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DEIGN AND DEVELOPMENT OF AUTOMATED INTER AND INTRA ROW WEEDER CUM SPRAYER PRECISION FARMING

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ABSTRACT

Weed control is most important part in agriculture. It's affected the crop plant broththought out of its life and also problem creatinine in harvesting operation as well as decrease yield quality. If growth of weeds is not manage at a initial time, its results considerable reduced the crop yield. Weeding is most important operation, at perfect timely. Manual weeding is generally costly and timely operation. However, mechanical weed control is one of the best solution. But specially, the main challenge to both researcher and innovative farmers is the properly control of the intra-row weeds. Develop a mini tractor operated inter and intra row weeder cum sprayer for precision farming. The machine development (fabrication) work, research work and testing were done at ASPEE, Agricultural Research and Development Foundation, TANSA Farm, Mumbai. Developed machine performed in inter row weeding by tractor PTO powered rotary weeder and intra row weeding by automated weedicide spraying. The developed weeder machine was tested and evaluated in three crops like Brinjal, castor and cotton. The overall operation by the automated inter and intra weeder was found satisfactory with almost no damage.

***Key words*:** Weeder, Intra row Weeder, Precision weeder, Development weeder.

Introduction

The Indian economy depends on rural areas income and this income surce of rural area manily based on agriculture. Agriculture has gives fundamental support to the Indian economy since independence. Almost half of India's population, 115.5 million agricultural families are directly or indirectly depends on agriculture and their related activities. India has covers almost 328.7 million hectares, or 2.4 % of the world's total land area. But only 159.7 million ha land is available for agricultural purposes. It has contributed nearly 18 % of the country's GDP (Jakasania, 2019). India has huge amount of agriculture land area, so massive resides are produced here (Makavana *et al*., 2018). India ranks second worldwide in horticulture produces. The scenario of horticultural crops in India has become very encouraging (Agravta *et al*., 2018). The demand for petroleum products has expanded because of the world's rising industrialization and motorization in recent years. The world's population uses more petroleum than any other single energy source, including natural gas, coal, nuclear energy, and renewable energy sources (Gajera *et al*., 2024). Weeds are an unwanted plant which is grow with in any crops. It is nesseccory to timely control of weeds. Farmers have been using manual device for this operation, they were time consuming, laborious as well as boring, very tedious and costly also (Balas *et al*., 2022A). There are several constrains in Indian agriculture such as climate change, insects and pests but, weeds are one of the major reasons for declining the yield per unit area. Weeds grow far more quickly than crops do, and if they are not controlled and maintained, they may take over the entire field (Balas *et al*., 2022C). Weeds are reduce to agricultural production, crop yield and quality and also increases in harvest costs (Balas *et al*., 2022B). There are several contains in Indian agriculture such as climate change, insects and pests but, weeds are one of the major reasons for declining the yield per unit area. However, thus in order to achieve a higher yield, improved agricultural practices of weed management needs to be taken up (Chauhan and Srivastava, 2002). Tractor and tractor-based technology have played an crucial role in improving energy efficiency and reducing drudgery while executing agricultural activities, among other technologies. Now a day most of the operations in agriculture are being performed by machines. This reduces the human efforts which have been the principal motivating force in mechanization (Chavda *et al*., 2022).

Agricultural mechanisation entails the use of various power sources as well as improved farm tools and equipment in order to reduce human and animal drudgery, improve cropping intensity, precision, and timeliness of crop input utilisation, and reduce losses at various stages of crop production (Agravta *et al*., 2023). Mechanization attempts precision and timeliness which are importantly known to address drought like situations particularly in agriculture. Overall, though importance of mechanization is well understood the pace in mechanization is still low (Balas *et al*. 2022).

Methodology

Development of Major Components of Automated Inter and Intra Row Weeder

Development of automated inter and intra row weeder for field crops. The basic emphasis was given on simplicity and minimum cost of fabrication. The different parts of machine were fabricated by different sized square sections, angle bar, flat and MS sheet. The frame was meant for holding different components of automated inter and intra weeder. That may be subjected to bending, tension, and vibrations. The main frame is meant for holding different components, which may be subjected to bending, tension, and vibrations (Balas *et al*., 2018A).

