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A Prognosticated Analysis of the Development of Mechanisation in Potato Cultivation: Indian Scenario

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ABSTRACT: Potato is the third important crop of the world next to rice and wheat, plays a prominent role in ensuring food security in developing countries. The extent and trend of mechanization for various field operations during potato cultivation were studied to analyse the available options and evolving a strategy for mechanizing potato cultivation. Though the overall mechanization status of the country was low, mechanization in potato cultivation was found to be at a higher level in India. Among the different field operations, advanced machines for earthing-up and plant protection operations were still lacking. It was inferred that more attention has to be given in developing combination implements which can combine different operations so as to minimize the operational expenses. Semi-automatic machines at affordable cost are expected to rule the potato fields in India for the near future.

Keywords: Potato Mechanization, Combined Implements, Multifunctional Implements, Multipurpose Frame, Active Implements, Passive Implements.

INTRODUCTION

The global population is expected to reach 10.4 billion by 2050 (Debrezion *et al.*, 2020; Tedla *et al.*, 2019), creating food shortages for nearly 820 million people (Tamburino *et al.*, 2020). The ongoing urban expansion and agricultural labour migration to urban areas for better jobs (Donoso, 2016) will further worsen problem. Potato (*Solanum tuberosum* L.), is positioned as the third important crop next to rice and wheat (Ahmed *et al*., 2020), commercially cultivated in 149 countries, consumed by more than one billion people globally (Birch *et al.*, 2012), highlights its importance as both food security and income generation crop. In addition, it is a reservoir of essential proteins and amino acids, making it an important nutrient rich food crop (Mushinskiy *et al*., 2021).

China and India leads potato production globally, but far behind USA and UK in terms of productivity (Lakhiar *et al*., 2018). The major difference of Indian agricultural sector with that of USA and UK is the status of mechanisation. Mechanisation helps in reducing operational cost, saves time and energy (Maslov *et al*., 2020), leading to increased production and productivity (Jat *et al.*, 2020). However the future and sustainability of agriculture sector depends a lot on the extend of investments done in mechanisation (Swetha *et al.*, 2016). In the case of potato cultivation, an in-depth analysis based on past experiences will be helpful to orient the researchers in a proper direction. Hence such a study is highly relevant to examine the present trend of mechanisation of potato cultivation in India with a view to present a road map to potato mechanisation.

INDIAN TRENDS IN FARM POWER DEVELOPMENT AND AGRICULTURAL MECHANISATION

Agricultural mechanisation was considered as an important ingredient to usher in a second green revolution in India(James and Ahmed 1994). Even though the role of machinery in maximising agricultural production is widely accepted all over the world (James and Pillay 1998), there existed much variation in the pace of mechanisation between different regions.

Observing the agricultural mechanisation scenario in India, the period 1966-2000 witnessed the demand for animal drawn implements such as ploughs, cultivators, puddlers, sowing equipment, cane crushers along with plant protection equipment's such as sprayers and dusters. This period was dominated by small scale manufactures. By 2005 there was a tractor for every 50 ha and the farm power availability was estimated to be 1.231 $kWha^{-1}$. The potential manufacturing establishments were on the development stage (Kulkarni, 2005) and mechanisation packages based on crop and region were being developed. Machines/implements for different farm operations were available, but the investment capacity of the farmers was a major constraint. Mechanisation was increasing at a faster rate in the states like Punjab, Haryana and Uttar Pradesh, followed by Gujarat, Maharashtra, Rajasthan and certain areas of Tamil Nadu and Andhra Pradesh at a moderate pace. However, the topographic and socio-economic constraints in many areas of India like the north-eastern states, created bottlenecks in the advancement of agricultural mechanisation.

Though the production and use of agricultural machines increased, farmers faced problems related to after sales service, shortage of trained professionals and ineffective feed-back system (Mehta, 2013). By 2012-13 there was 33 tractors/1000 ha (dominated by 23-30 kW tractors), a compound annual growth rate of 20% and 28% on rotovator and combine harvester sales (Mehta *et al.*, 2014). The tractor manufactures grew from 13 in 2005 (Kulkarni, 2005) to 23 in 2015, with an addition of 261 crop production machinery and 12 power tiller manufacturers (Mehta *et al.*, 2015).

