REVIEW OF LITERATURES ON THE DESIGN AND DEVELOPMENT OF POTATO HARVESTING MACHINE

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Abstract - *Now a day's agricultural mechanization becomes mandatory in developing agricultural productivity hence a lot of research papers have been done on the mechanization of agricultural machineries all over the world amongst design and development of potato harvesting machine is one. The aim of this article is to give a brief information about the previous works in design and development of potato harvesting machine all over the world and the current potato harvesting culture in Ethiopia to motivate the researcher in adding values on the sector and reduce the effort required for harvesting root crops in addition to saving labor cost required for harvesting, especially for small scale farming by reviewing the literatures on the design and development of potato harvesting machine.*

Key Words: mechanization, agricultural productivity, harvesting machine, harvesting culture, motivate, small-scale farming, reviewing.

1. INTRODUCTION

All over the world denech its local name or potato (*Solanum tuberosum L.*) ranks under the fourth important highly nutritious crops and it ranks first in production volume over other underground root tubers grown in over 125 countries. **(Gebru *et al.*, 2017)** the total world production for potatoes was 376,826,967 metric tons and, China was by far the largest producer, accounting for 26.3% of world production. India follows china by covering 11.6% of world potato production. **(FAO 2016)**

In the 20th century, a potato was introduced to Africa by Europeans. And the production has been kept on progressing from 2 million tons in 1960 to a record 16.7 million tons in 2007. **(FAO, 2008)** Due to the increase of cropping area and progressive on using productive seed varieties, potato production in Africa tripled from 1994 to 2011, from 8 to 24 million metric tons. Researches show that sub-Saharan African country covers half of the continent potato production. **(CIP, 2018)** By irrigating potatoes in the north delta of the river Nile Egypt produce 2.6 million tons by the year 2007 and found first among African countries over potato production. Malawi and South Africa are the second and third highest potato producer countries by accounting for 2.2 and 1.2 million tons respectively**. (CIP, 2018)**
Denech its local name or potato was introduced to Ethiopia in 1858 by German immigrants and following decades cultivated in highland areas of the country as an "insurance policy" against cereal crop failures. Because of Ethiopia has 70 percent of arable land - mainly in highland areas above 1 500 m – which is believed to be suitable for potato production the country has possibly the greatest potential for potato Among African countries. **(Dagninet et.al, 2015)** potato could play a key role in ensuring national food security. According to the report, potato production in Ethiopia has increased from 280 000 tons in 1993 to around 525 000 tons in 2007. **(FAO, 2008)** and the central, eastern, northwestern, and southern parts of Ethiopia cover approximately 83% of the potato farmers **(A. Hirpa, 2010).**