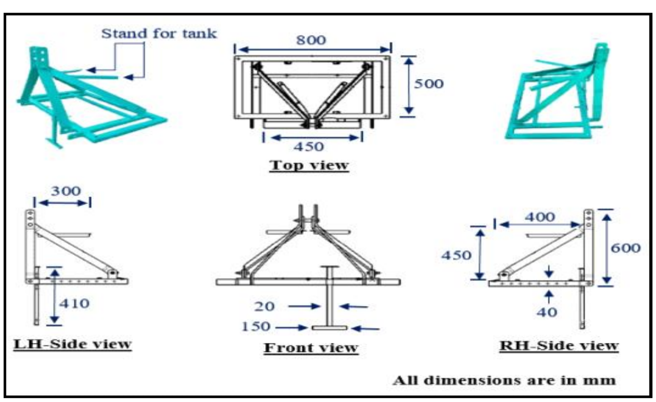

Fig. 1: Detailed Drawing of Main Frame.

This rectangular frame used as a main frame for accommodating all components of developed machine. Mild steel square pipe of 40 mm outer dimension with 5 mm thickness available in market was considered for fabrication. The main frame was fabricated using 40×40×5 mm square hollow pipe as per standard dimensions given in BIS code IS4468 (Part-I) 1997 for category-1.

Mast-Hitch

A standard 3-point mast-hitch was fabricated with mild steel flats (80×7 mm) and fitted to the main frame. For hitch, two mild steel flats (80×7 mm, Length 750 mm) were marked first 100 mm and second 200 mm. The flats were bent by holding in a fixer using hydraulic press at the marked points to obtain 120° external angle at first marking and 120° internal angle at the second marking position (BIS code IS4468 (Part-I) 1997 for category-1).

For mast, two mild steel flats (80×7 mm, Length 650 mm) were marked first 100 mm and second 150 mm from the respective ends. The flats were bent by holding in a fixer using hydraulic press at the marked points to obtain 120° external angle at first marking and 120° internal angle at the second marking position. One end of flats were joined each other by nut and bolt (Fig. 2). Another ends were joined to frame by arc-welding.

Rotary Blade Unit

In rotary weeder, blades were attached to a flange mounted on a rotating shaft usually by pin or nuts & bolts. Commonly three types of blades L-shaped blades, C-shaped blades and J-shaped blades were used in weeder. The C-shaped blades have greater curvature. They were recommended for better performance in heavy and wet soils. The J-shaped blades were used for loosening, destroying the soil surface compaction and giving better ventilation to the soil. Generally, it was used for tilling hard as well as wet soils. Whereas L-shaped blades were the most common widely use for the fields with crop residue, removing weeds (Bernacki *et al*., 1972 and Khodabakhshi *et al.*, 2013). Design of blades depends

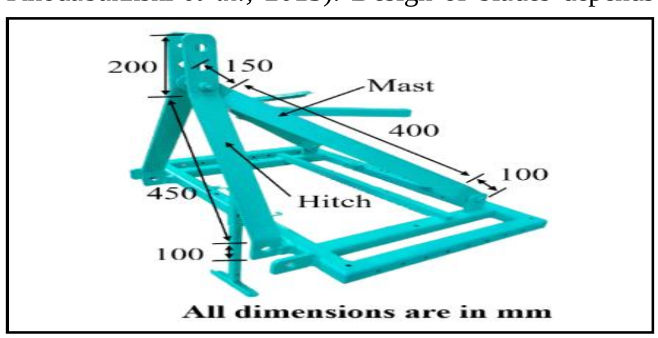

Fig. 2: Mast-Hitch.

up on the PTO power and soil type.

a. Tangential force acting on the blade

b. Rotary Blade design

a. Tangential force acting on the blades:

The maximum tangential force which can be endured by the rotary shaft should be considered. The maximum tangential force occurs at the minimum tangential speed of blades was calculated by the following (Bernacki *et al.*, 1972)

$$K_s = \frac{C_S \times N_C \times \eta_C \times \eta_Z \times 75}{\mu} \quad (1)$$

Where;

K_s = Maximum tangential force, kg

C_s = Overload factor (1.5 for non-rocky soils and 2 for rocky soils)

N_c = Tractor power, hp

η_c = Transmission efficiency of tractor (0.9)

η_z = Coefficient of reservation of engine power (0.7 - 0.8)

μ = Minimum tangential speed of blades

Tangential peripheral speed (μ) can be calculated using the following equation

$$\mu = \frac{2\,\pi\,N\,R}{60 \times 1000} \quad (2)$$

Where;

N = rpm of rotary shaft, rpm

R = Radius of rotary shaft, mm

$$\mu = \frac{2\,\pi \times 100 \times 140}{60 \times 1000}$$

μ = 1.4653 m/s

Substituting values of rpm of rotary shaft (100) and its radius (140 mm) in eqn. (2) then tangential peripheral speed was obtained as 1.4653 m/s.

