



Design and Fabrication of a Low-Cost Multipurpose Agricultural Robot for Seeding, Weeding and Spraying

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Abstract—Small and marginal farmers carry out sowing, weeding and

I. INTRODUCTION

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Agriculture still employs a large share of India's workforce, yet the land it works on is highly fragmented. According to the Agriculture Census 2015–16, small and marginal holdings (below 2 ha) make up about 86% of all operational holdings, and the average holding is close to 1.08 ha [1]. On plots of this size a tractor is rarely economical, so sowing, weeding and spraying are done by hand or with bullock-drawn tools. Three problems follow. Labour is increasingly hard to find during peak season, its cost eats directly into already thin margins, and manual spraying exposes the worker to pesticides for hours at a time.

Field robotics offers a way out, and the research community has shown that small autonomous or semi-autonomous machines can take over many repetitive field operations [2]–[4]. The difficulty for a smallholder is that most commercial agricultural robots are either built for large farms or dedicated to a single job. Buying one machine for seeding and another for spraying defeats the purpose of a low-cost solution.

This work addresses that gap by combining the three most labour-intensive in-season operations—seeding, inter-row weeding and spraying—on a single small platform that one person can carry and operate. The contributions of the paper are as follows:

- 1) a compact mechanical layout that places a seed hopper, a rotary weeder and a spray boom on one chassis without the tools interfering with each other;
- 2) a first-principles sizing of the drive motors, seed-metering speed, spray rate and battery capacity, so that the design can be adapted to other crops and field conditions;
- 3) a simple two-mode control scheme (manual through an Android application and semi-autonomous row following with obstacle stop) built from widely available, inexpensive parts.

The rest of the paper is organised as follows. Section II reviews related work. Section III states the problem and objectives. Section IV describes the design of each subsystem, and Section V covers fabrication and cost. Section VI sets out the evaluation procedure, Section VII discusses advantages and limitations, and Section VIII concludes the paper.

spraying largely by hand, which is slow, costly when labour is scarce, and puts the operator in direct contact with agrochemicals. Tractor-mounted implements solve part of the problem but are too large and too expensive for fragmented holdings, and most low-cost field robots reported so far handle only one task. This paper presents the design and fabrication of a compact, battery-powered robot that carries a seed-metering unit, a rotary weeder and a two-nozzle sprayer on one mild-steel chassis. The drive is sized from a rolling-resistance and gradient analysis, which gives a required torque of about 10.2 kg·cm per wheel on a 5° slope; 12 V geared motors rated at no less than 15.3 kg·cm were therefore specified. An Arduino Mega 2560 coordinates the tools and accepts commands from an Android phone over Bluetooth, and two ultrasonic sensors stop the robot when an obstacle comes within 30 cm. At a working speed of 0.3 m/s the design delivers a theoretical field capacity of 0.054 ha/h, 20 cm seed spacing with a six-cell roller at 15 rpm, and an estimated 2.8 h of operation from a 12 V, 18 Ah battery. The indicative component cost is roughly INR 15,000, which places the machine within reach of small farms, nurseries and greenhouses.

Index Terms—agricultural robot, multipurpose farm machinery, seed metering, mechanical weeding, pesticide spraying, Arduino, Bluetooth control, small-scale farming.



II. RELATED WORK

Durmuş *et al.* [5] described AGROBOT, a general-purpose autonomous mobile platform intended to carry different agricultural payloads, and made the case that a common base with interchangeable tools is more practical than a dedicated machine for each task. At the student-project scale, Amrita Sneha *et al.* [6] built an AVR-based robot for ploughing, seed dispensing and pesticide spraying that used ultrasonic sensing for navigation. Balaji *et al.* [7] reported a smartphone-operated robot that digs, levels the soil and sprays water, powered by a battery charged from a solar panel.

Ranjitha *et al.* [8] combined seed sowing, grass cutting and pesticide spraying on a solar-powered robot controlled through a Bluetooth Android application. Chandana *et al.* [9] focused on automatic ploughing and seeding together with plant health monitoring, while Hymavathi *et al.* [10] designed a solar-powered vehicle that tills, sows, sprays fertiliser and sprinkles water as it moves along crop lines. Thaitanun *et al.* [11] took a platform approach, developing a multipurpose base to which different agricultural modules can be attached. Broader reviews [3], [12], [13] identify cost, robustness on uneven soil and reliable row navigation as the main barriers to adoption.