1.1 Development of Potato Harvester

The harvesting process, though mechanically assisted by the late 1800s, still relied on hand pickers to collect the crops, and continued to do so until the mid-20th century. After the mid-20th century different technologies are begin to emerge on potato harvesting mechanisms. England was the first country were mechanical potato digger was developed in the late 19th century. The machine was similar to plows, with a flat share in place of a moldboard, and a row of prongs, angled to bring the potatoes to the surface **Aniket U., (2017)**. **Muhhamad et al, (2006)** mentioned The Mechanical harvest of potato relative to manual harvest causes 65% frugality at harvest time and 45% at harvest costs. These numbers result show importance of activities in the field of agriculture. The modification on improving the efficiency of the machine continues. **Schrumpf (1946) cited by tapan kumar khura (2008)** found that per cent of damage of the potato tubers was approximately 6.8 during digging. **Hawkins (1957)** studied the designed potato digger effect on tuber damage. During investigation, the elevator discharge height end above the ground was varied in five steps in range varying from 300 to 500 mm. The digger forward speed and elevator speed were kept 2.5 km/h and 50.82 m/min, respectively. It was seen that almost all of the major injuries, half the minor injuries and one-third of the feathering occurs when the potato tubers were lifted from the ground by the shovel. It was shown that in an increase in relative velocity of the elevator or a change to more severe agitation tuber injuries will also increase. Hence, mechanical injuries could be decreased considerably if machine were equipped with an effective method of varying the agitation during the operation. **Hensen (1970)** conduct a field survey on a potato harvesting machines in the field. The data did not establish any direct relationship between the amount of injury and the type of harvesting machine being used. It was reported that machine operation and tuber handling techniques were principal factors that causes injury. From 40 to 90 per cent of the potatoes skinned, and cut to some extent during harvesting and handling operations. **Johnson (1974)** conducted an experiment on a vibrating blade of a potato harvester and found that the vibrating blade was successful in meeting most of the design criteria. The blade performance was observed in a range of vibration speeds between (0 to 700 strokes/min) and stroke length (0 to 20 mm) at varying rake angle of the blade from 10 to 30^0. The result indicates that a vibrating blade was feasible since it can cause a rapid break-up of the soil and assisted in separation of soil from potatoes. Material flow and soil separation was better at the stroke length of 20 mm. good soil separation and feeding was found at vibration speed of at least 450 strokes/ min. Slight additional improvement was observed in operating at higher speed. The change in blade angle from 10 to 30^0 will not show a difference. Shape of the tine had not affect & maximum tine length for satisfactory feeding was 450 mm. **Trivedi and Singh (1975)** developed a two row mechanical digger evaluated at different forward speeds with three blade shapes mounted at rake angle of 20^0. The conclusions drawn after the test were the convex blade type performed a better result than the concave one with the total recovery of 87.60 to 93.44 per cent while it was only 77.47 to 82.14 per friction angle of the soil. Cent for concave type blade and the depth of operation of potato digger should be 200 mm in order to avoid damage and loss of potatoes. The digger can give best results at 4 km/h speed of operation and safely operated by a 20 hp tractor and. **Mc Rae (1977)** An earlier survey shows that harvesters leave 0.5 to 1 ton/ha of potatoes in or on the ground. It was found that damage could be different caused by incorrect setting of shares, violent agitation on webs often accompanied by sharp stones as well as roll back on base-web rods. The test result showed that 21 per cent of harvested potatoes were below the standard required for storage. **Singh and Garg (1977)** developed and tested two-row tractor drawn and single-row bullock drawn potato digger prototype. The result shows that per cent of exposed tubers were about 90 percent and the remaining 10 per cent were covered by the loose soil. By considering percentage of the tubers bruised, cut or left undug were negligible. Comparing the tractor drawn and bullock drawn diggers they could harvest from 2.5 to 3 ha/day and 0.75 to 1 ha/day respectively. The labour requirement for picking the potatoes was found to be about 160 man-h/ha. **Verma (1977)** conducted the experiment on potato digger with oscillating