By putting the tangential speed value in eqn. (2) the maximum tangential force acting on blades obtained as follows.

$$K_S = \frac{1.5 \times 17 \times 0.90 \times 0.80 \times 75}{1.4653} \quad (3)$$

K_S = 939.73 kg

Using the tangential peripheral speed and other parameters the maximum tangential force was determined as 939.73 kg.

The soil force acting on each of the blade (Ke) was calculated by the following equations:

Ke = (Ks × Cp)/(Nb × Ne) (4)

Where;

Ks = Maximum tangential force, kg

Cp = Coefficient of tangential force (2)

Nb = Total number of blades on rotary shaft assembly (12)

Ne = Ratio of number of blades

Which act jointly on the soil to total number of blades considered the above definitions, Ke can be calculated as

Ke = (939.739 × 2) / (12 × (3/12))

= 313.2463 kg

b. Rotary blades design:

The design of rotary weeder depends on the type of blade and also on the working condition. The total power coming from PTO was distributed between the blades. The number of flanges was calculated by the following equation

$$i = \frac{b}{b_i} \quad (5)$$

Where;

i = Number of flanges

b = Working width of rotary blade assembly (800 mm)

b_i = Distance between the two flanges on the rotary shaft (Assumed 130 mm)

Therefore, the total number of flanges obtained:

i = 800 / 130

= 6.15 E ≅ 6

Generally use for tilling hard and wet soils whereas L-shaped blades were widely use for the fields with crop residue and removing weeds (Bernacki *et al.*, 1972 and Khodabakhshi *et al.*, 2013). Blades were connected to the flange with the help of nuts, bolts and washers (Fig. 4). Two blades on left side of the flange and other two blades on right side of the flange were fitted by using nut and bolt system. Rotary blade unit consisted of two parts, *i.e.* (1) Flange (2) Blade. There were a provision to increase the width of cut by increasing the number of flanges on either side of the gear box. The width of cut

Fig. 4: Gear-Box with Rotary Blade Assembly.

of one side of blades assembly and their weight were 400 mm and 6.1 kg respectively.

Power Transmission System

The power transferred with minimum losses from the engine to rotary unit blade was main aim of this system. Tractor PTO power was transmitted to input shaft through universal shaft. Input shaft was transmitted to gear box help of bevel gears. Rotary blades unit were directly joined to gear box shaft by pin.

Input Power Shaft

It was fitted on the main frame by using two pedestal bearings. It takes power from tractor PTO through the universal shafts and further it transferred power to the bevel gear set up. The diameter of the input shaft was determined by using following equation (Khurmi and Gupta, 2011) (Balas *et at*., 2018B).

$$T = \left(\frac{\pi}{16}\right) \times \tau \times d^3 \tag{6}$$

Where;

T = Torque, N-m

τ = Torsional shear stress, N/mm^2

P = Power, (12.67 kW)

d = Diameter of solid shaft, mm

Power coming from mini tractor,

$$P = \frac{2\pi NT}{60} \tag{7}$$

Where,

N = Speed, rev/min (100)

$$T = \frac{12.67 \times 60 \times 1000}{2 \times 3.14 \times 100} = 1210.5095 \times 10^3 \text{ N-mm}$$

Now putting the value of T in eqn. (6) and using τ = 60 MPa = 60 N/mm^2 for mild steel.