During the period 2010-2012 the use of higher hp tractors were increasing, 40-50 hp range increased from 24-28%, 50 hp and above increased from 14-17%, while 31-40 hp decreased from 46-42% and 21-30 hp range from 15-12%. Further by 2017 the farm power availability was increased to 2.025 $kWha^{-1}$ as a result of implementing the Sub-Mission on Agricultural Mechanization (SMAM) (Anonymous, 2018) and is expected to reach 3.74 $kWha^{-1}$ by 2032–33 (Tiwari *et al.*, 2019a). Presently, the overall farm mechanisation in the country is about 40-45%, which is comparatively lower than China (48%), Brazil (75%) and 95% in USA (Tiwari *et al.*, 2019b).

STATUS OF MECHANISATION IN POTATO CULTIVATION IN INDIA

Potato when cultivated in traditional way requires huge quantities of manual labour, scarcity and high cost of labour led to the increased use of tractor mounted implements for land preparation, planting, fertiliser application, earthing-up, spraying, weeding and harvesting among large scale producers (Koga *et al.*, 2013). Presently, on an average 90-95% of seed-bed preparation, 80-90% of planting, 80-90% of plant protection and weed control and 70-80% of harvesting are mechanised in potato cultivation (Tiwari *et al.*, 2019b).

Wide range of machines/implements are available for the plains, while there are lesser choices for hilly terrain (Mehta *et al.*, 2018). The possible reason for this is that more than 85% of the potato farms are concentrated in the plains (Chandel *et al.*, 2015). The cost of the available machines/implements are also posing a barrier towards mechanisation (Nare and Singh, 2019). Among the tractors used in potato cultivation, 60 hp is the maximum power, while 40-50 hp is more common (Chandel *et al.*, 2015). Thus there is a necessary to develop smaller size and low-cost implements for improving and sustaining potato cultivation (Salimzyanov *et al.*, 2020).

A. Mechanising various field operations for potato cultivation

(i) Tillage for potato crop. In potato cultivation, tillage is the highest energy consuming and costly operation (Özgöz *et al.*, 2017). In addition to land preparation for planting, earthing-up at different plant growth stages is essential (Tiessen *et al.*, 2007). Rigorous loosening of top soil to a depth of 15-25 cm is important is essential to get better yield (Barakat *et al.*, 2020; Mancinelli *et al.*, 2020). Thus, active tillage implements like rotavators are being widely used in recent years. The potato growing farmers of Brazil preferred rotavator as it gave fine tilth and they found it to be better for crop development. A similar trend were also seen among potato growing farmers of India (Nare and Singh, 2019). In fact 14 cm tillage depth using rotavator was found to be sufficient for potato crop (Dai *et al.*, 2020).

(ii) Potato planting. Potato is planted either on ridges, flat-bed or flat-bed followed by ridging(Anonymous, n.d.). It is essential to have 10-15 cm thick soil cover on top of the tuber seeds after planting (Tantowijoyo and Fliert, 2006). The tuber to tuber spacing should be in the range 22-30 cm(Anonymous, 2016) and row to row spacing between 60-90 cm (Burke, 2017). Tubers planted on ridges should have a minimum width of 25-30 cm and height 30-35 cm for better crop growth (Anonymous, 2016). Potato planters drop the tubers at prescribed spacing and cover them with soil forming a small bund or a ridge.

A variety of potato planters suiting various scales of operation have been developed and are available. Consideration the potato cultivating conditions in India, (Horo and Hanke, 2019) suggested that Semi-Automatic Potato Planter (SAPP) are more suitable. It was found that recent efforts were more on developing Automatic Potato Planter (APP) for potato and missing was identified as a major problem in APP (Wang *et al.*, 2020). To reduce the problem of missing in APP, reseeding system using a laser sensor was tried by (Shufeng *et al.*, 2020). It was found that the attachment could increase the planter efficiency from 91.35-98.5%. To reduce the complexity, (Wang *et al.*, 2020) developed a re-seeding system using one-way clutch principle and attained 99.9% efficiency when tested on a one-row potato planter.

(iii) Fertiliser application. Potato crop on an average consumes 3.8 kg N, 0.6 kg P and 4.4 kg K is consumed for every ton of potato produced (Alva *et al.*, 2011). Traditionally granular fertilizers are applied manually during planting and at different crop develop stages (Mehta *et al.*, 2018). In medium and large scale farms of India, tractor mounted planters with fertilizer drilling facility is used (Pronk *et al.*, 2015). Soluble fertilizers are either supplied along with irrigation or applied on foliage using commercially available sprayers (Mehta *et al.*, 2018).