blade. It was justified the adoptability of an oscillating tool to a root harvesting machine which gave reduction in draft and better soil break-up. The experimental potato digger with oscillating blade was tested at frequencies up to 9 Hz and amplitude up to 30 mm with an arc motion coinciding with forward motion of travel. The oscillatory blade reduced the draft up to 76 per cent and increased the soil separation up to 96 per cent. **Singh and Singh (1979) evaluated** the performance of three different shapes of digging blades (convex, concave and sweep types), mounted on a two row mechanical digger. The convex blade gave best results in terms of maximum recovery and minimum damage to potatoes. The mechanical digger incorporating the convex blade was compared with the potato spinner and elevator digger under field conditions. Case of two row mechanical digger the recovery was maximum to approximately 92 per cent with the elevator digger, and minimum of 73.4 per cent in case of two row mechanical digger. The digger gave best performance at forward speed of approximately 4 km/h. **McKyes and Desir (1984)** conducted field experiments in clay and sandy clay loam soils using flat tillage blades of varying width, depth and rake angle. Measured quantities of draft force and disturbed soil areas for the different test conditions were compared to those predicted by a model of soil wedge failure in front of narrow blades, with reasonable agreement. Both the specific draft force per unit soil area and the degree of soil loosening were observed to increase with the relative narrowness of the tillage blades and with the rake angle, as predicted by the model. **Missener (1985)** created a system used to assess the potato tubers damage criteria. The damaged or skinned tubers were classifieds as the broken skin or flesh damage that can be removed a 1 mm deep stroke of an ordinary potato peeler. This damages was classified as slightly or severely tuber damage. **Sharma and Verma (1986)** tested a single row tractor drawn oscillatory potato digger. The maximum percentages of unexposed tubers were found to be 14.14 per cent at a velocity ratio (ratio of oscillation frequency of blade over the forward speed of tractor,) of 1.35. Correspondingly the percent unexposed tubers were reduced to 6.6 per cent at a velocity ratio of 2.82 at a constant frequency of oscillation of 8 Hz. The unexposed tubers were found as high as 49.94 per cent when the blade was not oscillated and worked in the fixed mode. The average cut tubers were found to be 0.5 per cent under varying forward speeds from 0.35 to 0.75 meter per second. With the increase in forward speed and frequency of oscillation, the skinning damage increased in both the cases. The average skinning damage with oscillated blade was 4 per cent whereas it was damage with oscillated blade was 4per cent whereas it was 4.88 per cent in case of non-oscillated blade. **Sharma *et al.* (1986)** designed and developed an oscillatory potato digger. The power to oscillate the digger share was obtained from the tractor PTO shaft through a gear box equipped with bevel gear and pinion. The oscillation frequencies were obtained by keeping the same throttle position of the engine but by using the sprockets with the required number of teeth on the gear output shaft and the eccentric shaft. The gear box had a speed reduction ratio of 4.5. A high carbon steel digger blade of 570 X 260 X 8 mm size was tested at different frequencies varying from 0 - 8 Hz and forward speeds ranging from 0.35 to 0.75 m/s. The result showed that the exposed and cut tubers were approximately 49.94 per cent and 0.4 per cent, respectively without any oscillation of blade. **(Ibrahim et.al, 1989)**, the design and developed multi-purpose root crop digger the developed digger had studied through different parameter level such as (15, 20, 25°), (17, 20, 23 cm), and (2, 3.5, 5 km/h) for tilt angle, blade width and forward speed, respectively. And then damage to the tuber is minimized and highest lifting efficiency was observed at 20 cm blade width, 20° tilt angle and 3.5 km/h forward speed. **Misener *et al.