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Comparative field performance evaluation of different type of Pusa Electric Power Units

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ABSTRACT

Pusa developed three walk-behind type electric power units were evaluated in 9.96 ha area for tillage in polyhouse, secondary tillage, planking and weeding-cum interculture operations at research farm of ICAR-IARI during *kharif* and *rabi* 2020 and 2021. The power of four-wheel and two-wheel electric power units was 350W while Pusa mini electric prime mover was having 450W power. The controlling-cum-guiding force for operation of four-wheel power unit, two- wheel power unit and mini electric prime mover was found 26.72, 30.9 and 22.7 N, respectively. Correspondingly, the draft force was 210, 245 and 300 N. Based on the rigorous field study, the effective field capacity with these electric power units were 2.3 times higher than manual operated four-wheel weeder for wide-row crops. The field efficiency with four-wheel, two-wheel electric power unit and mini electric prime mover was 78–83.26, 78.6–81.25 and 69.2–92.6% in weeding-cum-interculture operation, respectively. The walk-behind electric power units are also found to reduce operator's drudgery by 80–85%. The mini electric prime mover was found 32.7% cheaper than the four-wheel and 17.2% than the two-wheel power unit. Its command area is one ha for secondary tillage and 5 ha for weeding-cum-interculture operations in wide-row crops.

Keywords: Custom-hiring, Electric energy, Electric prime mover, Field evaluation, Wide-row crops

Farm mechanization plays an important role in increasing system productivity of agriculture. Various sources of farm powers are being used in agriculture for increasing timeliness in farm operations, metering the input and reducing the drudgery of workers. Singh and Singh (2021) reported the farm power availability of 2.76 kW/ha in the country during 2020–21. Of this, contribution of mechanical power is 74.42% which is run primarily by diesel fuel. The Automotive Industry Standards (AIS) suggested for reducing pollution with a viable option of electric vehicles and providing incentives to farmers (Pushkar 2019). The use of electric power using battery as energy storage system is being studied globally for its potentiality in mobile farm operations with tractor, solar powered electric tractor, orchard tractors, autonomous or self-drive agricultural machines, agricultural robots, precision agriculture, walk-behind electric machine for tillage, sowing/planting and plant care, interculture, harvesting, etc (Kiran et al. 2017, Mathan et al. 2019, Sahoo and Raheman 2020, Singh 2020, Prasanth et al. 2020).

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Considering global concern on emission of CO_2 in atmosphere, an attempt has been made at ICAR-Indian Agricultural Research Institute, New Delhi since year 2015 to work on electric power for mobile farm operations to increase the working efficiency of farm workers with minimal drudgery (Singh *et al.* 2019a, b; Singh *et al.* 2020, IARI 2020). There is a need to study the comparative performance of Pusa developed walk-behind type electric (battery-assisted) power units in various crops under field condition to assess their suitability.

MATERIALS AND METHODS

ICAR-Indian Agricultural Research Institute, New Delhi developed walk-behind type battery-assisted four-wheel power unit, two- wheel power unit and mini electric prime mover were assessed for their performance and suitability in different crops. The guiding-cum-controlling force required by the operator to guide these power units was measured using resistive type sensor. The resistive sensor was mounted on the handle of each power unit. The excitation voltage of 5V and 0.8A was set to the sensor. Force applied on its surface area acts to change its resistance which further resulted in obtaining the digital output in terms of force.

The four-wheel electric power unit (30 kg) was developed during 2016 which consisted of 350W 24V permanent magnet DC motor, a 350W controller, accelerator, pack of two 12V 24Ah battery, handle, aluminium frame, 400 mm pneumatic drive wheel, 250 mm front wheel and power transmission unit. A sweep type tool of 250 mm was attached at front on central hitch using nut-bolts. The two-wheel electrical power unit (37 kg) was developed during 2020. It consisted of 350W 24V permanent magnet DC motor, a controller, 5V 3.5 mA accelerator, pack of two 12V 24Ah battery, handle, aluminium frame, 400 mm pneumatic drive wheel, power transmission unit and rear hitch system.

The mini electrical prime mover (48 kg) was developed during 2020. This prime mover consisted of 450W 24V permanent magnet DC motor, a 800W controller, accelerator, pack of two 12V 24Ah battery, handle, ladder type MS C-chassis, 400 mm hutch type drive wheel, power transmission unit and rear hitch system. A sweep, two/three tine 300 mm cultivators and 600 mm planker were attached in two-wheel and mini prime mover at the rear on central hitch using nut-bolts..