The diameter of shaft comes out as,

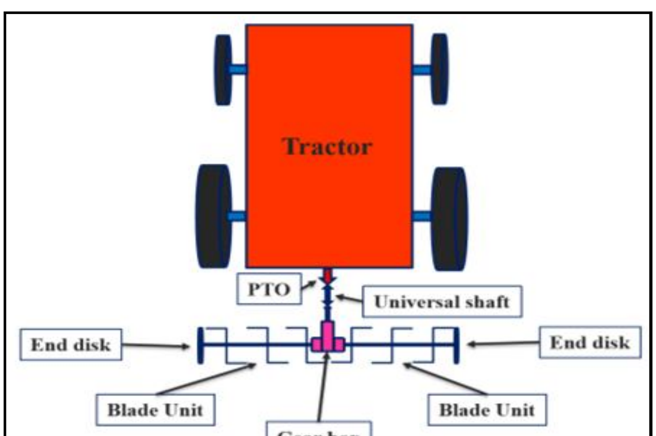

Fig. 5: Detailed Drawing of Power Transmission Path.

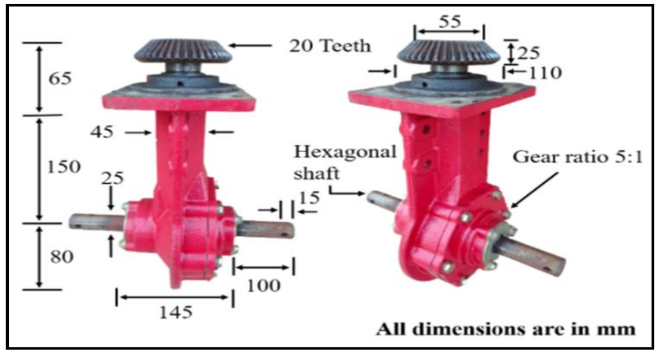

Fig. 6: Gear Box.

$$d^3 = \frac{1210.5095 \times 1000 \times 16}{3.14 \times 60}$$

$\therefore$ d =36.8456 mm ~35 mm

Based on availability a mild steel shaft of 35 mm diameter and 130 mm length was used in the fabrication.

Gear Box

Gear box consists of bevel gears which receives the mechanical power from the engine at top portion by universal shaft. Gear box was fitted on main frame with help of MS angle (Size: 50 × 50 × 5 mm, Length 400 mm). Nuts and bolts (size: Dia. 8 mm, thread 18 BSW, length 50 mm) were used to join the MS angle and gear box on frame. Top portion of gear box has same teeth bevel gear, same rpm was transmitted to the bottom section of gear box. The bottom section of gear box having gear ratio of 5:1.

N_1 = PTO rpm (540)

N_2 = Rottory blade, rpm

Gear ratio = 5:1

So,

$$N_2 = \frac{N_1 X T_1}{T_2} \tag{8}$$

N_2 = 540 × 1/5 = 108 rpm

Weedicide Tank and Tank Platform

Plastic weedicide tank has water storage capacity was 25 lit and its mounted on the flat MS sheet fitted to

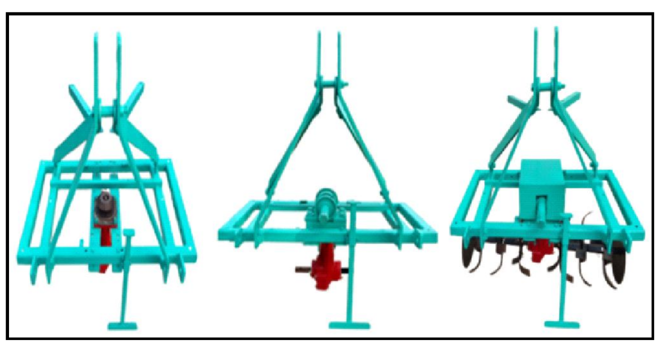

Fig. 7: Rotary Blade Unit with Frame.

main frame. A rubber sheet placed between tank and tank platform to act as a shock absorber during the weeding operation. Weedicide tank platform was made of MS sheet having size of 385×335 mm and 8 gauge (4 mm). Two MS angle bar (Size: 25×25 mm, thickness: 4 mm and length: 450 mm) has one end was fixed on mast by arc-weld joint at 600 mm height from lower portion of frame. MS sheet was fixed on two MS angles by four nuts and bolts (Size: Dia. 9.8 mm, Length 25 mm, Thread 16 BSW). Four MS angle bars having size 25×25 mm (length 190 mm and thickness 3 mm) was joined to MS sheet at one end directly by arc-welding (Fig. 9). Weedicide tank was placed in between four bars. It was fixed C-shape clamp (MS flat 50x5 mm and thickness 4 mm, length 570 mm) by nuts and bolts (Fig. 9).

