CHAPTER - III

MATERIALS AND METHODS

This chapter deals with the procedure followed and materials used to achieve the objectives of the research problem. Developed implement was evaluated and its performance and comparison with existing method was done. Design was done by using Creo Parametric 2.0 software. Materials and methods used for this project are noted sequentially in the subsequent text. Its performance evaluation and economical parameters have also been included.

3.1 Location of experiment

To fulfil objectives the stubble shaver cum fertilizer applicator was developed in the department of Farm Machinery and Power Engg., College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Field experiments were conducted on Netrang Farm, Tal. - Kamrej, Dist.- Surat during the academic year 2017-2018. Some laboratory experiments were conducted in the department of Farm Machinery and Power Engg.

3.2 Conceptual design of stubble shaver cum fertilizer applicator

A stubble shaver cum fertilizer applicator machine are used to shave stubble of harvested sugarcane in uniform pattern and apply fertilizer. The stubble shaver cum fertilizer applicator machine consists of a frame with cutting blade, off-barring system, fertilizer applicator and three-point linkage unit.

The working principle of stubble shaver cum fertilizer applicator machine which is having rotating action of cutting blade was trim non-uniform height of stubble into a uniform height. At the same time fertilizer is also being applied by means of ground wheel- rotor assembly. Ground wheel rotor assembly consists of a ground wheel, two shafts and a rotor mechanism by which fertilizer is applied. The shaft of metering mechanism gets drive from ground wheel with help of chain and sprocket. The rotor cups are exposed to the fertilizer which takes fertilizer from the auxiliary box and delivers to the opening of fertilizer tube.
Further it is delivered to the fertilizer tubes which are attached to the boot at rear side of the tynes. This machine also pulverizes soil by means of cultivator tynes provided in off barring system. The cultivator tynes of off barring system cuts the exposed roots coming out in sideways of furrow as well as it penetrates into the soil so fertilizer is applied at uniform depth.

![Conceptual model of the machine](image)

**Plate 3.1: Conceptual model of the machine**

3.2.1 Agronomical parameters

3.2.1.1 Row to Row spacing

In general, the row spacing of sugarcane crop was kept as 120 cm distance between furrow in heavy soil and 105 cm distance in light to medium soil. Planting is done by placing in the furrows (Anon., 2017c).

3.2.1.2 Diameter of stubble

The diameter of cane varieties of Co-265, were measured as 2.3 to 3.81 cm.

3.2.2 Design Considerations

The stubble shaver cum fertilizer applicator machine was developed on the basis of consideration.
(a) Functional requirements

(b) Engineering considerations

(c) General considerations

(a) **Functional requirements**

Following functional requirements were considered for developing the machine.

1. Speed of Power Take Off shaft was considered as 540±10 rpm.
2. Average speed of operation of tractor in the field was consider as 2 to 5 km/h.
3. It should reduce drudgery involved.
4. It should shave the sugarcane stubble from ground level properly.
5. It should minimize the stubble damage.
6. The machine should shave the stubble from the field in 75 cm width.
7. Two tynes of implement should performs off barring and trimming of old roots along the two shoulders of ridge up to average depth of 15 cm.
8. Fertilizer metering mechanism should place the fertilizer at desired depth.
9. It should be simple in fabrication and easy to manufacture using local available materials.
10. All the components should be operated using mechanical drives since it is the cheapest mode of power transmission in the speed and power.

(b) **Engineering considerations**

The following engineering parameters were considered in the designing of stubble shaver cum fertilizer applicator.

**i. Width of machine**

The width of machine should be such that it has maximum width of coverage for stubble shaving, off-barring and fertilizer application rate could accomplish the operation efficiently.

**ii. Depth of operation**

The depth of operation should be such that better interculturing operations, loosening of soil and application of fertilizer off-bearing system could be helpful.
iii. Speed of operation

The speed of operations should be in the range of 2 to 5 km/h.

c) General considerations

It should be simple in design, safe in operation and have sufficient power requirement compatible with 35-40 hp tractor. It should cut the uniform stubble of sugarcane, off-barring operation and fertilizer application at a higher rate than the existing methods. It should be cost wise cheaper as far as possible. At the same time, it should be strong enough and durable.

