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e-Powered Multi-purpose two-row seeder for smallholders

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ABSTRACT

Spinach and coriander are cultivated using traditional method by majority of marginal and small landholders. No seed drill is available for sowing of these vegetable crops. The objective of present study was to provide such a seeder that can reduce manual work done by farmers. An attempt was made to develop electric power (e-power) walk behind seeder at ICAR-IARI, New Delhi in year 2015. The major workload was shared by e-power. The unit consisted of a DC geared motor, batteries, power transmission unit, independent seeding units with vertical cell fed metering mechanism, swinging handle and frame. The seeder was tested for spinach, coriander and wheat seeds. Lab study on sticky belt indicated that wheat seed showed better uniformity in distribution followed by spinach and coriander. From field studies, output with e-powered 350W seeder was 1130 m^2/h at a speed of about 2.9 km/h with field efficiency of 90.3% for tested seeds. The average draft requirement of machine was 106.1N. The developed equipment provided 2.5 times more output than manually operated seed drill with reduced drudgery by 2.6 times in terms of muscular force requirement.

Key words: Electric powered multi-purpose seeder, Gender-friendly, Small farm, Vegetable seed sowing

Small landholders cultivate 42% of the operated land and constitute 83% of total landholdings (Mehta *et al.* 2019). Between 1970–71 and 2005–06, there has been a reduction in average farm size from 2.28 ha to 1.21 ha. Share of smallholdings in use of irrigation, fertilizer consumption, high yielding varieties, cropping intensity and output value per ha was better than other category of landholdings but lagged behind in using improved farm machines (Chand *et al.* 2011). Suitable farm equipment as per their need may be one of the solutions to increase utilisation of farm machines for better resource productivity.

Marginal and small landholders utilise their part or whole land for vegetable production such as spinach (*Spinacia oleraceae*) and coriander (*Coriandrum sativum*). The acreage under coriander in the country was 0.6625 million ha (GoI 2017) while area under the spinach crop was 2122 ha (FAO 2016). A study showed that the spinach farming is highly labour intensive and it accounted 35.3% of total expense (Sutradhar 2014). Traditional method of sowing spinach and coriander is prevalent in the country. Onions, carrots, chicory, beets, beans, corn, leek, radish, spinach, sunflowers and various other vegetables can be sown by precision planters or pneumatic seed drills depending on the type of seed discs but these cannot be used for coriander (Rajan 2017 and Singh *et al.* 2004). A French company has made one to seven row, manually operated seeder for vegetables at a cost of ₹ 56720 (709 €) for one row and 711€ for additional rows (ICS 2017). In fact there is no manually operated seeder for sowing spinach and coriander. The manually operated seeder (Vatsa and Singh 1996, Pandey *et al.* 2006, Singh *et al.* 2006, Singh *et al.* 2017) requires intense physical activity in its operation and now-a-days farmers demand such a machine that consumes less power, and has better efficiency with minimal drudgery. There is a vast scope to utilise electric power for mobile operation in agriculture. Hence, in this study an attempt was made to provide suitable seeder with e-power unit to sow vegetable/cereal seeds for small farmers including hill farmers.

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MATERIALS AND METHODS

The study was conducted at ICAR-IARI, New Delhi (28.08°N and 77.12°E, 228.61 m amsl) in 2015–19. The lab experiment was carried out from May to October when mean maximum daily temperature ranged from 32.2°C to 40°C and the mean minimum temperature from 12.2°C to 27.5°C. The field experiment was carried out from November to January.

The following design considerations were taken into account to develop two-row multi-purpose seeder consistent with e-powered unit: (a) option for variable row spacing to sow other similar crops or same crops with different production system, (b) minimum drop height of seed from hopper in soil to have less scattering of seeds, (c) free dispersion of seeds from hopper to furrow opener, (d) higher field capacity with proper seed placement, (e) detachable components with ease in adjustment and fabrication, (f) compatible with electric/solar power source, (g) minimum manpower requirement and (h) better manoeuvrability.

Assessment of power requirement for seeder: It was based on force requirements in operation of manual seed drill, volume of soil worked, weight of machine and a thumb rule.

The pull and push-cum-guide forces were 83 N and 32 N in operation of 10 kg manually operated CIAE modified single row seed drill for cereal crops sowing (Singh *et al.* 2006) at speed of 2.5 km/h. Calculation of power was done as per the standard formula:

Power for pulling the seed drill = Work/ time = 83 N × 1 m × 0.69 s = 57 W

Power for pushing-cum-guiding the seed drill = Work/ time = 32 N × 1 m × 0.69s = 22W

Power required for two-row seeder = (pull + push+ idlepower) + 50% of total power = 79 + 40 + 80= 179W.

