ABSTRACT

In order to improve mechanisation in onion harvesting in small land holdings and to increase the annual working hours of hand tractors, a hand tractor powered topper cum digger (TCD) was designed and developed for carrying out topping of onion leaves and digging of topped onion bulbs simultaneously. Onion seedlings (Pusa Red variety) were grown to study the engineering properties of onion plants required for designing an onion harvester. For minimizing the cutting power and maximizing the topping efficiency, operational parameters such as rotational speed of topping unit, working width and forward speed of the harvester are to be optimized. Hence, a laboratory setup was developed comprising a processing trolley, two rails and an onion bulb holding unit. The processing trolley comprised nylon wire type topping unit, a torque sensor, an 850 W DC motor to supply power to the topping unit, a 350 W DC motor for the movement of processing trolley, one motor controller for each motor and a data acquisition system. The range of cutting speed, cutting width, and forward speed varied were 1200 to 1800 rpm, 300 to 600 mm, and 0.22 to 0.33 m s^{-1} , respectively. The mean power requirement for topping of onion leaves was observed in the range of 257.11 to 302.50 W. Based on multiple regression technique, models were developed as a function of cutting speed, width, and forward speed of the harvester for estimating cutting torque and topping efficiency. A prototype of TCD was designed and developed for a 9.70 kW hand tractor taking into considerations the laboratory findings. It comprised a topping unit at the front and a digger cum vibratory conveying unit at the rear end of the hand tractor and the later was fixed after removing the complete assembly of tiller unit of the hand tractor. Both topping and digging units covered the complete track width of 600 mm of the hand tractor. The topping unit consisted of a nylon wire type cutter for cutting the matured onion leaves, a torque sensor to measure torque required to cut leaves, a linear actuator for lifting of the entire topping assembly, and a telescopic shaft to set the height of cut. The topper was powered by taking power from the flywheel of the hand tractor. The digger cum vibratory conveying unit consisted of a multiple v-shaped digging blade for loosening and uprooting the topped bulbs, rod type vibratory chain conveyor for conveying the topped bulbs to the rear side of the harvester, agitators for oscillation of the conveyor to separate soil from the bulbs, a pair of gauge wheel to maintain the depth of digging, a pair of rotary disc, and power transmission system to supply power from the rotor shaft of the hand tractor to the rollers of the conveyor and a hitching arrangement to attach the digger cum conveyor unit to the hand tractor. Further, an arrangement was made to mount a torque sensor for measuring the torque requirement for carrying out conveying of the onion bulbs. Draft requirement was measured using a calibrated S-type load cell (5 tonne capacity) with the help of a dummy tractor to decide the value of rake angle and depth of digging. For minimum draft and percentage of damaged bulbs and maximum digging efficiency, the value of rake angle and digging depth was selected as 21° and 70 mm, respectively. The draft value at the corresponding rake angle and digging depth was found to be 746.6±142.4 N. The height of cut above the crown was measured and found to be 31±7 mm. The topping efficiency, digging efficiency, field efficiency, actual field capacity and damage percentage of onion bulbs were found to be 82%, 92%, 65%, 0.042 ha/h and 10%, respectively. Fuel consumption of hand tractor was obtained as 0.993±0.27 l/h. The total power requirement for harvesting onion crop (including topping, digging, and conveying) was found to be 0.81 kW in the 1st gear of the rotor shaft of the hand tractor. Harvesting of onion crop using the developed TCD could save 73% of cost and 96% of time with respect to the traditional onion harvesting method. The performance of the developed TCD was found to be satisfactory and could be used effectively by small land holding farmers raising onion crops. However, further improvement like attaching a storage unit behind the rear side of the developed TCD for collection of topped onion bulbs may be tried with rigorous testing with other varieties of onion crop.

Keywords: Onion topper cum digger; mechanical harvesting; digging efficiency; topping efficiency; equipment development