3.2.3 Assessment of draft and power requirement

The draft requirement of the tractor operated stubble shaver cum fertilizer applicator cultivator will be estimated using factors related to implement and the type of soil. The specific soil resistance of medium black soil of the area was considered as 0.40 kg/cm² (Kepner et al., 2005).

Total working width = No. of tine × tine spacing  
= 2 × 80 = 160 cm = 1.60 m

Cross section area of 2 furrows = 160 × 15 = 2400 cm²

Maximum draft = 2400 × 0.40 × 9.8 = 9408 N

Speed of travel = 4 km/h = 4000 m/h =1.11 m/s

The power required for the designed draft was estimated using formula suggested by (Kepner et al., 2005)

\[
\text{Total power required, kW} = \frac{\text{Draft(N)} \times \text{Speed(m/s)}}{1000} \quad \text{...(3.2)}
\]

\[
= \frac{9408 \times 1.11}{1000} \\
= 10.44 \text{ kW} \\
= 13.99 \text{ hp}
\]
3.2.4 Design of functional components of stubble shaver cum fertilizer applicator machine

The design of the functional components and different mechanisms were carried out. The machine consists of frame, stubble shaving unit, fertilizer application and off barring system. The design of following components was taken up:

I. Stubble shaving unit
II. Fertilizer application unit

3.2.4.1 Design of shaving unit

The design of shaving unit consists of design of hollow shaft, design of flange and design of blade.

3.2.4.1.1 Design of hollow shaft

Design of hollow shaft is given by (Khurmi and Gupta, 2013),

We know that allowable shear stress of mild steel,
\[ \tau = \frac{\tau_u}{F_S} = \frac{360}{6} = 60 \text{ N/mm}^2 \]  
\[ \text{\quad \ldots(3.3)} \]

Where,
\[ \tau_u = \text{Ultimate Stress, MPa or N/mm}^2 \]
\[ F.S = \text{Factor of safety} = 6 \]
\[ P = \text{Power of tractor} = 37.3 \text{ kW} \]
\[ T = \frac{P \times 60}{2\pi N} = \frac{37.3 \times 60 \times 1000}{2 \times 3.14 \times 174} = 2048.10 \text{ N.m} \]  
\[ \text{\quad \ldots(3.4)} \]

Let,
\[ d_i = \text{Inside diameter} = 76 \text{ mm} \]
\[ d_o = \text{Outer diameter} = 86 \text{ mm} \]
\[ T = \frac{\pi}{16} \times (d_o)^2 \times (1 - \left[\frac{d_i}{d_o}\right]^4) \times \tau \]  
\[ 2048.10 \times 10^3 = 0.196 \times 636056 \times \times (1 - 0.600) \times \tau \]  
\[ \tau = \frac{2048.10 \times 10^3}{0.196 \times 636056 \times 0.4} \]
\[ \tau = 41.07 \text{ MPa or N/mm}^2 \]
Since this maximum stress is below the permissible value of 60 MPa or N/mm$^2$, therefore the design is safe.

3.2.4.1.2 Design for flange

Design of flange is given by (Khurmi and Gupta, 2013),

The thickness of the flange ($t_f$) is taken as 0.2d.

\[
t_f = 0.2 \times 86 = 17.2 \text{ mm} = 18 \text{ mm}
\]

Let us now check the induced shear stress in the flange, by considering the flange at the junction of the hub in shear. We know that the torque transmitted ($T$),

\[
T = \frac{\pi D^2}{2} \times \tau_c \times t_f
\]

\[
2048.10 \times 10^3 = \frac{\pi (86)^2}{2} \times \tau_c \times 18
\]

\[
\tau_c = 9.79 \text{ MPa or N/mm}^2
\]

Since the induced shear stress in the flange is less than the permissible value of 14 MPa or N/mm$^2$ therefore the design for flange is safe.

3.2.4.1.3 Length of blade

The width of generally grown sugarcane furrow ridge around 40-50 cm. So, considering the overall width and length of blade was kept half of the furrow width. To get the desired cutting of blade for stubble of sugarcane, the length of blade was kept as 22.0 cm.

3.2.4.1.4 Width of blade

Due to declined standing of sugarcane plant from the center of a row, results in a wider row. In order to cover this width as well as considering the shaving unit, the width of blade was kept as 8.0 cm.