Performance of these machines was evaluated at research farm of ICAR-IARI, New Delhi during 2020 and 2021 in *kharif* and *rabi*. Four-wheel, two-wheel and mini electrical prime mover was operated in 2.1258, 1.235 and 6.6 ha area during seasons for maize, moong bean, pearl millet, pigeon-pea, soybean, chrysanthemum, marigold, spinach and gram crops, respectively (Fig 1). Secondary tillage was also performed during *rabi*. Data on cone index, speed, depth of operation, number of weeds before and after the weeding in one and two pass, soil moisture content, bulk density and battery-run time was recorded using standard methods. Effective field capacity, field efficiency and weeding efficiency were calculated as per standard formula. The electric energy consumption/ha was assessed based on number of charging of 24V 24Ah battery during operation in different fields. Further, the watt-h is converted to energy (joule) by multiplying 3600. Power consumption at different depth of operation was measured using energy meter that was connected in parallel with the battery power source to load (Fig 2).

The cost of operation of each power units was calculated as per IS:9164-1979. Cost of four-wheel power unit, two-wheel power unit and mini electric prime mover was ₹35000, ₹40000 and ₹45000, respectively with 10 years life period. Correspondingly, the estimated use of operational hour per year was 200, 300 and 500 h. Repair and maintenance cost was taken 17.32% of price of the electric power units and cost of electricity for charging was ₹10 per pack of 24V 24Ah battery. Operator cost was taken as ₹350 per day. The overhead cost was 20% of fixed and operating costs which is added in obtaining total cost of operation of electrical power units. The cost of operation of sweep, cultivator and planker was also calculated ₹1.35, ₹5.15 and ₹3.86/h considering the price of ₹700, ₹4000 and ₹1000 for use of 200, 300 and 100 h, respectively. Life of attachment was kept 8 years and repair and maintenance cost was 24.56% of average price of attachments. The command area for suitable electric power unit is calculated based on minimum time available (10 days) for secondary tillage in *rabi* and 45 days for weeding-cum interculture operation. Post hoc analysis is performed using R statistical software to assess the significance in performance and cost of operation amongst these three electrical power units.

Fig 1 Walk-behind mini electric prime mover for interculture operation.

RESULTS AND DISCUSSION

Guiding force at operator's hand was found lowest (22.7 N) with mini electric prime mover followed by 26.72 N with four-wheel and 30.9 N with two-wheel electric power unit. This indicates easy handling of mini electric prime mover. Kumar *et al*. (2017) reported draft of manually operated 30 cm rotary weeder in tomato and okra was 176.6 N and 181.4 N, respectively. Singh *et al.* (2016) also found push force of 155.4 N with 250 mm manual operated four-wheel weeder. According to the force analysis of experiencing the operator, electric power units reduced force (drudgery) by at least 80–85% during operation. Draft force of four-wheel, two-wheel and mini prime mover was found 210, 245 and 300 N, respectively. The cone index was 0.4–1 N/mm^2 for depth from 10–150 mm. The weeding-cum-interculture zone for these crops were up to 75 mm and cone index was found up to 0.8 N/mm^2 which is similar to the findings of Maity *et al.* (2013).

Four-wheel electric power unit was evaluated in wide

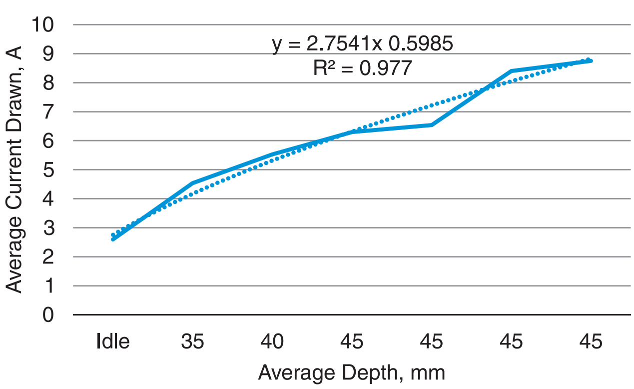

Fig 2 Current drawn by 4-wheel unit at different load (depth) conditions in field.