* (1989)** improved design for soil separation and vine removal mechanism on a potato harvester. The vines were caught between the pressure belt and diviner belt and transferred to a trash conveyor that deposited them on the ground to the side of the machine. The damage index of potatoes by this machine was 34.6 per cent of that obtained with commercial harvesters. **Varshney *et al* (1989)** designed and developmed of a simple prototype bullockdrawn potato digger for use in Gujarat State. Field testing of the new digger determined a work capacity and draught requirement of 0.325-0.50 ha/day and 75.0-95.0 kg, respectively. Labour requirements for picking exposed potatoes were 130-135 man-h/ha as opposed to 600 man-h/ha for fully manual digging and harvesting. **(Kang, and handelson 1991)** design a two-row, three-point-hitch vibrating digger. Each row was composed of a pair of four-bar linkages to which two side plates are attached. A bottom plate for each row was composed of a soil-cutting blade followed by soil-sieving bars. The motion of the bottom plate was also designed to assist with soil flow. The oscillating assemblies were PTO driven by a cam through roller chain drive. The greatest amount of black spot (24.9%) was observed at highest frequency (1227 rpm) and slowest travel speed [1.7 km/h (1.05 mph)]. Un recovered potatoes significantly increased (7.2-24.0%), as travel speed increased from 1.7-3.3 km/h. Draft force decreased as vibration frequency increased and travel speed decreased. Draft varied from about 7.9-12.2 KN over the range of combinations of frequency and travel speed levels. **Vatsa *et al* (1993)** designed and conduct an experimental for oscillatory sieve potato digger. The performance was evaluated on Kufri-Chandramukhi variety of potato after removing haulm 25 days before harvesting. The data concerning tubers covered with soil and tubers damage, were collected at different forward speeds of 0.29, 0.44, 0.58 and 0.84 m/s, sieve oscillations of 2 and 4 Hz for 4 different digging share shapes (rectangular, convex, triangular and Vscoop types). The maximum recovery of potato was obtained at a velocity ratio (the ratio between peripheral speed of separating unit and forward speed) of 1.38 at which the recovery of potatoes for different shares varied between 60.02 to 91.73 per cent at 2 Hz sieve oscillation and 82.47 to 99.23 per cent for 4 Hz sieve oscillation. The percentage cut and bruised potatoes was less than 2.40 and 0.75 per cent, respectively. The V-scoop share gave maximum recovery of 99.23 per cent and minimum damage of 0.65 per cent cut and 0 per cent bruised tubers.**Vatsa, *et al* (1996)** studied the comparative field performance of various power tiller operated potato diggers. The maximum tuber exposure was obtained with HPKV digger (90.0per cent) followed by vibratory blade digger (87.5per cent), TNAU digger (80.5per cent) and reversible plough (73.0per cent). The percentage of cut tubers ranged from 2.0 to 9.8 for different diggers. **McKyes and Maswaure (1997)** conducted an experiment to observe the effects of variables included rake angles to the horizontal of 30, 60 and 90°, widths of 75 and 150 mm and depths of operation of 100, 150 and 200 mm the geometric parameters of flat tillage tools on their draft, cutting efficiency and loosening of a moist clay soil. The resulting draft requirement increased with width, depth and rake angle of the tool. The cross sectional area of soil disturbed did not change appreciably with rake angle, but the significant increase in draft with angle resulted in markedly diminished soil cutting efficiency (area divided by draft). The degree of soil loosening was generally smaller at a rake angle of 60° than at 30 or 90°, and tended to be higher at greater depths of operation. In addition, a larger depth to width ratio generally increased the degree of loosening. Results for the soil studied indicate that the best implement design for low draft, high cutting efficiency and superior soil loosening should have a rake angle of about 30° and should be fairly narrow with a depth to width ratio of 2 or more. **(Niyamapa and Salokhe, 2000)** The experiment continues and a new vibrating tillage tools have developed. While testing the tool it was indicate that with an increase forward speed draft increased slightly but later it decreased during oscillating operation. But draft increased continuously with increase in forward speed in the case of the non-oscillating operation. The ratio of draft from oscillating to non-oscillating mode varied from 0.63 to 0.93. The total power required for oscillating operation was 41–45% more than the power required for non-oscillating operation. A lot of researches are conducted on potato harvesting machine to minimize the damage and to increase the overall performance of the machine. **Awady (2003)** evaluate the performance of a single row tractor drawn reciprocating potato harvesting machine at forward speeds (1.40, 2.30, 2.95 and 3.50 km/h), blade rake angles (10°,14°and 20°) and digging depths (25, 30 and 35 cm). The result indicates that an optimum operating condition were at the forward speed 2.30 km/h, rake angle 14° and digging depth 30 cm with an actual field capacity 0.23 ha/h, in addition the machine has least percentage losses, costs and high harvesting efficiency compared with the manual method. **Singh *et al* (2004)** compared with conventional methods and tractor-mounted