Journal of Scientific & Industrial Research
Vol. 84, July 2025, pp. 742-748
DOI: 10.56042/jsir.v84i7.16580

Development of Two-Row e-Powered Transplanter for Root Washed Type Paddy Seedlings

Aware V V[1]*, Jadhav P S[1], Jadhav M L[1]*, Aware S V[1], Shahare P U[1] & Rajemahadik V A[2]

[1]College of Agricultural Engineering and Technology, [2]College of Agriculture, DBSKKV, Dapoli 415 712, Maharashtra, India

Received 21 January 2025; revised 06 June 2025; accepted 17 June 2025

A two-row e-powered paddy transplanter was developed for root-washed type seedlings. The developed transplanter was manually pulled in puddled field but had a direct current electric motor driven transplanting mechanism powered by lithium-ion battery. Power was supplied to the seedling pickers-cum-holder and seedling shifter-cum-erector through the speed reduction-cum-transmission unit. The seedling pickers-cum-holder picked the seedlings from the bottom of the tray containing root-washed type seedlings by the picking and pushing cam assembly and transplanted into two rows by the seedling shifter-cum-erector. A new holding and releasing mechanism cam was developed and wooden float with aerodynamic curve was fabricated for the developed transplanter for smooth operation. Results of field performance showed that field efficiency of existing and e-powered transplanter were 45.70% and 56.71%, respectively. Field capacity of existing and e-powered transplanter were 0.029 ha/h and 0.036 ha/h, respectively. The cost of e-powered paddy transplanter was ₹32454/- and operating cost was ₹161/h. The developed transplanter was found suitable for transplanting with root-washed type seedlings.

Keywords: Cam profile, Field performance, Float shape, Hand-cranking, Lithium-ion battery

Introduction

Paddy is an important cereal crop of the Konkan region of Maharashtra (India) and grown on 0.36 Mha with production of 1.56 Mt and productivity of 2.9 t/ha.[1] Manual transplanting is the prevailing traditional practice of paddy crop establishment, which is tiresome as done in bending posture causing the undue stress on the spinal cord, lower back, legs and knees with "moderately heavy" workload, low field capacity of 40 m^2/h and highly laborious activity.[2] Studies showed that traditional paddy transplanting requires about 25% of the overall labour requirement for cultivation of paddy crop.[3] The down serge in labour availability during peak season rang the alarm of the mechanization need in transplanting operation.[4] Several attempts have been made in country to mechanize the direct seeding as well as transplanting of paddy.[5–8] In present epoch, self-propelled or power-operated paddy transplanters with mat-type nursery seeder are being used in several paddy pockets of India.[9–12] Despite of their satisfactory performance, they did not succeed to attract the farmers in Konkan region as about 72% and 25% of the cultivable land of the region is marginal and medium sized, respectively with undulated topography.[13] Kavitkar *et al*. (2022) developed a hand-cranking type manually operated paddy transplanter for root-washed type seedlings, having the average field capacity and field efficiency as 0.03 ha/h and 60.4%, respectively.[7] To enhance the operator's performance and comfort, several studies have been conducted to power the transplanting operation with an alternate power source. Patil (2017) developed an engine-powered four row transplanter. The power source was rested on single wheel and connected to transplanting mechanism using universal coupling.[8] The sinkage and maneuverability were the shortcomings of the developed transplanter. More (2018) conducted an experiment to power the hand cranking type transplanter using 2-stroke petrol engine (1.75 hp @ 6500 rpm).[14] However, the weight of transplanter was increased from 22 kg to 28.65 kg due to engine installation, which increased the pulling force of the transplanter in puddled field. Hence, it can be conclude that these prototypes seemed unfit to harness the principal benefits of the power assistance. Hence, identification of a light weight, smooth, durable and robust power source was the needed.