row (0.4–0.75 m) sown crops in *kharif* and *rabi* at depth of 40–45 mm. The effective field capacity of the electric power unit was 0.0424, 0.0574, 0.0506, 0.0535 and 0.0529 ha/h in maize, moong bean, pearl millet, pigeon pea and soybean crops at speed of 2.72, 2.8, 2.55, 2.57 and 2.71 km/h, respectively. The field efficiency varied from 78–83.26%. The variation in field efficiency was due to the size of field and crops (Singh *et al*. 2016). Weeding efficiency also varied from 76.2–95.37% in these crops. The variation in weeding efficiency was due to uneven condition of weeded area as sweep type tool attached with this machine performed slicing action in soil at a 4-wheel track. This unit performs satisfactorily in slanting face of ridge sown crop without extra effort by operator. The power unit started overturn at about 40° in sloppy land. A fully charged pack of battery was found to cover 0.1545, 0.2570, 0.3115, 0.2808 and 0.3413 ha area in maize, moong bean, pearl millet, pigeon pea and soybean crops, respectively. The distinction in observation was because of variation in steadiness in operation of the machine due to variation of field length, weed intensity, soil moisture content and bulk density. The maximum energy consumption and operating cost/ha was 13.41 MJ and ₹1784 in weeding operation. Study was also conduced to see the power consumption in operation of four-wheel electric power unit at different depth. The current drawn varied from 2.6–8.75Ah during idle run in field to a depth of 45 mm with r^2 value of 0.9717 in power trendline (Fig 2). This shows the variation of power consumption from 62.4–210 W. This variation is due to the roots of weed during operation in field at constant depth. This also indicated drawl of maximal power of 210 W (60% of its capacity) for successful operation with this 350 W power unit.

Two-wheel electric power unit was assessed in *kharif* and *rabi* for tillage in polyhouse, secondary tillage and planking. The depth of operation for secondary tillage was 60–70 mm. The effective field capacity was 0.0297, 0.038 and 0.093 ha/h in tillage, secondary tillage and planking at operational speed of 1.5, 2.02 and 1.95 km/h, respectively. Low speed of operation was kept during tillage operation in polyhouse due to restricted bed size where speed of operation for secondary tillage and planking was about same due to open field. The highest energy consumption/ha was found 32.72 MJ in secondary tillage followed by 23.62 MJ for tillage in polyhouse and 14.92 MJ for planking operation. Singh and Singh (2014) also reported highest operational energy consumption in seedbed preparation. The variation of electric energy consumption was due to bulk density of the bed/ fields. A fully charged pack of batteries was found suitable for 0.0876 ha in tillage in polyhouse, 0.0634 ha in secondary tillage in open field and 0.1389 ha in planking. Weeding-cum-interculture operations was also performed in spinach, chrysanthemum, pigeon pea and marigold crops with sweep type tool and two/three tine cultivators at row spacing of 60 cm. The effective field capacity of this electric power unit was 0.033, 0.039, 0.0251 and 0.0293 ha/h at speed of 1.4, 1.6, 1.5 and 1.5 km/h for weeding-cum-interculture operation at depth of 45–60 mm in spinach, pigeon pea, chrysanthemum and marigold crops, respectively. The variation in field efficiency was due to only field size. The energy consumption with this power unit was 8–9 MJ/ha for weeding-cum-interculture operation except 20.94 MJ in spinach sown at row spacing of 20 mm. This is due to very small size of plot as well high moisture content and bulk density of soil in spinach. It is also clear from the data that this electrical power unit is more suitable for weeding-cum-interculture operation in wide-row sown crops than secondary tillage. The maximum operating cost per ha was ₹3250 in secondary tillage.

The mini electric prime mover was evaluated for secondary tillage and planking operations and weeding-cum-interculture operation in gram, pigeon pea, marigold

Table 1 Performance data of mini electric prime mover during *rabi* and *kharif*

Particular	*Rabi*			*Kharif*			
	Secondary tillage	Planking	Gram	Pigeon pea	Pigeon pea	Marigold	Chrysanth-emum
Soil moisture content, % d.b.	13.5	13.4	12.06	10.2	15.3	16.5	15.37
Bulk density, g/cc (d.b)	1.12	1.05	1.13	1.13	1.23	1.21	1.19
Row spacing, cm	-	-	60	30	70	60	70
Depth, mm	50–75	-	40–60	45–70	45–70	45–75	50–75
Speed, km/h	2.2	2.2	1.5	2.0	1.5	2.5	2.4
Effective field capacity, ha/h	0.0442/0.0546	0.1118	0.0311	0.0555	0.0321	0.06	0.065
Field efficiency, %	80.4/82.8	84.7	69.2	92.6	71.3	80.0	90.28
Weeding efficiency, %	-	-	-	-	70.3	-	-
Electric energy consumption, W-h/ha	6509/5756	3433	2880	3145	2205	1600	1440
Energy consumption, MJ/ha	23.43/20.72	12.35	10.36	11.32	7.93	5.76	5.18
Battery run time, h	2/1.83	1.5	3.22	3.2	3.5	2.96	2.64
Cost per ha, ₹	1875/1588	769	1397	1562	1163	720	573