(Idle power was taken as per Singh *et al.* 2019).

On the basis of volume of soil to be worked, per meter length was calculated based on number of lugs in drive wheel and its area, and number of rotation in one meter or revolution + furrow opener.

Force calculation per revolution of ground wheel:

[Size of lugs (25×5) × depth (40) × number of lugs (12) + number of furrow opener (2) × its area] × soil resistance (0.005N/mm^2): 300N

Hence, Force required per unit length: 300N /0.628 = 477.7 N force

Power required: 477.7 × 0.69 s = 329.5 W

On the basis of weight of the proposed seeder [40 kg (392.4 N)] and speed of operation of 2.5 km/h).

Power required = 392.4× 0.69s= 270W

Based on thumb rule of weight over drawbar power ratio of 120 kg/kW (0.12 kg/watt drawbar power) at tractive efficiency of 0.82 (Jan and Philip 2006). Considering this also, the power requirement was assessed to 333W for 40 kg e-powered seeder.

Design of seed metering mechanism: Physical properties of seeds were measured using standard methodology for size, sphericity, bulk density and angle of repose to design metering unit including hopper and furrow opener. Seed metering mechanisms are of several types such as Fluted feed type, Internal double run type, Cup feed type, Cell feed mechanism, Brush feed mechanism, Auger feed mechanism, Picker wheel mechanism, and Star wheel mechanism (ICAR 2013). Cell feed mechanism was opted for developing vertical circular seed metering plate. The seeds of spinach, coriander and wheat have bulk density of 538.9, 234.1 and 838.8 kg/m^3, respectively. Correspondingly seed rate per hectare of these crops are 30, 15 and 120 kg. One thousand grain weight of spinach, coriander and wheat seeds indicate the attainable seed rate of these seeds with same metering mechanism due to similar seed to seed and row spacing. The volume of seed hopper of each seeder unit is 1.4l. The seed box of a seed drill was trapezoidal in shape for free flowing of seeds. Mild steel sheet was used to fabricate hoppers. This metering system is directly attached with ground wheel of 211 mm diameter which was kept for speed ratio of 1:1. Number of cells in the roller was calculated as:

$$n = \frac{\pi D}{i.x}$$

where n, number of cells on roller; D, ground wheel diameter (21.1cm); I,gear ratio (1:1); x, required seed to seed spacing (5 cm). n was 13

The peripheral velocity of this cell roller is kept low i.e. 7.385 m/ min as compared to 16.5 m/min taken normally for conventional seeder for cereal (Sharma and Mukesh 2013). The size of cell was kept 8 mm length, 7 mm width and 5 mm depth slightly slanted towards bottom making area of 5 mm^2.

Diameter of seed plate was determined by the following equation:

$$d_r = \frac{V_r}{\pi N_f}$$

where d_r, diameter of circular seed plate (cm); V_r, peripheral velocity of plate (738.5 cm/min); N_r, RPM of plate (49); thus d_r was 48 mm.

Computer aided design of cell type metering roller was made for fabrication on additive type 3D printer. Polylactic acid (PLA) material was used for its fabrication. The tensile strength and bulk density of this material is 37 MPa and 1.3 g/cc, respectively. The density of fabricated material was kept to 50% due to fewer loads on metering roller. Finally, computer aided design of a seeder was made for fabrication in the research workshop.

Seed metering unit: Independent seeding unit was used due to the requirements of seeding in varying row which was mounted on square shaft with nut-bolt on e-powered unit. Variation in row spacing with independent seeding unit can be obtained from 215 to 450 mm. Two-three cells are filled at a time in hopper occupying 60°(30+30)° angle from vertical and seeds start falling in boot of furrow opener at from 90° to 210° rotation. Idle rotation of cell fed metering system is 210° to 330°. Furrow opener in each unit was mounted directly beneath the hopper which helped in reducing seed scattering while dropping and placing seeds in soil. The e-powered multi-purpose two-row seeder was fabricated as per earlier developed concept at ICAR-IARI, New Delhi (Singh *et al.* 2016, 2019). View of developed seeder and its technical specifications are given in Fig 1 and Table 1.