*Authors for Correspondence
E-mail: vijayaware75@gmail.com, jadhav16maahi@gmail.com

Fig. 1 — Existing two-row hand cranking type manual paddy transplanter

Chemical batteries like lead-acid, lithium-ion, lithium-phosphate *etc* are being choice as power source over traditional diesel or gasoline-powered systems for on and off-road vehicles due to high power-to-mass ratio and rapid research advancement. In India, small agricultural equipments ranging from field preparation to harvesting of crops are being designed with the batteries powered brushless direct current (BLDC) or direct current (DC) motors due to their availability in wide range capacity. The studies have been conducted to perform different farm operations *viz*., secondary tillage[15], seeding devices[16–18], interculture operations[19,20] and harvesting[21–23] using electric power. Limited literature is available for battery application in transplanting work. Considering these facts, the present study was undertaken for development of e-powered paddy transplanter for root washed type nursery seedlings.

Materials and Methods

Study of Existing Transplanter

A two-row hand cranking type paddy transplanter developed by Kavitkar *et al*. (2022) was selected for the study (Fig. 1a).[7] In this transplanter operation, the operator has to do cranking by the right hand for transplanting and pull the transplanter with the left hand while walking in reverse direction (Fig. 1b). It was observed that continuous cranking-pulling operation causes repetitive motion and awkward posture, resulting in shoulder and lower back pain of worker. This pain may become a source of injury to the operator in long run. Hence, it was decided to power the cranking operation to enhance the operator's performance and comfort.

Design of Power Source

The electric power was preferred over IC engine to avoid dependency on fossil fuels and smooth operation.[24] It was necessary to keep transplanter weight as low as possible as it was to be pulled by the operator. Hence, the lithium-ion battery was chosen as lead-acid batteries have high power-to-mass ratio. The motor power selection was done on the basis of required cranking force.

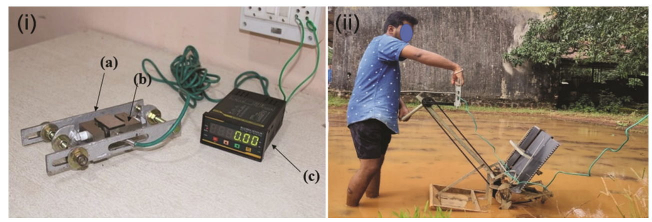


Fig. 2 — Cranking force measurement: (i) Setup — (a) An attachment for cranking force measurement (b) S-type load cell & (c) Digital load indicator; (ii) measurement in actual field

Measurement of Cranking Force in Field

Force measurement setup was developed to measure the cranking force using calibrated S-type load cell (Make: Rudrra; LC: 0.02 kg) in actual field conditions (Fig. 2). A linear relation was found from calibration and it was used for predicting actual force required for cranking. The average cranking force was 81.24 N.

Selection of Motor and Battery

The radius of cranking handle was 0.22 m. Hence, the observed torque (T) was 17.87 N.m. The motor power required was calculated by standard relation given in Eq. 1.

$$\text{Power, W} = \frac{2 \times \pi \times N\ (rpm) \times T(N.m)}{60}. \qquad \dots (1)$$

To specify the required speed (N), the field performance parameters of existing transplanter were considered. The transplanter transplanted two hills per rotation of crank in a row. Hence, area covered per rotation was 0.15 m^2 with the hill to hill spacing of 0.15 m and width of transplanter as 0.5 m. The desired field capacity was 300 m^2/h, hence required speed (N) was calculated as 33 rpm. So, the design power was 247 W from Equation 1 by considering factor of safety as 4. Hence, a 24V DC motor having standard speed of 360 rpm was selected with a 10 Ah lithium-ion battery weighing 1.9 kg. Chain-sprocket power transmission was used to achieve the desired speed of 33 rpm at the main shaft.

Modifications in Existing Transplanter

It was observed that picking mechanism was causing jerks to the handle and increasing peak cranking force as there was sudden rise in cam profile of existing transplanter. Also, the flat shape at the front side of the float was causing more resistance in pulling and allowing mud entry in the float.