Table I summarises these systems. Two observations shaped the present design. First, most prototypes achieve multi-functionality by stacking tools without sizing the drive or power system for the combined load, which leads to stalling and short run times in soil. Second, very few report the design equations behind their choices, which makes them hard to reproduce. The design in Section IV tries to address both points.

TABLE I
SUMMARY OF RELATED MULTIPURPOSE AGRICULTURAL ROBOTS

Ref.	Operations	Control / power	Remarks
[5]	General-purpose carrier for field tasks	Autonomous	Modular platform
[6]	Ploughing, seed dispensing, spraying	AVR MCU, ultrasonic	Row navigation
[7]	Digging, levelling, water spraying	Smartphone; battery + solar	No weeding
[8]	Seed sowing, grass cutting, spraying	Bluetooth app; solar	Closest to this work
[9]	Ploughing, seeding, plant health	Automatic; sensors	Monitoring focus
[10]	Tilling, sowing, fertiliser, water	Autonomous; solar	Line following
This work	Seeding, weeding, spraying	Bluetooth + semi-auto; 12 V battery	Sized drive and power

III. PROBLEM STATEMENT AND OBJECTIVES

Manual sowing, weeding and spraying are labour-intensive and slow, and labour shortages at peak season delay these operations and raise cultivation costs. Farmers spraying by hand are directly exposed to pesticides and fertilisers. Existing machines are mostly single-function, bulky and expensive, which puts them out of reach of small and marginal farmers. What is needed is a compact, affordable machine that can perform several of these tasks with minimal human intervention.

The objectives of the project were therefore: (a) to design and fabricate a robot that performs seeding, weeding and spraying on a single platform; (b) to sow seeds at a uniform, adjustable spacing and depth; (c) to remove inter-row weeds mechanically and spray pesticide or fertiliser without the operator standing in the spray; (d) to provide remote-controlled

and semi-autonomous operation; and (e) to keep the total cost low enough for small and medium-scale farms.

IV. SYSTEM DESIGN

A. Overall Architecture

Fig. 1 shows the functional block diagram. An Arduino Mega 2560 acts as the central controller. Its inputs are a Bluetooth link (HC-05 module paired with an Android application), two front-facing HC-SR04 ultrasonic sensors and a wheel encoder used to estimate ground speed. Its outputs drive four geared DC motors through two BTS7960 H-bridge modules, a seed-metering motor through an L298N driver, and, through relays, the weeder motor and the spray pump. A 12 V sealed lead-acid (SLA) battery supplies the motors directly, and a buck converter provides 5 V for the logic.

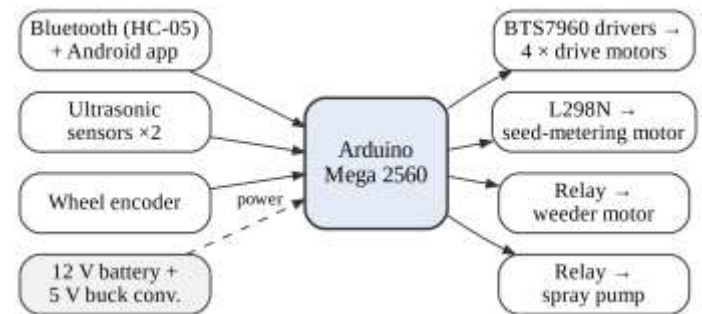


Fig. 1. Functional block diagram of the multipurpose agricultural robot.

B. Mechanical Layout

The chassis is a 600 mm × 450 mm frame welded from 25 mm mild-steel square tube, which is cheap, easy to fabricate in a college workshop and stiff enough to carry the payload. Fig. 2 shows the arrangement. The heaviest items—the 10 L spray tank and the battery—sit low and towards the rear axle, while the seed hopper sits in the middle so that the seed tube drops between the axles, where the height of the furrow opener is least affected by pitching of the frame. The weeder is mounted ahead of the front axle and the spray boom at the very front, so that the weeds are disturbed before the spray reaches the row. Four 150 mm diameter rubber wheels with a ground clearance of about 150 mm allow the robot to straddle young row crops. The main specifications are listed in Table II.