two-row potato digger of harvesting in a farmer's field. The actual field capacity was highest (0.56 ha/h) in tractor drawn potato digger during the second pass. The highest field efficiency (77.8 per cent) was also observed in tractor drawn potato digger. The total tractor hours per hectare required for tractor drawn potato digger was 5.3. An analysis of the labour requirements of tractor drawn potato digger showed a saving of 1280 man-hours/ha. Tractor drawn potato digger also provided 26 per cent more yield than potato harvested with tractor drawn cultivator. Tractor drawn potato digger provided the lowest tuber damage (0.8 per cent) and lowest yield loss (1.7 per cent) compared with the other method of harvesting. **Hirunstitporn (2005)** conducted study to determine the ratio of the elevator speed of potato (Solanum tuberosum) digger to ground speed of walking tractor to maximize its efficiency. The damage index, the percentage of potato with no damage, the percentage of potato covered by soil and the percentage of non-harvested potato were used. It was found that the ratio was 1:9:1 and the engine speed at 1470 rpm yielded the most effective results due to the fact that there was low damage index, high percentage of potato with no damage and low percentage of potato covered soil. The field test showed that the damage index was 35.70 and 2.30, respectively. The potato with no damage was 93.96 and 96.54per cent, and the potato covered by soil was 1.46 and 1.86per cent, respectively. **(Sukhwinder Singh, 2006)** A tractor mounted, two row multipurpose potato diggers (MPD) was developed and tested the developed machine has major components of three point hitch system, frame, two flat columns joining frame and blade. The blade was made of two replaceable, high carbon steel shovels for easy penetration in dry field conditions and to prevent it from wear. The prototype can successfully dig both early (60-65 days, without removing haulms), and main crop at optimum moisture conditions at row-to-row spacing of 610 mm as well as 686 mm. The labor requirement was reduces by 37% compared with complete manual harvesting with khurpa and the damage reduces by 72% when digging the crop early using the developed harvester. In digging main crop at optimum moisture content, MPD was compared with elevator digger (ED) MPD exposed 3.5% less tubers than ED and field capacity was 0.36 ha/hr more than ED. In dry field conditions exposure was 15.9% in case of MPD. Percentage of potatoes exposed by the MPD was directly proportional to its forward speed. In 2006 **(Younis et al, 2006)** a two-row potato digger with **vibrating digging blade** that was mounted on a tractor was developed and tested by using a variety of potato Sponta at different levels of travel speed (0.9, 1.5, 1.9, and 3.2 km/h), oscillation amplitude (3, 5, 6, and 10 mm), and oscillation frequency (400, 600, 800, 1000, and 1200 rpm). And conclude that at the conventional digging blade oscillation frequency of 1200 rpm and amplitude of 10 mm, the drawbar pull of the vibrating digging blade decreased by 25.17, 25.91, 28.43, and 30.47% at travel speed of 0.9, 1.5, 1.9, and 3.2 km/h, respectively. **Singh *et al.* (2008),** from Indian Center of Potato Research (ICPR), designed an animal drawn one row V-shaped ridger type potato digger share in which the lifter rods were attached behind the share. The digger device saves 94.00 per cent of labor cost; operating time was reduced by 60.50 percent in comparing to traditional harvesting tools like spade and hand pulling. **Ibrahim, (2011)** A potato digger (single – row) was developed by adding digging blade to a rotary machine. The blade was designed, fabricated and tested. The developed digger was evaluated at three levels of forward speed (1.2, 2.3 and 4.9 km/h) and three levels of digging depth (12, 17 and 22 cm). Evaluation was based on the following parameters: field capacity, harvesting efficiency, missing tubers, damaged tubers, consumed energy and cost. The results of the study recommended operate the digger at 2.3 km/h and 22 cm depth where the evaluation parameter were field capacity of 0.33 fed/h, harvesting efficiency of 97.13 %, missing tubers of 7.6 %, damaged tubers of 4.3%, consumed energy of 18 kW.h/fed and cost of 90.6 L.E/fed. Using the developed machine, the harvesting time decreased by about 30% compared with the other harvesting methods (manual and local plough), also the harvesting cost was decreased by 13 % and 30.4 % compared with manual harvest and local plough respectively. **(Abdelah et al in 2012)** modified PTO-operated one-row harvester, the machine attached behind the tractor, to be fitted on the tractor's two-hitch system and it contains digging blade, a frame, a gearbox, a hitching system, and a riddle system.