Seedling Holding and Releasing Mechanism Cam

The cam of picking mechanism of existing transplanter had sudden rise in its profile causing abnormal jerks to the handle (Fig 3a).[25] The stroke length of the cam was determined from the size of the radial intermediate axis. There was sudden rise of 20 mm in 15° rotation. The cam profile was modified to reduce the sudden jerk by smoothing cam rise. The cam profile was marked and cut on an M.S. flat plate of 3 mm thickness. In the newly developed cam, outstroke of 17°, dwell period of 14° again rise of 4° then dwell period of 10°, return stroke were 9° and the remaining 126° was resting (Fig 3b). Hence, two steps of rise were provided in order to reduce abnormal jerks. Total 17 mm rise was in two steps first 14 mm in 17° rotation and next 3 mm rise in 4° rotation of cam. There were two dwells *viz*. 14° rotation after first rise and 10° rotations after second rise. The resting was during remaining 126° rotation of cam.

The displacement diagram of modified seedling holding and releasing cam is shown in Fig. 4.

Shape of Float

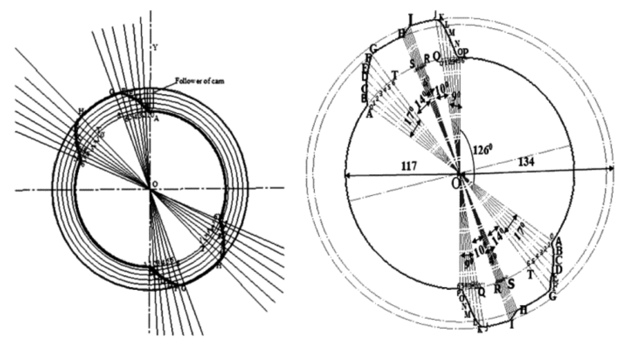
The wooden float was modified for its shape in front side. The aerodynamic curve was given with 100 mm front edge height. The size of curved wooden float was kept as 700 × 400 mm. The existing and developed curve-edge wooden floats are shown in Fig 5.

Developed e-Powered Paddy Transplanter

The developed e-powered transplanter is shown in Fig. 6. The detailed specification of developed transplanter is given in Table 1. The transplanter was equipped with wooden float to slide on puddled soil and handle to pull it. The transplanter consisted of two trays for placing root-washed seedlings to transplant them in two rows simultaneously. As transplanter started, the desired numbers of seedling were picked with the help of seedling picker-cum-holder operated on holding and releasing mechanism cams. The nursery shifter-cum-erector was used for transplanting the seedlings in the puddled field. The seedling picker-cum-holder and shifter-cum-erector shafts were powered by DC motor mounted on handle.

No-load and Load Test for Battery Discharge

The transplanter battery was tested under no-load and load conditions. The measurement at no-load was made in the laboratory and at load it was measured in puddled field. The voltage of battery was measured at regular interval during test.



(a) Existing cam profile (Kavitkar 2016) (b) Modified cam profile

Fig. 3 — Construction of existing and modified seedling holding and releasing cam (a) Existing Cam Profile (Kavitkar, 2016), (b) Modified Cam Profile

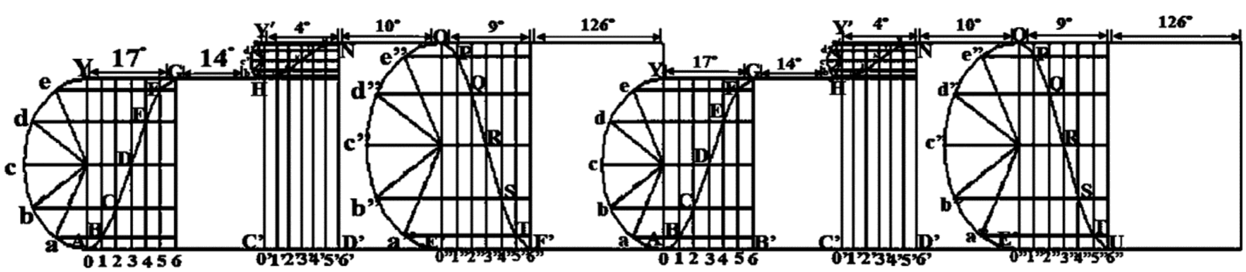


Fig. 4 — Displacement diagram of seedling holding and releasing cam

Performance Evaluation

The comparative field performance of the existing transplanter and developed e-powered paddy transplanter was conducted in puddled field (Fig. 7) at Department of Farm Machinery and Power, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli in the kharif season of 2022. The interval between puddling and transplanting was 36 h. The parameters *viz*. puddling index, water layer depth, pulling force and depth of planting at the time of transplanting were measured. The sample for puddling index was collected in a graduated cylinder of 0.5 L capacity with the help of a steel tube of 12.5 mm diameter by dipping it at 100 mm depth in the puddled soil at five random locations.[26,27] The following observations were also taken during field evaluation.