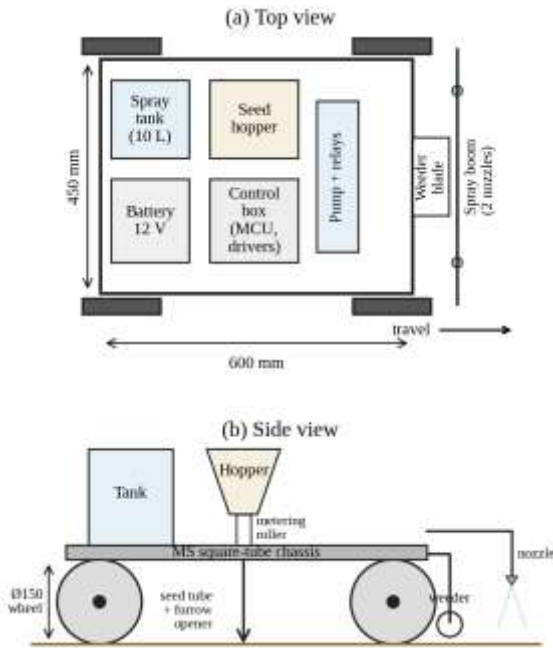


Fig. 2. Schematic layout of the robot: (a) top view showing placement of the tank, hopper, battery and control box; (b) side view showing the seed-metering path, weeder and spray nozzle.

TABLE II
MAIN DESIGN SPECIFICATIONS

Parameter	Value
Overall chassis (L × W)	600 mm × 450 mm
Chassis material	25 mm MS square tube
Estimated gross mass (loaded)	≈ 25 kg
Wheels	4 × Ø150 mm, rubber
Drive	4 × 12 V geared DC, 60 rpm, ≥ 15.3 kg·cm
Working speed	0.3 m/s (1.08 km/h)
Controller	Arduino Mega 2560
Communication	HC-05 Bluetooth, Android app
Obstacle sensing	2 × HC-SR04, stop at 30 cm
Seed metering	6-cell roller, DC motor
Weeder	Rotary blade, 12 V DC motor
Sprayer	12 V diaphragm pump, 2 nozzles, 10 L tank
Battery	12 V, 18 Ah SLA

C. Drive Motor Sizing

The traction force F that the wheels must supply is the sum of rolling resistance, the gradient component of weight and the force needed to accelerate the robot [14]:

$$F = C_{rr}mg + mg \sin \theta + ma \quad (1)$$

where $m = 25$ kg is the loaded mass, C_{rr} is the rolling-resistance coefficient, θ is the field slope and a is the acceleration. For wheels on loose, tilled soil a coefficient of 0.12 was assumed, with a design slope of 5° and $a = 0.1$ m/s². These values give rolling, gradient and inertial components of 29.4 N, 21.4 N and 2.5 N respectively, for a total of $F \approx 53.3$ N. With a wheel radius $r = 0.075$ m and four driven wheels sharing the load equally, the torque per wheel is

$$T_w = Fr / 4 \approx 1.0 \text{ N} \cdot \text{m} \approx 10.2 \text{ kg} \cdot \text{cm} \quad (2)$$

A safety factor of 1.5 was applied to cover wheel slip, uneven load sharing and soft patches, giving a required rating of 15.3 kg·cm per motor. The wheel speed needed for the working speed $v = 0.3$ m/s is

$$N = 60v / (2\pi r) \approx 38 \text{ rpm} \quad (3)$$

so 60 rpm motors were chosen and run below full speed using PWM, which leaves headroom for faster headland turns. The mechanical output at the design point is

$$P = T_w \omega \times 4 = 1.0 \times 4.0 \times 4 \approx 16 \text{ W} \quad (4)$$

Fig. 3 shows how the torque requirement changes with slope and soil condition. The selected rating covers slopes up to about 11° on the design soil and about 9° on very soft ground ($C_{rr} = 0.16$), which is adequate for the level fields typical of the region.

