness =6.5 mm
Fig-2b Shank with clamp

Effective field capacity and cost of operation were 0.03 ha/h and Rs 1250/ha, respectively. Labour requirement was 34 man-h/ha excluding 150 h for picking the tubers which showed saving of 38.25% in labour and 60.93% in cost of digging (including picking of potato) over traditional digging by spade. Damage to the digger with improved digger was 1.10% and there was no special skill required in fitting and adjustment. The power tiller drawn improved digger [Fig-4] of 300 mm size and 12.2 kg weight was operated at 2.22 km/h which gave effective field capacity of 0.055 ha/h and digging efficiency of 89.85%. The width of operation of power tiller mounted unit was 100 mm and its weight were 18.33% higher than animal drawn improved digger. Draft of power tiller mounted improved digger was 415 N which was 81 N higher than animal drawn improved digger. Labour requirement was found 14 man-h/ha higher in digging using power tiller mounted improved digger as compared to digging by animal drawn improved digger. The tuber loss was found maximum (4.65%) in digging by power tiller mounted improved digger which was 3.55% higher than digging by animal drawn improved digger and 3.87% higher than traditional practice of manual digging using narrow spade [Fig-5]. A net saving of Rs 1950/ha was observed over manual digging [using narrow spade] in animal-based farming system [cost of operation, Rs/ha = 3200/-]. The potato growers in Sikkim may get benefit of 60.93% in cost of digging over existing traditional manual digging method [narrow spade]. The cost of operation of digging using power tiller mounted improved digger was Rs 625/ha more as compared to digging by animal drawn improved digger. The savings in time and cost of digging by power tiller mounted unit were 42.95% and 41.40% compared to manual digging practice by narrow spade. The savings in labour requirement in animal drawn and power tiller mounted improved diggers were 38.25% and 42.95% as compared to traditional method. The command area of improved digger is 2-3 ha per growing season for the animal drawn unit. Investment made on improved potato digger can be recovered by using unit for digging tubers on 0.18 ha. It is estimated that 3100 animal drawn improved diggers would be required to cover the total area of 6200 ha for which the initial investment would be Rs 4.65 million. The capital investment made for purchase of power tiller mounted unit can be recovered by potato digging in 1.51 ha. The digging of potato using power tiller mounted unit (unit price: Rs 2000/) for covering 2/3rd of total potato crop area in Sikkim state, would require 2067 units which will require investment of Rs 4.14 million.

Conclusions

The following conclusions can be drawn from the study.

i. Maximum tuber loss was 4.65% in digging by power tiller mounted improved digger which was 3.55% higher than digging by animal drawn improved digger and 3.87% higher than traditional practice of manual digging using narrow spade.

ii. Draft required in power tiller mounted improved digger was 415 N which was 81 N higher than animal drawn improved digger.

iii. A net saving of Rs 1950/ha was observed over the traditional method of manual digging [using narrow spade] in animal-based farming system.

iv. Savings in time and cost of digging by power tiller mounted unit were 42.95% and 41.40% compared to manual digging practice by narrow spade.

v. Savings in labour requirement in animal drawn and power tiller mounted improved diggers were 38.25% and 42.95% compared to traditional method.

Application of research: The effective equipment for potato digging in hilly region of north eastern region (Sikkim) succeeded in saving of labour, time and cost of digging operation. It is cost effective digger which completes task in time reducing human drudgery

Research Category: Agriculture Engineering

Abbreviations

CAD: Computer Aided Drawing, N: Newton, Ha: Hectare
CAEPHT: College of Agricultural Engg. and Post Harvest Technology
CAU: Central Agricultural University

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Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Improved Potato Diggers in Terrace Condition of Sikkim in India

Fig-3 Test trial of animal drawn improved digger

Fig-4 Power tiller mounted improved digger in operation

Fig-5 Manual Picking of Potato

Table-1 Test trials of improved diggers on terraces in West Sikkim district at Daramdin

Parameter	Observed values		
	Animal drawn single row improved potato digger	Power tiller drawn single row potato digger	Traditional practice of digging by narrow spade
Variety	Holland	Holland	Holland
Soil moisture content (dry basis), %	16.80	16.80	16.80
Working width, mm	200	200	55
Depth of digging, mm	120	120	100-120
Speed of operation, km/h	1.72	2.22	-
Effective field capacity, ha/h	0.030	0.055	0.003
Field efficiency, %	88	82	78
Digging efficiency, %	93	89.8	85.5
Draft, N	334	415	-
Size of tubers harvested, mm	40-60	40-60	40-60
Total losses, %	1.10	4.65	0.78
Cost of operation, Rs/ha	1250	1875	3200
Labour requirement, man-h/ha Digging Picking	184 34 150	170 20 150	298
Saving over traditional digging practice Labour, % Time, % Cost of operation, %	38.25 38.25 60.93	42.95 42.95 41.40	- -

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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