Studies showed that foliar spraying are more effective and required lesser than soil application using granular fertilizers (Ali and Jasim, 2020).

The first implement that combined fertiliser application with potato planting was an animal drawn planter cum fertiliser applicator in 1879 (Cumings and Houghland, 1939). A two-row tractor mounted planter fitted with fertiliser applicator gave 2.47 tonnes ha^{-1} extra yield than conventional broadcasting method (Cooke *et al.*, 1954). In India, power tiller operated potato planter cum fertiliser applicator was developed by (Gupta *et al.*, 1994). It had an EFC of 0.04 ha h^{-1} with 60% FE, reduce 45% operation cost and 90% labour requirement. It is evident from the studies sited that spraying of nutrients in combination with planting is more economical and beneficial as there is lesser losses, better absorption and requires lesser quantity which is also more environment friendly. In addition, the spraying unit can be used for applying plant protection chemicals too, making the implement more versatile meeting the requirements of multifunctional implement (MFI).

(iv) Application of plant protection chemicals. Potato crop is prone to pest and disease attack, thus spraying plant protection chemicals cannot be avoided (Kapsa, 2008). In fact, spraying during planting itself was found to be essential in controlling Pest and diseases (Melnichuk *et al.*, 2019). Among the diseases, blight is a highly problematic, it's recommended to adopt protective fungicides spraying to delay and control the appearance of blight(Sharma *et al.*, 2019). In addition to the diseases, potato crop has to be protected from a wide verity of insects that affect directly by damaging the tubers and indirectly by damaging the above ground vegetative mass (Vincent *et al.*, 2013).

Conventionally boom sprayers with hollow-cone nozzles is being widely used. They are associated with considerable losses to the ground and lesser penetration into dense canopy (Ade and Rondelli, 2007). Air assisted ones were reported to be better in reducing drift, increase penetration and there by provide better deposition uniformity (Scudeler and Raetano, 2006). Lever-operated knapsack sprayer (Sanabria *et al.*, 2020) and battery operated knapsack sprayer (Mhatre *et al.*, 2021) are becoming common among the potato cultivators of the hilly regions and small scale potato farmers in the plains. Taking into consideration the spraying frequency in potato crop, losses to ground is a matter of both economic and environmental concern (Lesmes-Fabian *et al.*, 2012).

(a) Electrostatic sprayers. The environmental problems created by agro-chemical spraying is becoming a matter of serious concern in India. Spraying with electrically charged droplets reduces both the quantity needed and wastage to ground (Lane and Law, 1982). In addition to this, deposition rates are generally 1.5 to 2.4 times (Lane and Law, 1982) and have even reached up to 4.9 times (Gupta *et al.*, 1992) more than that of uncharged spray. Providing air assistance to charged droplets further increases the coverage and deposition (Sumner *et al.*, 2000). Analysing the spectral distribution, Electrostatic Sprayer (ES) produced smaller droplet size and increased evenness of distribution and deposition (He *et al.*, 2016).

An air-assisted ES having better efficiency while spraying in agricultural fields was developed by(Patel *et al.*, 2016a). Further, Patel *et al.* (2016b) developed an external air assistive device for electrostatic spraying nozzles for increasing the deposition rate during high wind conditions. Considering the Indian agricultural scenario, (Kumar *et al.*, 2017) developed an air-assisted electrostatic nozzle for small scale farmers capable of producing a charge-to-mass ratio of 10 m Ckg^{-1}. A hand-held air-assisted ES was developed by (Patel *et al.*, 2019) for the small and medium scale formers of India. The sprayer was highly efficient in its class, light in weight, capable of producing 1.5 kV, discharge 110 $ml\text{-}min^{-1}$ with 2.8 $kgcm^{-2}$ air pressures and induced 8 $mCkg^{-1}$ charge onto the droplets.

Considering the wide use of Power knapsack sprayers in Indian farms, a cost effective electrostatic induction spray charge (EISC) unit was developed by (Khatawkar *et al.*, 2020a) as an attachment to power knapsack mist-blower. It had better performance compared to ESSMBP90 in terms of Charge to Mass Ratio within the spray throw of 100 to250 cm. As further improvement (Khatawkar *et al.*, 2020) developed a highly cost effective knapsack air-assisted embedded ES. Considering the effectiveness and cost barrier breaking developments in electrostatic sprayer technology, adding it to any MFI for potato cultivation can provide greater benefits as potato crop requires soil, seed tuber and canopy spraying.