Performance Evaluation

Laboratory test: Sticky Belt Method was used to ensure the uniformity in seed metering. As per BIS code

Fig 1 Attached developed seeder on e-powered unit

Table 1 Technical dimensions of e-powered two row Seeder

Particulars	Dimensions
Weight (kg)	40.0
Overall dimension (l × w × h) (mm)	800 × 660 × 760
Number of hopper	2
Ground wheel number and type	2 with 12 spikes
Diameter of ground wheel (with lugs) (mm)	210
Number of cells on metering roller	13
Diameter of roller, mm	48
Thickness of roller, mm	16
Number of furrow opener and type	2 & inverted T
Size of furrow opener (l × w × h) (mm)	27 × 100 ×160
Depth adjustment through furrow opener (mm)	40
Hopper shape	Trapezium
Size of square shaft for mounting seeding unit (mm)	500 × 15 × 15
Row spacing adjustment (mm)	215 to 450
Handle	Swinging
Power transmission ratio	5.1:1
Drive wheel of e-power unit	2
Source of electric energy	Battery (24V, 12Ah)
DC geared motor (W)	250 / 350

[IS 6316-1993], seeding unit was mounted on a 3 m long belt to travel under the action of furrow wheel in such a way that the speed of the belt is equal to the running speed of the drill by providing rotation to metering unit through a wheel. Wheel mounted on seeder is fixed in such a way that it tightly grips on belt for generating frictional force. Four speeds of travel were selected i.e. 1.45, 1.85, 1.98 and 2.64 km/h for assessing the uniformity of seed metering. The speed was maintained by changing the pulley on motor shaft attached to sticky belt. A sticky layer of grease was applied at a width of 100 mm to the belt to facilitate proper embedding of seeds without any displacement. The lab experiment was conducted on the set up for spinach, coriander and wheat seeds. Analysis was made for seed distribution, seed scattering and visual seed damage. The seed distribution efficiency and scattering of seeds at different speed are shown in Fig 2.

Field evaluation: The developed e-powered two row seeder was tested in the field of ICAR-IARI, New Delhi. The machine was operated by a worker for sowing the selected seeds (spinach, coriander and wheat) with two power range of DC geared motors (250 W and 350 W) to assess the optimum power for its manoeuvrability. Soil parameters (bulk density and moisture content), field parameters (speed of operation, turning time, power consumption and operator feedback) and draft requirement were measured as per standard procedure. Seed germination was counted for sown crops with the machine as well as manually with a seed drill for wheat. The recorded parameters are given in Table 2 and Table 3.

RESULTS AND DISCUSSION

Seed distribution, scattering and damage: Comprehensive laboratory study on seed uniformity clearly showed (Fig 2) that wheat seeds showed highest uniformity (92–95%) in distribution followed by spinach (81–93%) and coriander

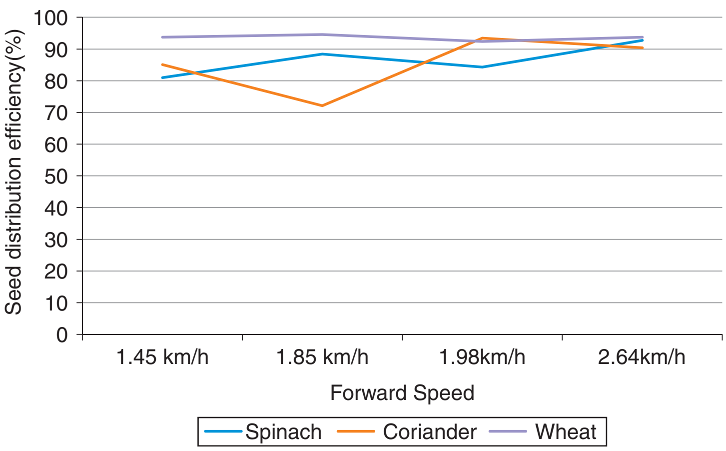

Fig 2 Seed distribution efficiency of selected seeds at different speeds.

Table 2 Data on operation of e-powered two-row seeder for sowing seeds in variable row spacing

Particulars	Dimensions	
Power of motor (W)	250	
Number of operators	1	
Soil moisture content (% db)	12.30 (%)	
Idle power consumption (W)	50–60	
Power consumption during operation (W)	100–175	
Draft requirement in its operation (N)	106.1±37.3	
Seeding depth (mm)	25–35	
Speed of operation (km/h)	2.16	
Turning loss/turn (s)	5	
Seed rate (kg/ha)	Spinach	Coriander
	30	12
Area covered (ha/h)		
215 mm spacing	0.0812	
300 mm spacing	0.1134	
Field efficiency (%)	87.5	
Average plant population per metre length	72± 21	63 ± 20

Table 3 Data on operation of e-powered two-row seeder for sowing seeds

Particulars	Dimensions		
Power of motor (W)		350	
Number of operator		1	
Soil moisture content (% db)		13.0	
Bulk density, g/cc (wb)		1.031	
Idle power consumption (W)		60–70	
Power consumption during operation (W)		105–196	
Seeding depth (mm)		20–30	
Number of rows		2	
Row spacing (mm)		215	
Average turning loss per turn (s)		4	
	Spinach	*Coriander*	*Wheat*
Seed rate (kg/ha)	30	15	120
Total number of seeds per m^2	260	344 (split)	292
Average speed of operation (km/h)	2.91	2.84	2.91
Area covered (ha/h)	0.113	0.1102	0.113
Field efficiency (%)		90.3	
Average plant population/m length	52 (52–70)	82 (48–135)	74 (54–92)
Average plant population/m length with manual seed drill	-	-	65 (36–101)