3.2.4.1.5 Thickness of blade

The thickness of blade was calculated by the formula

\[
\frac{M}{I} = \frac{F}{Y}
\]

\[
\text{...(3.8)}
\]
Where,

M = Bending moment acting on the blade section, kg-cm
I = Second moment of inertia of cross section about the neutral axis, cm\(^4\)
F = Bending stress, kg/cm\(^2\)
Y = Distance from neutral axis to the extreme edge, cm

As,

\[
M = \frac{\text{Weight of machine (kg) \times length of blade (cm)}}{2} \quad \ldots(3.9)
\]

\[
= \frac{170 \times 22}{2}
\]

\[
= 1870 \text{ kg-cm}
\]

Take, \(F = \text{Allowable bending stress} = 900 \text{ kg/cm}^2\) (Pandya and Shah, 1986)

\[
Y = \frac{\text{Average height of stubble (cm)}}{2} \quad \ldots(3.10)
\]

\[
= \frac{18}{2} = 9.0 \text{ cm}
\]

Now, \(I = \frac{tb^3}{12} \quad \ldots(3.11)\)

\[
= t \left(\frac{8}{3}\right) / 12 = 42.66 t
\]

Where,

\[
t = \text{Thickness of blade, cm}
\]
\[
b = \text{Max. width of blade, cm}
\]

By putting above value in eq. 3.8
\[
t = 1870 \times 9 / (42.66 \times 900)
\]

\[
= 4.38 \text{ mm} \approx 6 \text{ mm}
\]

Considering, the factor of safety and availability of material, the thickness of blade was selected as 6.0 mm.

3.2.4.2 Design of Fertilizer unit

3.2.4.2.1 Design of Fertilizer box

Volume of Fertilizer box is given by (Sanodiya, K. 2015),

\[
V_b = 1.1 V_S \quad \ldots(3.12)
\]
\[ V_s = \frac{W_s}{Y_s} \]  

...(3.13)

Where,

\( V_b \) = Volume of fertilizer box, cm\(^3\)

\( V_s \) = Volume of fertilizer, cm\(^3\)

\( Y_s \) = Bulk density of fertilizer, g/cm\(^3\) (Take density of fertilizer = 0.984 g/cm\(^3\))

\( W_f \) = Weight of fertilizer, g

Design of fertilizer box, 70.0 kg fertilizer fill in the box at a time.

\[ V_b = 1.1 \frac{W_f}{Y_f} \]

\[ V_b = 1.1 \times \frac{70000}{0.984} \]

\[ V_b = 78252.03 \text{ cm}^3 = 0.0782 \text{ m}^3 \]

On the basis of survey in field the farmers requirement of fertilizer rate for sugarcane was considered 180-220 kg/ha. but it is impossible to fill the hopper, this much larger. According to this, the volume of hopper was selected.

3.2.4.2.2 Fertilizer Delivery Tube

It is required that fertilizer fall freely from the feed cup though the tube into the furrow. Uniform fertilizer rate is achieved when all fertilizers are released by the metering device from the same height with the same velocity. In a multi-row machine, the fertilizer tubes guide the fertilizer to different furrows. Polyethylene tubes of 25 mm diameter and 2 mm thick were used to convey fertilizer from hopper to furrow opener by gravity. The inclination of the tubes from the vertical was kept smaller than 25° (Endrerud, 1999).

The time of fall of a fertilizer though a tube is affected by the size and type of tube and bouncing of fertilizers against wall of the fertilizer tube. While designing a fertilizer drill, the fertilizer tube should be kept vertical or its inclination from the vertical should be smaller than 25°. The velocity of a fertilizer falling freely from a height ‘\( h \)’ is given by,

\[ V^2 = V_0^2 + 2gh \]  

...(3.14)

Where,

\( V \) = final velocity of fertilizer due to fall, m/s
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\[ V_0 = \text{initial velocity of the fertilizer, (travelling speed) m/s} \]

\[ g = \text{gravitational acceleration, } 9.81 \text{ m/s}^2 \]

\[ h = \text{Height of hopper from ground wheel.} \]

\[ V^2 = (0.83)^2 + 2 \times 9.81 \times 0.90 \]

\[ = 18.34 \]

\[ V = 4.28 \text{ m/s} \]

Therefore, the velocity of fertilizer falling freely from a height of 90 cm is 4.28 m/s.