Total number of seedlings per hill was measured at six different locations for existing and developed transplanter. The missing hills were measured as non-existence of seedlings at any transplanting point due to floating, buried and inability of the finger to pick the seedlings in 1 m^2 area as per IS 18718-2024.[(28)] The actual field capacity was measured using the area covered and the time it took to cover the area, including time spent in turning the transplanter at headland and loading the seedlings as expressed in equation 2. It is the machine's real average rate of coverage, based on total field operating time. The field efficiency was expressed in percentage of the ratio of actual field capacity and theoretical field capacity.

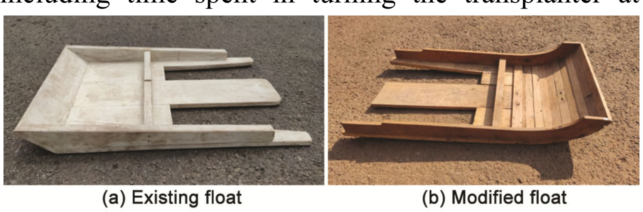


Fig. 5 — Existing and modified wooden float (a) Existing float (b) Modified float

$$AFC = \frac{A}{T_p + T_i} \quad \text{... (2)}$$

where, AFC = actual field capacity (ha/h), A = actual area covered (ha), T_p = productive time (h) and T_i = non-productive time (h).

Statistical Analysis

Student's T-Test was used to verify the significance of e-powered transplanter over the existing transplanter on the basis of recorded performance parameters. The statistical analysis was conducted in SAS software (SAS on demand for academics).

Table 1 — Specifications of developed e-powered paddy transplanter

Sr. No.	Particulars	Specifications
1	Weight of transplanter, kg	24.11
2	Overall dimension (L×W×H), mm	700 × 400 × 826
3	Row-to-row distance, mm	250
4	Type of float	Curve Wooden Float
5	Power source	Lithium-ion battery operated DC motor
6	Motor specification	24 V-250 W
7	Battery specification	24 V – 10 Ah
8	Battery dimension (L×W×H), mm	350 × 75 × 90
9	Battery weight, kg	1.94
10	Power transmission	Chain and sprocket
11	No. of rows	2

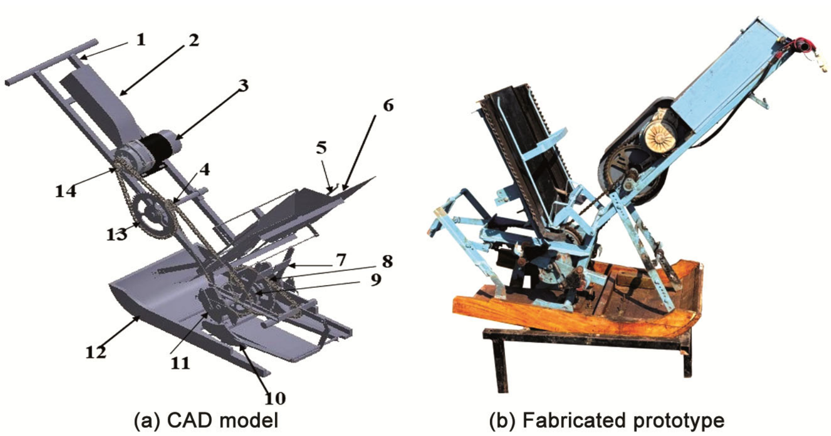


Fig. 6 — Developed e-powered paddy transplanter (a) CAD model (b) Fabricated prototype: 1) Handle, 2) Lithium-ion battery, 3) DC motor, 4) Sprocket with 9 teeth, 5) Seedling frame, 6) Seedling tray, 7) Main frame, 8) Sprocket with 36 teeth, 9) Nursery holding and releasing mechanism cam, 10) Nursery shifter cum erecter, 11) Nursery planting mechanism cam, 12) Float, 13) Sprocket with 44 teeth, 14) Sprocket with 9 teeth.