Testing on the field the modified machine achieved the highest undamaged rate, the lowest damaged potato rate and minimal losses, were forward speed of 2.3 km/h, digger tilt angle of 14º, distance between the blade and elevator chain of 5 cm, chain speed of 2.41 m/s, riddle voltage of 4.63 V and riddle inclination of 7º. **Subba .et al. (2012)** operated an experimental potato digger mounted on a tractor (18 hp). The machine was tested at three digging depths by adjusting the top link lever of the tractor 3 point hitches (60, 63, and 65 of the top lever lengths). By increasing the top lever length, the digging blades penetration would be decreased. The results indicated that, with the moisture of the field soil 42.90% and constant tractor forward speed (1-2 speed gears) used in this function, 1.69, 7.14, and 4.71% of the potato damage occurred by the 60, 63, and 65 cm length of the top link lever, respectively. In addition, tractor fuel consumption was decreased by increasing the length of the top link lever. Fuel consumption decreased from 2.06 to 1.47 l/h by increasing the length of the tractor top lever from 60 to 65 cm. **Azizi, *et al*. (2014)** designed, constructed and evaluated the performance of tractor drawn potato diggers with rotary blades. The losses and potato tuber damage (4.00%) which was high with potato harvester with rotary blades in digging and lifting potato tubers. The recommended blade angle should not be higher than 15° and blade angle of 10° was found to be optimum. They further state that increasing operational speed of the digger and the angle lead to unwanted accumulation of soil in front of the blade. **(Shamsuddin, S. 2014)** design, fabricate and test a prototype sweet potato harvester for bris soil and in sandy soil texture (fine sand 94.53%), having moisture content of 9.16% and average bulk density of 1.44 g-cm^{-3}. The experiment was tested in three different types (Flat or plane, V-shaped and Hoe type) blades of soil digging devices to determine the optimum draft force. Both Plane and V-shaped blades had 30 cm length, and 13 cm width, and the Hoe type had, 25 mm diameter, 30 cm length and 6.5 cm width three rods with sharp cutting edge. The result shows that the highest draft caused by a plane blade type at depth of 20 cm and area of soil disturbed 0.180 m^2 was 0.54 kN-m^{-2}. The best result was occurred by V-shaped blade with a rake angle of 30^o at 20 cm depth had an average draft of 0.51 kN-m-2, with soil disturbance area of 0.185 m^2. The machine had harvesting efficiency in bris soil 93.64% and 90.49% for Telong (Plot A) and VitAto (Plot B) varieties, respectively. The total productive time and unproductive time in plot A, was 14.8 hours to harvest a hectare of sweet potato (0.068 ha/hr) at a tractor speed of 0.56 km/hr. In plot B, the total time required to harvest a hectare of sweet potato was 8.35 hours (0.12 ha/hr) at a tractor speed of 0.99 km/hr. The average field capacity or harvesting time for two plots were 11.47 hr/ha. The average field work rate was 0.087 ha/hr or 34 man-hr/ha this shows a best result compared to manual harvesting of 150 man-hrs/ha. **(Shirwal, , 2014) tested and conducting through experiments** a mechanical carrot harvester having varies design variables of lengths of soil separators (40, 60 and 80 cm), rake angles (15°, 25° and 35°) and at soil separators angles (0°, 10° and 20°) with soil moisture content of 12 per cent. The evaluation Performance parameters were like percentage of carrots harvested, percentage of carrots damaged, soil separation index and power requirement and the maximum percentage of carrots harvested was 97.4 per cent at soil separator length of 60 cm, rake angle of 25° and soil separator angle of 20°. Minimum carrot damage was 4.87 per cent was obtained at 40 cm soil separator length and 20° soil separator angle. Carrots damaged obtained in the range of 4.63 to 4.97 per cent between 25° and 35° rake angle. The length and angle of soil separator was highly affected the soil separation index hence the minimum soil separation index 0.23 was found at 80 cm and 20° of length and angle of soil separator, respectively. The average power requirement to operate mechanical carrot harvester at a speed of 2.3 km/h was 4.44, 5.3 and 5.75 kW at 15°, 25° and 35° of rake angle. **Alhaseen *et al.* (2015)** designed a single row potato harvester that consists of two main part, potatoes digger (blade), potatoes tubers elevator (tubers - clods separator) having 1.40 m length, 22^0 inclination angle from the horizontal and operated at 2.50 m/s forward speed. **Bangar *et al.*(2016)** designed, developed and tested a reciprocating potato harvester driven by PTO shaft at digger tilt angles of 12 and 24 degrees and forward speeds of 1.80, 2.00 and 2.60 km/h. The amount of lifted and uplifted tubers was affected by the forward speeds and lifting chain speeds. The increase in forward speed up to 6.40 km/hr will increase the amount of lifted tubers. The lowest level of lifted tubers was found at a forward speed of 8.60 km/h as compared to other forward speeds. **Ibrahim Issa, (2020),** Designed and test a potatoes digger harvester to harvest tubers in an efficient manner. The parameters used in an experimental site to study were: tractor forward speeds (2.5, 4.5 and 6.5 km/h), blade angles (12°, 17°, and 22°) and the conveyor speeds (2.8 and 4 km/h). The maximum field efficiency was 91% was found at forward speed of 2.5 km/h and conveyor speed of 4 km/h. The maximum required power for the machine was 16.13 kW was measured at forward speed of 2.5km/h and digger angle at 22°. The increase in digger angle at 12° and 22° will increase the lifting of potatoes to 87.63% and 95.14% respectively. With the increase in blade angle, decrease in forward speed and conveyor speed the total potato damage decreases. Hence, the lowest potato damage percentage was 2.67% at forward speed of 2.5 km/h, digger angle of 22° and the conveyor speed of 2.8 km/h and the highest damage percentage was 4.63% at forward speed of 6.5 km/h, digger angle of 17° and the conveyor speed of 4 km/h.