(v) Potato Harvesting. Harvesting operation is crucial and expensive in potato cultivation as the tubers are underground, requiring precise judgement (Cunha *et al.*, 2011). Manual harvesting is time consuming and requires about 600-700 $man\text{-}hha^{-1}$ (Kumar and Tripathi, 2017) and results in 20-30% losses due to human judgment error (Sharma *et al.*, 2019). Mechanical harvesting is commonly performed using either animal drawn or tractor operated implements. Tractor operated implement types include blade type diggers (BTD), rotary type diggers, digger cum elevator (DCE) and oscillating/vibratory diggers (Kumar and Tripathi, 2017). Potato combine is another option, though expensive they can cover about 3-4 ha per day and requires very little labour (Mehta *et al.*, 2018).

Potato harvesters fitting various scales of operations are commercially available and are being widely used in India. Based on operating cost, field capacity and losses, two-row BTD is a better choice, while DCE was more effective in exposing the harvested tubers (Singh and Singh, 1979). The cost of the DCE was 5.8 times more than two-row BTD, but its operating cost is 58.6% lesser (Kumar and Tripathi, 2017). The operating cost and losses of potato combines are respectively 49.03% and 3.97% less than tractor mounted BTD, but requires large cultivated area and very high initial investment (Cunha *et al.*, 2011). This forms a major limiting factor for its wider adoption among the Indian farmers.

Injuries to tubers during mechanical harvesting affects the quality of the harvest (Siberev *et al.*, 2019). On an average its estimated that damages during mechanical harvesting is about 10-16% (Kumar and Tripathi, 2017). Tubers get injured as the result of abrasive interaction with soil clods and the parts of the harvester (Bentini *et al.*, 2006). It was found that optimum moisture content (15%) at the time of harvest (Arfa, 2007) and tuber collation force less than 250 N will not result in tuber damage (Sang *et al.*, 2012). The potato DCE injures about 2-2.5% of the tubers, which was 2.7% less than digging using plough, 2.5-4.5% less than manual harvesting (Kumar and Tripathi, 2017) and 1.5-2% less than rotary potato digger (Azizi *et al.*, 2014).

Cost, time required for harvesting, quantity harvested and damage caused are the main factors that Indian farmers consider. Potato DCE is the most suitable specialized implement for harvesting in India. While incorporating the harvesting operation into MFI, setting the DCE unit can be complex and will make the MFI costly. A BTD with a vibrating steel bar grid can possibly give similar performance as DCE with the additional benefits of easy fabrication. Such an implement is likely to be much simpler and low cost, making the MFI affordable to Indian farmers.

NEED FOR IMPROVED COMBINATION MACHINES

Potato being a seasonal crop and subjected to high price fluctuations, reducing the cost of production is very important for the producer. To sustain the potato cultivation, machines/implements should be developed taking into consideration the actual problems. MFI capable of combining possible operations in one pass is such a concept.

In potato cultivation, tillage, planting, fertiliser application and soil chemical spray can be completed in one pass (P_1). As the crop grows, weeding, earthing-up and foliage spray can be done in another pass (P_2). P_2 may has to be performed two or three times during the crop period. Need based plant protection spraying (P_3) and harvesting (P_4) stand as separate operations. Thus, a single implement having provisions of performing P_1, P_2, P_3 and P_4 is the conceptual MFI envisaged to sustain potato cultivation. Technically superior components should be selected for the MFI such that their performance is effective and reliable for various operations.

Thus, taking into consideration the Indian potato cultivation scenario, an MFI powered by 37-45 kW tractor combining a rotavator, a semi-automatic planting attachment, a ridger and an ES spraying unit seems appropriate. There should be facility to replace the rotavator with a digger so as to perform all the sequential operations P_1, P_2, P_3 and P_4. This MFI will serve as a single combi-machine solution for mechanised potato farming and likely to be accepted by the farmers of India as it can handle all major field operations.

CONCLUSION

Studying the cultural practices, trend of mechanisation and the future needs of potato cultivation in India, a conceptual MFI for total mechanisation of potato cultivation is envisaged. The MFI is expected to be capable of performing tillage, planting, fertiliser application, plant protection as well as nutrient spray, earthing-up and harvesting. The proposed MFI can significantly reduce the potato production cost and help the farmer greatly in sustaining potato cultivation in India.

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Conflict of Interest. None.

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