Fig. 7 — Field evaluation of developed e-powered paddy transplanter

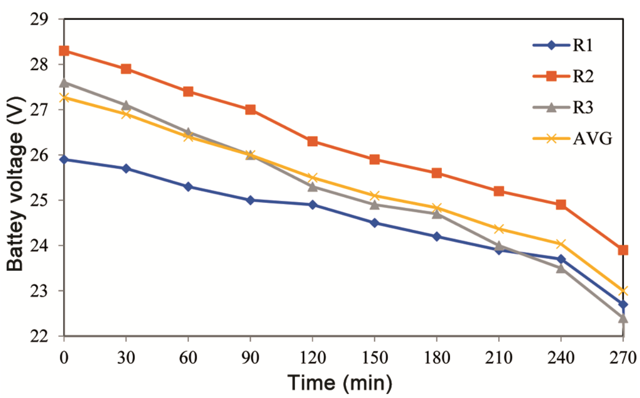


Fig. 8 — Battery discharge curve during load test

Cost Economics

Cost of operation of developed e-powered transplanter was determined as per IS 9164–1979 on per hectare and per hour basis.[29] As per standard, depreciation was assumed as 5% with straight line method. The values of annual use and working life of machine were taken as 240 h and 6 year. The cost of electricity was calculated as per the actual power consumption as 0.24 kW-h. The current labour charges were taken as ₹409 per day.

Results and Discussion

No-load and Load Test for Battery Discharge

It was observed that a fully charged battery (27 V) can run the transplanter at no load for 19 h before discharging to 21 V. During load test, the voltage was observed at an interval of 1 hour. Total working period of e-powered paddy transplanter was found as approximately 4 h 30 min to discharge a fully charged battery (Fig. 8).

Table 2 — Comparative field performance of existing and e-powered paddy transplanter

Sr. No.	Parameter	Existing paddy transplanter (Hand cranking)	e-Powered paddy transplanter	Calculated t-value	Pr > |t|
1.	Missing hills/m^2	6	3	5.59	0.001**
2.	Operating speed (m/s)	0.35	0.36	0.54	0.59NS
3.	No. of seedlings/hill	5	5	0.00	1.00NS
4	Depth of planting, mm	34	33	0.26	6.89NS
5.	Actual field capacity (ha/h)	0.029	0.036	2.88	0.017*
6.	Field efficiency (%)	45.70	56.71	2.86	0.017*

** = 1% level of significance; * = 5% level of significance; NS = Not significant

Comparative Field Performance of Transplanter

During the transplanting, average values of depth of and puddling index were 28 mm and 80%, respectively. The results revealed that, average missing hills and operating speed for manual paddy transplanter were 6/m^2 and 0.35 m/s, respectively and for e-powered paddy transplanter were 3/m^2 and 0.36 m/s, respectively. Average hill-to-hill spacing was found as 150 mm in both transplanters, while the average planting depth was observed as 34 mm in existing transplanter and 33 in developed transplanter. The average seedlings per hill for manual and e-powered paddy transplanter were 5. Actual field capacity of manual and e-powered paddy transplanter were 0.029 ha/h and 0.036 ha/h, respectively and the corresponding field efficiencies were 45.70% and 56.71%. Statistical analyses given in Table 2 showed that the missing hills significantly reduced in case of developed transplanter. It was also observed that the actual field capacity and field efficiency were significantly improved due to reduction in non-productive time.

Cost of Operation

The cost of existing hand cranking type manual paddy transplanter was ₹ 18,150/- and cost of operation for the given field capacity was calculated as ₹ 5,173/- per hectare. The total cost of e-powered paddy transplanter was calculated as ₹ 32,454/- including a set of two batteries (10Ah 24V Li-ion) with charger. The calculated costs of operation per hour and per hectare was ₹ 161/h and ₹ 4467/ha, respectively. Hence, the total saving was ₹ 706/- per hectare. The per cent cost saving with the use of developed e-powered transplanter over existing transplanter was found as 13.6.