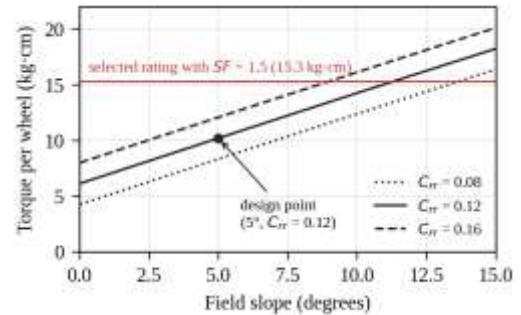


Fig. 3. Required torque per wheel as a function of field slope for three rolling-resistance coefficients ($m = 25$ kg, $r = 75$ mm, $a = 0.1$ m/s²).

D. Seeding Unit

Seeds fall from a sheet-metal hopper into a fluted roller with six cells on its circumference; each cell picks up one seed (or a small group, for fine seed) and releases it into a tube that ends just behind a small tine-type furrow opener. A short drag chain behind the tube covers the seed with soil. Because the roller is driven by its own motor rather than by a ground wheel, the seed spacing S depends on the forward speed, the number of cells n and the roller speed N_m :

$$S = 60v / (n N_m) \quad (5)$$

For maize or cotton at a 20 cm in-row spacing and $v = 0.3$ m/s, (5) gives $N_m = 15$ rpm. The controller reads the wheel encoder and adjusts the roller speed so that the spacing stays constant if the robot slows down in heavy soil. Fig. 4 shows the spacing obtained for different speeds; swapping the roller for one with a different cell size adapts the unit to other seeds.

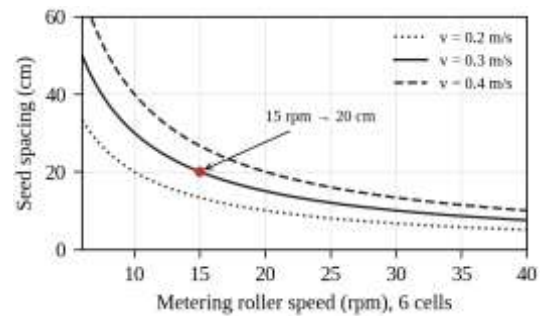


Fig. 4. Seed spacing versus metering-roller speed for a six-cell roller at three forward speeds. The design point (0.3 m/s, 15 rpm) gives 20 cm spacing.

E. Weeding Unit

Weeds between rows are removed mechanically by a rotary blade assembly mounted on a hinged arm ahead of the front axle. A 12 V DC motor drives the blades, and the arm is spring-loaded so that the blades follow the ground and ride over stones instead of stalling the motor. Removing weeds mechanically avoids an additional herbicide application, which reduces both chemical cost and the operator's exposure. The working depth is set with a slotted bracket to between 20 mm and 40 mm, which is enough to uproot young weeds without disturbing the crop roots.



F. Spraying Unit

A 12 V diaphragm pump draws liquid from the 10 L tank and delivers it to two flat-fan nozzles on a boom 0.5 m wide. The application rate R (L/ha) follows the standard sprayer calibration relation

$$R = 600 q / (v_k w) \quad (6)$$

where q is the total nozzle discharge in L/min, v_k is the forward speed in km/h and w is the swath width in m. With $q = 0.6$ L/min, $v_k = 1.08$ km/h and $w = 0.5$ m, $R \approx 667$ L/ha, which is in the range normally used for knapsack spraying of field crops. One tank therefore covers about 150 m² before refilling. The rate can be reduced by fitting lower-flow nozzles or by switching the pump in pulses from the controller. Because the operator controls the robot from the edge of the field, nobody walks through the spray.

G. Electrical System and Power Budget

Table III lists the estimated average current drawn by each load at 12 V, taking into account the fraction of time each tool is actually running during a typical pass. The drive motors dominate, as Fig. 5 shows; their electrical draw (about 38 W) is higher than the 16 W mechanical output of (4) because small geared motors are only about 40–50% efficient under load.