3.2.5 Fabrication of stubble shaver cum fertilizer applicator

In the process of designing and development of the tractor operated stubble shaver cum fertilizer applicator, the basic emphasis was given on simplicity of fabrication, use of locally available material and minimum cost of fabrication, ease of assembling and dismantling for repairs and inspection were duly considered. Major components of machine developed are as follow:

I. Frame

II. Stubble cutting unit

III. Off-bearing unit

IV. Fertilizer application unit

V. Power transmission system

3.2.5.1 Frame

The frame is meant for holding different components of stubble shaver cum fertilizer applicator. It is subjected to bending, tension, and vibrations. A rectangular tool bar type frame was fabricated from square hallow MS pipe for mounting stubble shaving unit, off-barring unit, depth control unit and fertilizer application unit. The components were fastened on the main frame using nuts and bolts. The three-point hitch was fabricated using 75 mm × 5 mm MS flat as describe in Plate 3.3. The fabricated frame and its specifications are in Plate 3.2, and Table 3.1 respectively.
Plate 3.2: Drawing and Fabricated frame

Table 3.1: Specifications of Frame

<table>
<thead>
<tr>
<th>Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material of fabrication</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Length, mm</td>
</tr>
<tr>
<td>Width, mm</td>
</tr>
</tbody>
</table>

Plate 3.3: Specification of three-point linkage
Table 3.2: Specifications of three-point linkage

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Dimen.</th>
<th>Description</th>
<th>Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Refer Plate. 3.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$d_1$</td>
<td>Dia. of hitch pin hole</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>$b'_1$</td>
<td>Width between inner faces of yoke</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>$b'_2$</td>
<td>Width between outer faces of yoke</td>
<td>79</td>
</tr>
<tr>
<td>4</td>
<td>$b'_3$</td>
<td>Linch pin hole distance</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>$L$</td>
<td>Lower hitch point span</td>
<td>670</td>
</tr>
<tr>
<td>6</td>
<td>$D$</td>
<td>Dia. of linch pin hole (upper hitch pin)</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>$D$</td>
<td>Dia. of linch pin hole (lower hitch pin)</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>$H$</td>
<td>Mast height</td>
<td>575</td>
</tr>
</tbody>
</table>

### 3.2.5.2 Stubble shaving unit

The function of Stubble shaving unit is rotating action flange with detachable eight blades were used trim non-uniform height of stubble into a uniform height. The bottom cutting blades was made up from specially heated steel with hard surface, 45° edge angle, vertical cutting angle 90° and fitted on blade disc. Overall dimensions of blade were 220 mm x 80 mm x 6 mm are in Plate 3.4. Blade had overall thickness of 6 mm. There were two holes on inner end of blade for attachment with disc, each hole having diameter of 14 mm and each blade was fixed at 45 mm of equal spacing on disc as shown in Plate 3.4.
3.2.5.3 Off-barring system

3.2.5.3.1 Cultivator tyne

Two shovels for off-barring operation have been used, as shown in Plate 3.5 with 425 × 70 × 4 mm dimensions for shovel. It was made up from high carbon steel and 665 × 70 × 28 mm dimensions for shank. It was made up from mild steel, 800 mm distance between tynes. The type of tyne, it is adjustable type. The specifications of off barring system are Table 3.3 respectively.

![Plate 3.5: Detailed drawing of cultivator tine; (a) front view (b) side view (c) Isometric view](image)

Table 3.3 Specifications of the Off-barring system

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Height of tine, mm</td>
<td>665</td>
</tr>
<tr>
<td>2</td>
<td>Width of tine, mm</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>Thickness of tine, mm</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>Tine spacing, mm</td>
<td>800</td>
</tr>
<tr>
<td>4</td>
<td>No. of tines</td>
<td>2 (reversible shovel type)</td>
</tr>
<tr>
<td>5</td>
<td>Material</td>
<td>Mild Steel</td>
</tr>
<tr>
<td>6</td>
<td>Height of shovel, mm</td>
<td>425</td>
</tr>
<tr>
<td>7</td>
<td>Width of shovel, mm</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>Thickness of shovel, mm</td>
<td>4</td>
</tr>
</tbody>
</table>
3.2.5.4 Fertilizer application unit

3.2.5.4.1 Fertilizer box

Fertilizer box was mounted on the main frame with rigid support as shown in Plate 3.6. It is useful to store and deliver the fertilizer to metering mechanism continuously. It was made up 18-gauge MS sheet. Its capacity was 70 kg capacity and trapezoidal in shape, it was large rectangular $840 \times 360$ mm at the top and narrow $840 \times 75$ mm at bottom with 180 mm height and an opening of 25 mm diameter. Plastic pipe was jointed at this opening to guide the fertilizer towards the auxiliary chamber with metering mechanism.