1.2 Development of Potato Digger in Ethiopia

Dagninet *et al.* (2015) states the existence of two types of predominant potato harvesting trends in Ethiopia, namely traditional plow and hand hoe. The performance of hand hoe on parameters exposing efficiency and percentage of damage was 100 and 0.78% respectively. However, it can be characterized as a low field capacity of 0.0025 ha/h, high drudgery and fatigue shown in (Figure 2.1).

Ebrahem *et al.* (2011) states that there were also a manual harvesting practices through making holes or slits by a stick or tool and tuber collecting by hand in small areas of potato harvesting. But, manual harvesting trend is very tedious, laborious and slow it requires at least 160 man-hour/hectare. However, most of smallholder farmers in the highland area of Ethiopia use this trend due to its low tuber damage and preservation of other crops during mixed farming system. **(Gebregziabher *et al.*, 2007)**Most Ethiopian potato farmers used the *ard* plow (locally known as *Maresha*) to dig and lift potato tubers though whose shape and structure have remained unchanged for thousands of years. Efforts made to improve the *ard* plow were based on experience, culture and trial and error methods. As a result, the prototypes developed were found to be expensive, heavy, complicated and did not fit on to the traditional plow frames. **Dagninet *et al.*, (2015)** test and conduct traditional plow and it has significant field capacity, damage loss and exposing efficiency of 0.22 ha/h,1.06%, 89.16%, and respectively.The Agricultural mechanization Research Directorate **(AMRD)** at Melkassa Agricultural Research Centers **(MARC)** modified groundnut digger, to harvest potato tubers in **2001**, it can attach easily to the local plow, *Maresha* (Figure 2.2a). The modified potato harvester was then compared and evaluated with the conventional potato digging using *Maresha* plough. The result shows that the improved potato digger had better exposing efficiency in the first ploughing and had a cumulative exposing efficiency of 92.47% when ploughed twice. Cumulative exposing percentage with the use of the local plough, on the other hand, was 89.36% in two ploughing. This indicates ploughing once with the improved digger is almost equivalent to ploughing twice with the traditional practice. Compared to local plough, unexposed potato remained in the soil after the second ploughing was lower for the improved one **(AMRD, 2001)**. **Dagninet, *et al.* (2015)** also evaluated this redesigned and improved version AMRD digger and found that an exposure efficiency, damage loss and field capacity of 90.069%, 1.03%, and 0.217 ha/h respectively. On the other hand, based on testing and performance evaluation of the AMRD digger, the improved design of Bahir Dar digger (BD) had been developed by Bahir Dar agricultural mechanization and food science research center in collaboration with universities of Bahir Dar and Addis Ababa. BD digger is animal-drawn with a smooth or rounded lifter edge with exposure efficiency, damage loss and field capacity of 92.906%, 0.81%, and 0.247 ha/h respectively. Increase in the rake angle of the digging shear increased depth of penetration of the lifter by 2.40 cm when the damage was decreased by 3-5% and the exposing efficiency increased by 2-3% compared to the AMRD potato digger. **(Dessye belay, 2020)** designed a single axle tractor operated potato digger elevator and the performance of the machine was tested at different plot area with variety of potato seeds in Ethiopia. The machine is attached to the tractor and it covers a hectare of farm land within 7.69 hour. As compared to the manual harvesting method both hand hoe and maresha harvesting labor cost of is decreased by 86.6% and 63.36% respectively. By using the machine minimum tuber damage was observed by increasing the blade rake angle at 25^0 and conveyor slope of 10^0. Since tractor is not accessible to small scale farmers of Ethiopia the tractor mounted potato digger and elevator has a limitation on addressing the need of many Ethiopian farmers.

Fig -1: Name of the figure

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