(72–93%) at all four speeds. In case of spinach, variation was due to bulk density (538.9 kg/m), varying shape and size. While in case of coriander, large variation was observed which may be due to lesser bulk density (290.6 kg/m) and split seeds. No visual damage was observed for tested seeds at any speed. The seed scattering was also assessed on sticky belt. It is observed from image analysis that some seeds of spinach, coriander and wheat were away from centre line at 2.64 km/h speed. The scattering was due to physical properties of seeds and development of centrifugal force in rotation of seed metering unit at high speed.

Performance evaluation: The e-powered two-row seeder was tested with 250 W and 350 W geared DC motor in field during year 2017–18 and 2018–19, respectively. In year 2017–18, performance of seeder was assessed for sowing of spinach and coriander in different row spacings i.e. 215 mm and 300 mm (Table 2). The speed of operation was 2.16 km/h. The power requirement in its operation varied from 100 to 175 W of which 40 W was idle power of e-powered seeding unit. Number of plants per metre length was 72 and 63 for spinach and coriander, respectively. Correspondingly, output obtained was 812 and 1134 m^2/h at 87.5% field efficiency for row spacing of 215 mm and 300 mm.

In year 2018, the e-powered seeder with 350W DC geared motor was field tested for sowing of spinach, coriander and wheat seeds at row spacing of 215 mm. The average plant population per metre was 52, 82 and 74 for spinach, coriander and wheat, respectively (Table 3). Output with the seeder was 1130 m^2/h at speed of about 2.9 km/h with 90.3% field efficiency. The current drawn from battery was in the range of 4–7 ampere. Higher ampere current was needed when there was more sinking of spiked ground wheel of seeder and drive wheel of power unit in pulverised seed bed. The current drawl from battery suggests the working for 2 h with the attached 24 V 12 Ah batteries. An additional pair of battery may serve the purpose of machine to work for about 4 h at a stretch. Discharged batteries can be charged up to 90% within available 3 h time. Thus, the machine can be operated for 8 h by charging the discharged batteries.

Manually operated sowing equipment was operated by two operators (one for guiding and another for pulling the seed drill) and output (Vatsa and Singh 1996, Pandey *et al.* 2006, Singh *et al.* 2006, Singh *et al.* 2017) obtained for wheat sowing was in the range of 350 to 460 m^2/h. After comparing with developed e-powered two-row seeder, it was found that this equipment has 2.5 times more output than manually operated equipment. Other advantage with the developed e-powered two row seeder is elimination of an operator with reduced drudgery by 2.6 times in terms of force. Moreover this equipment can be operated by an operator (male or female) for 8 h in a day while manual operated seed drill cannot be operated in a day for about 5 h due to requirement of rest pause (Singh *et al.* 2006) with manually operated one-row seed drill as calculated by the formula (Phesant 1991).

Power requirement assessment: Power requirement was assessed from 179 W to 333 W by 4 different ways at walking speed of 2.5 km/h. The developed e-powered seeder was operated in field using 250 W and 350 W geared DC motors (Table 2 & 3). It is found that seeder with 250 W motor was able to provide walking speed of 2.16 km/h while the average draft requirement of machine without e-power assistance was found to be 106.1± 37.3N. Hence, operator needs to put in some physical work during operation with 250 W motor. In case of 350 W DC geared motor, operator does not need to use physical power in operation of seeder and speed of operation was also not any factor. The influencing factors such as soil condition, equipment, tool geometry, mechanical power loss and human factors were observed for achieving intended output with mechanical equipment/ tool (Singh *et al.* 2018). Field testing suggests using either thumb rule of power estimation or volume of soil worked method for design/development of an equipment.

An e-powered multi-purpose two-row seeder was developed with independent seeding unit for operation by an operator in walk-behind mode to sow spinach, coriander and wheat in rows. The developed equipment provided 2.5 times more output than manually operated seed drill with reduced drudgery by 2.6 times in terms of muscular force requirement. Its field efficiency was 90.3%. The average draft requirement of machine without e-power assistance was 106.1 N. e-Powered unit with 350 W DC geared motor is optimum for field operation of two-row seeder with operator as compared to 250 W e-powered seeding unit. The developed e-powered seeder is suitable for smallholder and hill farmers in India due to its better manoeuvrability.

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