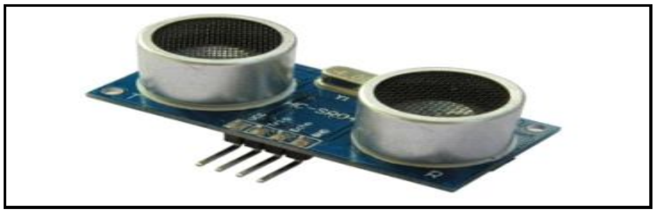

Fig. 11: Ultrasonic Sensor.

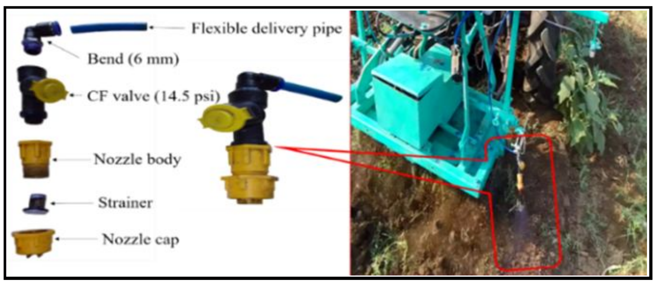

Fig. 12: Nozzle and its Accessories.

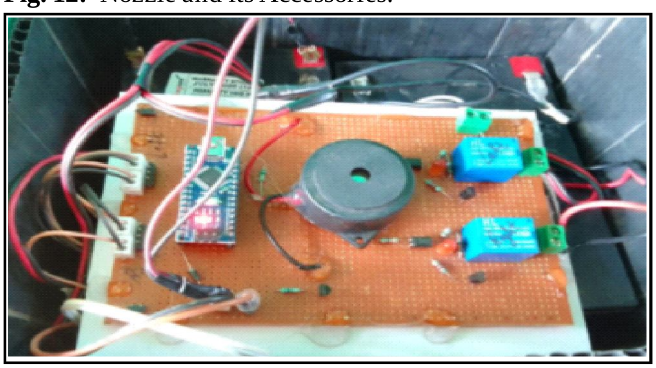

Fig. 14: PCB IC-Microcontroller.

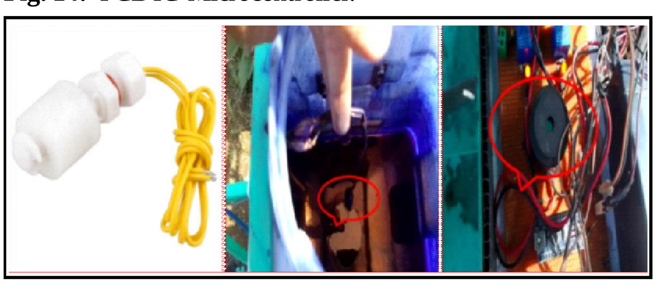

Fig. 15: Water Level Sensor With Sound Buzzer.

Pump cum Motor

Pumps cum motor were powered by battery. The pumps cum motor were fitted on the mast of frame just below the weedicide tank platform by nuts and bolts (Size: Length 25 mm, Dia. 6.5 mm and Thread 20 BSW). They were used to pressurized weedicide. It was passed to the delivery pipe. Delivery pipe connects the nozzle to spray the weedicide on weeds.