TABLE III
ESTIMATED POWER BUDGET AT 12 V

Load	Rated current	Duty cycle	Average current
Drive motors (4)	4×0.8 A	100%	3.20 A
Weeder motor	1.5 A	30%	0.45 A
Spray pump	1.0 A	40%	0.40 A
Electronics	0.3 A	100%	0.30 A
Seed-metering motor	0.3 A	50%	0.15 A
Total			4.50 A

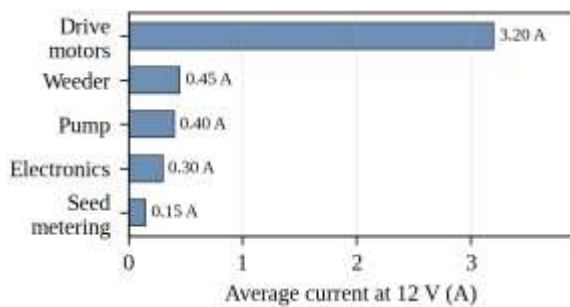


Fig. 5. Breakdown of the estimated average current drawn from the 12 V battery.

For a battery of capacity $C = 18$ Ah and a usable depth of discharge $D = 0.7$ (to preserve SLA battery life), the expected run time is

$$t = CD / I_{avg} = 18 \times 0.7 / 4.5 \approx 2.8 \text{ h} \quad (7)$$

A 30 A blade fuse protects the main supply line, and the logic supply is isolated from motor noise through the buck converter and separate ground returns.

H. Control Software

The firmware is written in the Arduino environment and structured as a simple state machine, shown in Fig. 6. After start-up the controller waits for a mode command from the phone. In manual mode each button in the application maps to a drive command (forward, reverse, left, right, stop) or to a tool on/off command. In semi-autonomous mode the robot drives forward along the row at the set speed with the selected tools running, and the operator only intervenes at the end of a row to turn it into the next one. In both modes the ultrasonic sensors

are polled continuously; if either reports an object closer than 30 cm, the drive motors stop immediately and the application alerts the operator. All actuators are also switched off if the Bluetooth link is lost for more than one second, so a dropped connection cannot leave the robot running unattended.

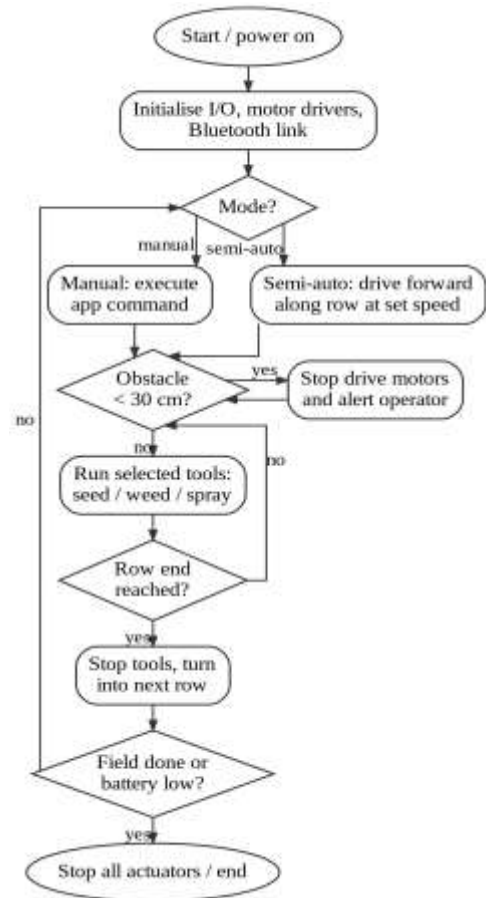


Fig. 6. Flowchart of the control program showing manual and semi-autonomous modes, the obstacle-stop loop and end-of-row handling.

V. FABRICATION AND COST

Fabrication was carried out in the college workshop with ordinary tools. The chassis tubes were cut, welded and drilled for the axle blocks, after which the motors were fixed to the frame with L-brackets and the wheels coupled directly to the motor shafts. The hopper was folded from 0.8 mm galvanised sheet and the metering roller turned from nylon rod with the cells milled into its surface. The weeder arm, spray boom and tank cradle were then bolted in place, the control box was wired, and the firmware was loaded and checked on the bench before the first field trial.

Table IV gives an indicative bill of materials based on typical Indian retail prices for these parts. The total of about INR 15,000 is a small fraction of the cost of even a basic tractor-mounted seed drill or boom sprayer.