Conclusions

An e-powered transplanter was developed for transplanting of root-washed seedlings in puddled field and also comparatively evaluated with existing hand cranking type paddy transplanter for its performance. The used lithium-ion battery was found suitable with total field time of about 4.5 h. Hence, a set of 2 batteries recommended for full-day continues work. The modification made in cam and float was found effective to enhance the transplanter performance. The actual field capacity of the developed transplanter was 0.036 ha/h, which was significantly more than existing transplanter. The transplanter works satisfactory in the field. The calculated cost of e-powered paddy transplanter was ₹32,454/- and operating cost was ₹161/h.

Acknowledgement

The authors are grateful to AICRP on Ergonomics and Safety in Agriculture and Allied Sector, ICAR-CIAE, Bhopal and Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli for facilities provided for the study.

References

1 First advance estimates of area, production & productivity of crops in respect of Maharashtra state for the year 2023-2024. Accessed on 20.12.24 at https://krishi.maharashtra.gov.in/Site/Upload/GR/FIRST%20ADVANCE%20ESTIMATES%202023-24%20Districtwise.pdf

2 Aware V V, Kavitkar C R, Patil M R, Shahare P U, Aware S V & Shirsat N A, Physiological cost and drudgery in paddy transplanting, *Int J Agric Eng*, **10(1)** (2017) 103–108.

3 Shahare P U & Bhat M R, Performance evaluation of semi automatic two row rice transplanter, *Int J Agric Eng*, **4(1)** (2011) 103–105.

4 Guru P K, Chhuneja N K, Dixit A, Tiwari P & Kumar A, Mechanical transplanting of rice in India: Status, technological gaps and future thrust, *Oryza – Int J Rice*, **55(1)** (2018) 100–106, http://dx.doi.org/10.5958/2249-5266.2018.00012.7.

5 Rajaiah P, Mani I, Parray R A, Lande S D, Kumar A & Vergese C, Design and development of precision planter for paddy direct seeding, *J Agric Eng*, **57(4)** (2020) 302–314, https://doi.org/10.52151/jae2020574.1723.

6 Jadhav M L, Nandede B M, Din, M, Jagadale M H, Agrawal K N & Potdar R R, Development of precision pneumatic hill drop planter and fertilizer drill for direct seeded rice: a response surface modelling approach, *Proc Indian Natl Sci Acad* (2025), https://doi.org/10.1007/s43538-025-00430-1.

7 Kavitkar C R, Aware V V & Wandkar S V, Development of hand-cranking type manual paddy transplanter for farm women of Konkan region, *J Agric Eng*, **59(2)** (2022) 137–147, http://dx.doi.org/10.52151/jae2022592.1771.

8 Patil S B, *Design Development and Testing of Power Operated Paddy Transplanter Suitable for Root Washed Seedlings*, Published Ph.D. Thesis, DBSKKV, Dapoli, Maharashtra, India, 2017.

9 Modi R U, Singh A, Ali M, Manes G S & Dixit A K, Status of mat type nursery raising techniques for paddy cultivation in India-A review, *SKUAST J Res*, **24(2)** (2022) 124–132, https://doi.org/10.5958/2349-297X.2022.00023.X.

10 Modi R U, Manes G S, Mahal J S, Dixit A K & Singh M, Design of an innovative tractor-operated seeder for mat type paddy nursery, *J Sci Ind Res*, **81(6)** (2022) 683–694, https://doi.org/jsir.v81i06.57997.

11 Modi R U, Manes G S, Mahal J S, Dixit A K & Singh M, Development and evaluation of tractor operated seeder for mat type paddy nursery under controlled field conditions, *Agric Mech Asia, Africa, and Latin America*, **53(3)** (2022) 54–63.

12 Modi R U, Manes G S, Mahal J S, Dixit A K, Singh A & Mahal A K, Field evaluation of tractor operated seeder for mat type paddy nursery, *Ind J Agric Sci*, **92(9)** (2022) 1066–1070, https://doi.org/10.56093/ijas.v92i9.108615.