Battery

Sealed lead acid batteries were used to operate the pump cum motor. Two 12 V batteries were connected in a series and produce a 24 V. Sealed lead acid battery

```
□       Programming in Arduino IDE
constintdirPin =5;
constintstepPin=6;
int flag;
#define trigPin1 2                    // Assignining trig pin of Ultrasonic Sensor
#define echoPin1 3                    // Assignining echo pin of Ultrasonic Sensor
long microSecond, cmDistance1, mmDistance1, cmDistance2, mmDistance2;          // few
variables to store values and mathematical operations
int pm=200;
void setup()
{
Serial.begin (9600); // To start serial communication between computer and Arduino
pinMode(trigPin1, OUTPUT);
pinMode(echoPin1, INPUT);
pinMode(5,OUTPUT);
pinMode(6,OUTPUT);
}
void loop()
{
digitalWrite(trigPin1, LOW);
delayMicroseconds(2);
digitalWrite(trigPin1, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin1, LOW);
microSecond = pulseIn(echoPin1, HIGH);
cmDistance1 = microSecond/58.3;
mmDistance1 = microSecond/5.83;
Serial.println("");
Serial.print("First distance : ");
Serial.print(cmDistance1);
Serial.print(" cm      ");
Serial.print(mmDistance1);
Serial.print(" mm");
if (cmDistance1 < 45)
{
if(flag==0)
{
digitalWrite(dirPin,LOW);
for(inti=0; i<1800; i++)
{
digitalWrite(stepPin,HIGH);
delayMicroseconds(pk);
digitalWrite(stepPin,LOW);
delayMicroseconds(pm);
}
flag=1;
}
}
else if (cmDistance1 > 45)
{
if(flag==1)
{
digitalWrite(dirPin,HIGH);
for(inti=0; i<1800; i++)
{
digitalWrite(stepPin,HIGH);
delayMicroseconds(pm);
digitalWrite(stepPin,LOW);
delayMicroseconds(pm);
}
flag=0;
}
}
}
```

Fig. 17: Arduino IDE Program. (Program of the automated inter and intra row weeder in java-basedduno IDE.)

was rechargeable.

Ultrasonic Sensor

Ultrasonic sensor was worked base on the measurement of reflected sound waves on height wise. The estimation of the distance was based on the physical principle of time of light, producing a short bust of sound in a unique direction. The wave returns to the receiver after impacting an object. The device measures the travel time of the acoustic signal and transforms it into a voltage signal. The output voltage can be converted into a distance.

The transducer ultrasound frequency was approximately 180 kHz with a sensor resolution of 3 mm when working in full evaluation range. The divergence angle was configured to result in a 0.20 m diameter footprint when placed at a height of 0.80 m. Ultrasonic sensors were connected to microcontroller with wire cable.

Nozzle

Flat fan nozzles were used to spray the weedicide. They were fixed at one end of holder by nuts and bolts. In between, the nozzle and its holder a flexible neck was

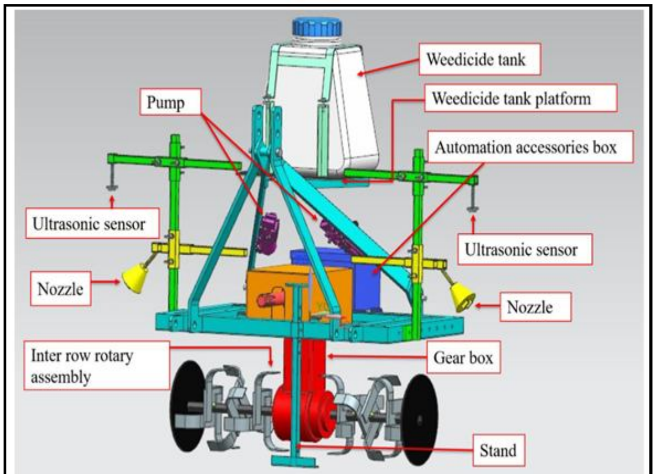

Fig. 18:

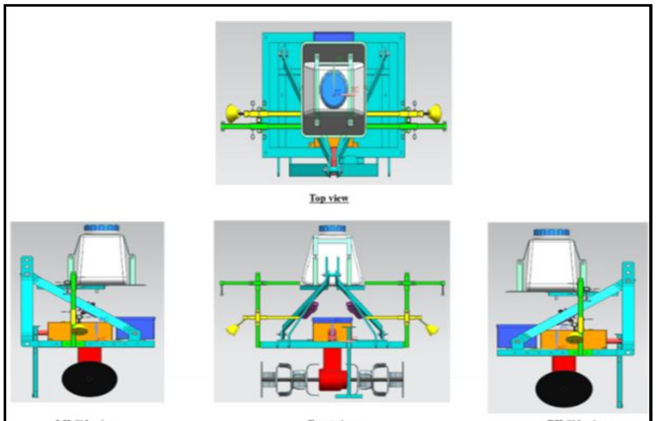

Fig. 19: Automated Inter and Intra Row Weeder.

Table 1: Detailed Specifications of Sealed Lead Acid Battery.