TABLE IV
INDICATIVE BILL OF MATERIALS

Item	Qty	Approx. cost (INR)
MS square tube, sheet, fasteners	—	2,500
12 V 60 rpm geared DC motors	4	2,400
Wheels, Ø150 mm	4	1,200
12 V 18 Ah SLA battery	1	2,500
Arduino Mega 2560	1	900
BTS7960 drivers / L298N	2 / 1	1,100



Item	Qty	Approx. cost (INR)
HC-05, HC-SR04 (2), relays, buck converter	—	700
Weeder motor and blades	1	800
Pump, tank, nozzles, tubing	—	1,200
Hopper, metering roller, motor	—	900
Wiring, fuse, switches, misc.	—	800
Total		≈ 15,000

VI. PERFORMANCE EVALUATION

The prototype is to be evaluated on a prepared plot of tilled soil using the procedure below, and the design values derived in Section IV serve as the reference against which the measurements are compared (Table V).

Forward speed and field capacity: the time taken to cover a marked 20 m run is recorded at the set PWM level, and the theoretical field capacity is calculated as

$$FC = wv \times 0.36 \text{ (ha/h)} \quad (8)$$

which gives 0.054 ha/h for $w = 0.5$ m and $v = 0.3$ m/s. The effective field capacity is obtained by dividing the area covered by the total time including turns and refilling. **Seed spacing:** the distances between successive seeds are measured along a 5 m row, and the mean and coefficient of variation are reported. **Spray rate:** the nozzle discharge is collected in a measuring jar for one minute and the rate is computed using (6). **Obstacle stop:** a board is placed in the robot's path and the distance at which it stops is measured. **Run time:** the robot is operated in semi-autonomous mode from full charge until the low-voltage cut-off.

TABLE V
DESIGN TARGETS AND MEASURED PERFORMANCE

Parameter	Design value	Measured
Forward speed	0.30 m/s	—
Theoretical field capacity	0.054 ha/h	—
Effective field capacity	—	—
Mean seed spacing	20 cm	—
Spray discharge	0.6 L/min	—
Application rate	≈ 667 L/ha	—
Obstacle stop distance	30 cm	—
Battery run time	≈ 2.8 h	—

VII. DISCUSSION

The main advantage of the design is that one machine does the work of three. A farmer who would otherwise buy or hire a seed drill, a weeder and a sprayer needs only one battery, one controller and one chassis, and the tools can be switched on independently as the crop moves from sowing to the growing stage. Operating the robot from the field boundary keeps the farmer out of the spray, and the motor-driven metering unit holds the seed spacing even when the forward speed changes—something ground-wheel-driven planters cannot do when the wheel slips.

The design also has clear limitations. Battery capacity restricts continuous operation to under three hours, which is enough for a small plot but not for a full day in the field. Small rubber wheels lose traction in wet or sticky soil, and the ultrasonic sensors cannot distinguish between a genuine obstacle and tall crop foliage, so the robot is best suited to young crops. Finally, although the robot is cheap compared

with commercial machinery, its initial cost is still higher than that of basic hand tools, so it is most attractive where labour is scarce or where it can be shared between several farmers.

The robot is suited to seed sowing in row crops such as wheat, maize and vegetables, inter-row weeding, and spraying of pesticides, fertilisers and herbicides. Its small footprint also makes it useful in nurseries and greenhouses, where large machines cannot enter.

VIII. CONCLUSION AND FUTURE SCOPE

A compact, low-cost robot that integrates seeding, mechanical weeding and spraying on a single chassis has been designed and fabricated for small and medium-scale farms. The drive, seeding, spraying and power subsystems were sized from first principles, leading to 15.3 kg·cm drive motors, a six-cell metering roller at 15 rpm for 20 cm spacing, an application rate of about 667 L/ha and an estimated run time of 2.8 h at a working speed of 0.3 m/s. Bluetooth control with an obstacle stop keeps the operator away from the machine and from the chemicals it sprays, and the indicative cost of about INR 15,000 keeps it within the reach of smallholders.

Future work will focus on GPS- or vision-based row following for fully autonomous operation, IoT-based remote monitoring of battery state and tank level, and a solar panel on the canopy to extend the working time in the field.

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