and chrysanthemum crops (Table 1). The effective field capacity of the prime mover in secondary tillage operation with sweep type tool and three tine cultivator was 0.0442 and 0.0546 ha/h, respectively at speed of 2.2 km/h. Correspondingly, the energy consumption was 23.43 and 20.72 MJ/ha. Higher energy consumption was found with sweep type tool for secondary tillage as compared to three tine cultivator. This is due to size of tool which increased number of passes. The planking operation consumed 12.35 MJ/ha. Effective field capacity for weeding-cum interculture operation with 2-tine cultivator in pigeon pea at row spacing of 30 cm was 0.0555 ha at speed of 2.0 km/h. The effective field capacity with three tine cultivators was 0.0311, 0.0321, 0.06 and 0.065 ha/h in gram, pigeon pea, marigold and chrysanthemum crops at speed of 1.5, 1.5, 2.5 and 2.4 km/h, respectively. The variation in speed for these crops was due to soil bulk density, row length and spacing. Operator maintained the comfortable speed as per his work rhythm. The energy consumption/ha was in the range of 5.18–11.32 MJ for weeding-cum-interculture operation in these crops. This variation was due to size of plot and field condition. The maximum operating cost per ha was ₹1875 in secondary tillage.

The average effective field capacity obtained with electric power units were 647 m^2/h in weeding-cum-interculture operation which is 2.3 times higher than the average (281 m^2/h) effective field capacity of manual operated four-wheel weeder for wide-row crops (Singh *et al*. 2016). The operating depth obtained with two-wheel and four-wheel electric power units was 40–60 mm while it was 45–75 mm with mini electric prime mover. Similar operating depth for weeding-cum-interculture was also reported by Ahmad (2012) and Senthilkumar *et al*. (2014). Field efficiency with four-wheel, two-wheel and mini electric prime mover was 78–83.26, 78.6–81.25 and 69.2–92.6% for weeding-cum-interculture operations, respectively. Senthilkumar *et al*. (2014) also reported field efficiency up to 64–71.5%. Better field efficiency with electric power units was obtained due to better handling and control by the operators. This has also attributed towards no damage to plants during weeding-cum-interculture operation with studied electric power units while Kumar *et al*. (2018) reported the plant damage with the power weeder (11%) followed by 1.17% with star weeder and 2.2% with wheel hoe. Weeding efficiency was 76.22–95.37% in maize, moong bean, pearl millet, pigeonpea and soybean crops with four-wheel electric power units while it was 70.3% with mini electric prime mover in pea crop. Senthilkumar *et al.* (2014) also found the weeding efficiency with manual hand hoe and power weeders (60, 45 and 30 cm width) in pulse crop 82.5, 73.45, 64.15 and 43.13%, respectively. The maximum operating cost/ha was found ₹1562 with mini electric prime mover for interculture operation in wide-row crops which was lowest as compared to power weeder (Senthilkumar *et al*. 2014 and Kumar *et al*. 2018). This indicates economical interculture operation with these electric power units.

MANOVA and Linear Discriminate analysis were used to assess the significance in performance evaluation data such as, field capacity, field efficiency and energy consumption obtained with four-wheel power unit, two-wheel power unit and mini electric prime mover and were found insignificant as per post hoc analysis. While, the cost of operation of mini electric prime mover was lowest (₹81.6/h) as compared to (₹95.1/h) two-wheel and four-wheel electric power units (₹108.08/h). Hence it can be beneficial in terms of economic point of view.

The study was carried out on comparative field performance of Pusa developed walk-behind electric power units found suitable for weeding-cum-interculture operation in wide row crops sown above 40 cm. A two to three tine cultivator can easily be attached with two-wheel electric power unit and mini electric prime mover in addition to sweep type tool. The mini electric prime mover is found energy efficient amongst studied electric power units in all the farm operations. This is mainly due to use of different power transmission system and also the load bearing capacity of the prime mover. The mini prime mover was found 32.7% cheaper than four-wheel and 17.2% with two-wheel power unit. This is due to utilization and suitability of the power units for different operations in *kharif* and *rabi* being a versatile power unit. These electric power units are found to reduce operator's drudgery by 80–85%. Based on energy consumption/ha, the command area of mini electric prime mover is 1 ha for secondary tillage operation and 5 ha for weeding-cum-interculture operations in wide-row crops.

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