Sr.	Particulars	Specifications
01	Type of battery	Sealed lead acid battery
02	Voltage, V	12
03	Capacity, mAh	4200

fitted to set a nozzle at appropriate angle (*i.e.* 45 degree). Pressurised weedicide from tank through pump cum motor was delivered to flat fan nozzle through flexible delivery pipe. Two individual flat fan nozzles were fixed on both sides of frame through holder. In between, delivery pipe and flat fan nozzle a constant flow valve (CF valve) was fitted. Pressurized weedicide was delivered to flat fan nozzle through constant pressure (*i.e.* 14.50 psi) valve.

Ultrasonic Sensor and Flat Fan Nozzle Holder

Ultrasonic sensors and nozzles were fixed on a holder by nuts and bolts with 120° flexible neck. Ultrasonic sensors were fixed on top of the holders. The holders were fabricated using MS square hollow pipe of 20×20×3 mm, 50 mm length. One end of MS square hollow pipe was arc-welded to MS flat (40×5 mm, length 140 mm). MS flat was directly attached to main frame by nuts-bolts (Size: Dia. 9.8 mm, length 70-80 mm and thread 16 BSW). This holder assembly was fixed on both sides of main frame by nuts and bolts. Stopper was made by two MS square hollow pipe (size: 30×30×3 mm and length 110 mm). They were fabricated at centre right angle by arc-welded joint. Two check-bolts fabricated by nuts directly joined on MS square hollow pipe by arc-welded. MS horizontal square pipe, for hold sensor as well as nozzle at one end and vertical MS square pipe for fixed at main frame, were joined by stopper. The telescopic arrangement was provided by stopper. The horizontal as well as vertical limit was adjusted by stopper as according to field requirement. Height and width of ultrasonic sensor as well as flat fan nozzle were important for its working performance. It was adjusted according to crop, crop variety, crop canopy, etc.

Table 2: Detailed Specifications of Ultrasonic Sensor.

Sr.	Particulars	Specifications
01	Model	HC-SR04 Ultrasonic sensor
02	Number of ultrasonic sensor	2
03	Power supply	+5V DC
04	Static current	< 2 mA
05	Effectual angle	< 15°
06	Ranging distance	20 mm – 4500 mm
07	Resolution	3mm
08	Trigger input pulse width	10mm
09	Mode of connection	VCC/ Trig (T) / Echo(R) / GND

Table 3: Detailed specifications of PCB IC-Microcontroller.

Sr.	Particulars	Specifications
01	Model	Arduino UNO-R3
02	Microcontroller	ATmega328P
03	Operating voltage	5 V
04	Input voltage (Recommended)	7 – 12 V
05	Input voltage (limit)	6 – 20 V
06	Digital I/O pins	14
07	Analog input pins	6
08	Flash memory	32 kB
09	Clock speed	16 MHz

Microcontroller

A microcontroller was a PCB-IC chip that executes programs for controlling other devices or machines. Arduino UNO-R3 microcontroller was used to control or regulate automation system.

Arduino UNO- R3 was a microcontroller board. It has 14 digital input/output pins, 6 analog inputs, 16 MHz crystal oscillator, USB connection, power jack and a reset button. Arduino Uno was powered via two 12 V batteries. Arduino Uno was directly connected with ultrasonic sensor, pump cum motor and battery.

Relay Circuit

Relay module was used to operate (start/ON-OFF) both pump cum motors for controlling precisely spraying of weedicide. Relay module receive the signal from Node MCU1.0 and it gives command to the pump cum motor to ON/OFF sprayer.

Water Level Sensor with Sound Buzzer

The water sensor was used to detect water level. When water level sensor was kept at a certain depth in the water to be measured, by the pressure exerted on the sensor's front surface detects the depth of water. When the water level exceeds the lower limit, sensor warns by triggering the sound buzzer installed.

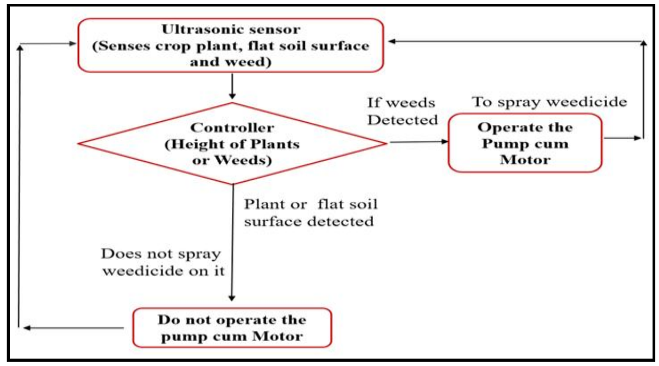

Fig. 20: Flow chart of Automated Weeder.