13 Patil S B, Shahare P U & Aware V V, Study of different commercially available paddy transplanters in Konkan region of Maharashtra state, *Int J Agric Sci Res*, **6(6)** (2016) 247–252.

14 More R Y, *Development and Performance Evaluation of Two Row Power Operated Paddy Transplanter for Root Washed Seedlings,* Published M. Tech. Thesis, DBSKKV, Dapoli, Maharashtra, India, 2018.

15 Ekka U, Singh S P & Singh M K, Comparative field performance evaluation of different type of Pusa electric power units, *Ind J Agric Sci*, **92(6)** (2022) 747–751, https://doi.org/10.56093/ijas.v92i6.115808.

16 Monpara A M, Kothiya A V & Swarnkar R, Development of bullock drawn battery powered planter, *Agric Res J*, **58(3)** (2021) 539–544, https://doi.org/10.5958/2395-146X.2021.00079.X.

17 Chavda S K, Swarnkar R & Chauhan V J, Design and development of pull type battery operated multi-crop planter for woman farmers in tribal region of Gujarat, *Int J Plant Soil Sci*, **34(22)** (2022) 1084–1096, https://doi.org/10.9734/ijpss/2022/v34i2231472.

18 Jadhav M L, Mohnot P, Jagadale M H & Nandede B M, Optimization of design parameters of pneumatic plug tray seeding mechanism for cabbage seeds, *J Agric Eng*, **60(1)** (2023) 14–23, https://doi.org/10.52151/jae2023601.1793.

19 Singh M K, Singh S P, Singh M K & Ekka U, Battery assisted four-wheel weeder for reducing drudgery of farmers, *Ind J Agric Sci*, **89(9)** (2019) 1434–1438, https://doi.org/10.56093/ijas.v89i9.93483.

20 Kiran U M, Kumar A, Ekka U E, Bana R S & Ramasubramanian V, Ergonomic assessment of walk-behind battery-powered two-wheel weeder, *J Agric Eng*, **19(2)** (2024) 157–168, https://doi.org/10.52151/jae2024612.1842.

21 Kiran I K M, Awal M A & Ali M R, Development and performance evaluation of a battery-operated small-scale reaper, *Agric Eng Int: CIGR J*, **19(2)** (2017) 217–223.

22 Singh S P, Singh M K & Ekka U, Battery-assisted offset rotary cutter for leafy green spinach and coriander, *RASSA J Sci Soc*, **2(3)** (**2020**) 187–192.

23 Sahoo A U and Raheman H, Development of an electric reaper: A clean harvesting machine for cereal crops, *Clean Technol Environ Policy*, **22** (2020) 955–964, https://doi.org/10.1007/s10098-020-01838-7.

24 Redpath D A, McIlveen-Wright D, Kattakayam T, Hewitt N J, Karlowski J & Bardi U, Battery powered electric vehicles charged via solar photovoltaic arrays developed for light agricultural duties in remote hilly areas in the Southern Mediterranean region, *J Cleaner Prod*, **19(17–18)** (2011) 2034–2048, https://doi.org/10.1016/j.jclepro.2011.07.015.

25 Kavitkar C R, *Ergonomic Evaluation and Refinement of Manually Operated Paddy Transplanter for Women Workers of Konkan Region*, Published M. Tech. Thesis, DBSKKV, Dapoli, Maharashtra, India, 2016.

26 BIS, *Test Code for Puddler* (IS: 11531–1985), Bureau of Indian Standards, New Delhi (1985).

27 Behera B K, Varshney B P & Goel A K, Effect of puddling on puddled soil characteristics and performance of self-propelled transplanter in rice crop, *Agric Eng Int: the CIGR Ejournal*, **10** (2009).

28 BIS, Paddy Transplanter — Test Code and Recommendations on Selected Performance Characteristics (IS: 18718–2024), Bureau of Indian Standards, New Delhi (2024).

29 BIS, Guide for estimating cost of farm machinery operation (IS: 9164–1979, re-affirmed 2022), Bureau of Indian Standards, New Delhi (1979).