Controller Panel Box

Controller panel box was used to operate automation system by toggle switch. It has three switches, one for left hand side pump cum motor and ultrasonic sensor, second one for right hand side pump cum motor and ultrasonic sensor and third was used to shut down the whole automation system. Controller panel box was portable and joined to automation accessories box with flexible wires. It was operated by tractor driver. MS sheet box having size 150×10×50 mm was fabricated using material MS sheet (11 gauge).

Circuit Connection of Automated Weeder Machine

Trigger pin of the ultrasonic sensor was connected to digital pin 2 of the arduino. Echo pin of ultrasonic sensor was connected to the digital pin 3 of the arduino. Where, VCC and GND are connected to the 5 V and GND of the arduino. Arduino and ultrasonic sensor get power from 12 V battery. Pump cum motor was a high voltage and high current device which were controlled though relay circuit. Pump cum motor driver (relay circut) was required to separate high current and high voltage device. Relay circut was connected to digital pins 5 and 6 in arduino.

Programming of Automated Weeder Machine

Arduino IDE programming platform allows the user

Table 4: Detailed specifications of Developed automated weeder.

Sr.	Description	Material	Specification	Qty.
01	Frame	MS square hollow pipe	40× 40×5 mm	3200 mm
02	Gear box	Cast iron	-	1
03	Inter row rotary assembly	Boron steel	-	24 Blade 6 Flange, 2 End disc
04	Weedicide tank	Plastic	25 lit.	1
05	Flat fan nozzle	Plastic	Discharge 0.500 lit/min	2
06	Ultrasonic sensor	-	HC-SR04	2
07	Sensor-nozzle holder	MS square hollow pipe	20×2 × 5 mm	250 mm
08	Pump cum motor	-	12 V, 2.2 A, 3.10 lit/min.	2
09	Gear box cover	Iron sheet	260×185 mm, 11 Gauge	1
10	Automation accessories box	Iron sheet	260×185 mm, 11 Gauge	1
11	Power input shaft	Mild steel	Dia. 30 mm	1300 mm
12	Stand	MS square hollow pipe	20×20× 5 mm	410 mm
13	Weedicide tank platform	Iron sheet	335×385 mm, 8 Gauge	1

to draft different kind of programs and load them into the arduino microcontroller. Arduino user-friendly programming language, which was based on programming language called processing. After the user has written his code, IDE compiles and translates the code to the assemble language. After translating the code, the IDE uploads the program to the arduino microcontroller. After testing the program it can be uploaded to the arduino by USB cable.

Results

Automated Inter and Intra Row Weeder Machine

An automated inter and intra row rotary weeder cum sprayer was developed for weeding operation. Developed machine consisted of a main frame, weedicide tank, weedicide tank platform, gear box, rotary blade with end disc and back cover. Two holders with nozzles and ultrasonic sensors on both side mounted on the main frame. Other components for automation i.e. controller, relay circuit and battery were covered by MS sheet box. MS sheet box was mounted at rear side of main frame. Developed machine performed in inter row weeding by PTO powered rotary weeder and intra row weeding by weedicide spraying. The intra row weeds were detected by ultrasonic sensors, which transferred signal to the controller. Controller operated the weedicide pump cum motor based on received signal whether the obstacle was a weed, a crop plant or a soil clod. If the obstacle was a weed, the controller started the pump cum motor to spray the weedicide, and if the obstacle was a crop plant, the pump cum motor did not spray the weedicide.

Detailed of material wise specification of developed automated weeder machine are given in Table 4.

Conclusion

The machine development (fabrication) work, research work and testing were done at ASPEE, Agricultural Research and Development Foundation, TANSA Farm, Mumbai. An automated inter and intra row rotary weeder cum sprayer was developed for weeding operation. Developed machine performed in inter row weeding by tractor PTO powered rotary weeder and intra row weeding by autametd weedicide spraying. The developed weeder machine was tested and evaluated in three crops like brinjal, castor and cotton. The overall operation by the automated inter and intra weeder was found satisfactory with almost no damage.

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