Plate 3.6: Fertilizer box

3.2.5.4.2 Fertilizer metering mechanism

Fertilizer metering mechanism consists of auxiliary chamber with rotor having two cups were made 18-gauge MS sheet on its periphery. The two cups were distance of 80 mm to maintain the continuous flow of fertilizer to the delivery tube. The size of the cup was made such that it could accommodate required amount of fertilizer. The rotor was mounted on shaft of 18 mm diameter. The fabrication and specification of metering mechanism are as shown in Plate 3.7 and table 3.4.

Plate 3.7: Fertilizer metering mechanism
Table 3.4 Specifications of the fertilizer metering mechanism

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rotor diameter, mm</td>
<td>98</td>
</tr>
<tr>
<td>2</td>
<td>Number of cups on periphery</td>
<td>10</td>
</tr>
</tbody>
</table>

The shaft of metering mechanism gets drive from ground wheel with the help of chain and sprocket. The rotor cups are exposed to the fertilizer which takes fertilizer from the auxiliary box and delivers to the opening of fertilizer tube. Further it is delivered to the fertilizer tubes which are attached to the boot at rear side of the shank.

3.2.5.5 Power transmission system

There were major two power transmission units viz., power transmission unit for cutting blade and power transmission unit for fertilizer applicator are shown in Plate 3.8.

3.2.5.5.1 Gear box

The power transmission system consists of bevel gear system which has two sets of bevel gears fitted at right angle to each other to transmit power received from tractor PTO to the blade shaft and the transmission of power at 90° with 31:10 number of teeth on crown gear and pinion gear. The driven gear has 31 teeth and driving gear has 10 teeth, it has maximum speed 175 rpm at 540 PTO rpm and 3.10:1 gear ratio. But sugarcane operation was done satisfactorily at nearly 150-200 rpm.

Plate 3.8: Power transmission system for cutting blade and fertilizer applicator

1. Rotary power from PTO shaft        2. Universal joint cross
3. Heavy duty bevel gear box          4. Rotary power to the cutting blade
5. Chain sprockets                   6. Ground wheel
3.2.5.5.2 Fertilizer applicator

Ground wheel of 50 cm diameter with chain and sprocket of 18 teeth was used. Power was taken from ground wheel to the fertilizer metering shaft with the help of chain and sprocket as shown in Plate 3.8. The gear ratio on ground wheel and sprocket on rotor shaft was 1:5 for ratoon crop.

3.3 Fabricated stubble shaver cum fertilizer applicator

Developed stubble shaver cum fertilizer applicator machine, its design drawing and specifications of all units are shown in following Plate.
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(a)

(b)
Plate 3.10: Drawing of stubble shaver cum fertilizer applicator (a) Side view (2D) (b) Front view (2D) (c) Side view (3D) (d) Isometric back view (3D)
### Table 3.5: Specification of developed stubble shaver cum fertilizer applicator machine

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Particular</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Name of the equipment</td>
<td>Stubble shaver cum fertilizer applicator</td>
</tr>
<tr>
<td>2</td>
<td>Type of hitch and its detail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linkage</td>
<td>3 - point</td>
</tr>
<tr>
<td></td>
<td>Powered by</td>
<td>PTO</td>
</tr>
<tr>
<td>3</td>
<td>Overall Dimensions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>1950 mm</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>1190 mm</td>
</tr>
<tr>
<td></td>
<td>Height</td>
<td>1500 mm</td>
</tr>
<tr>
<td>4</td>
<td>Main Frame</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material of construction</td>
<td>M.S pipe (square hollow: 50 mm × 50 mm × 3 mm)</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>1050 mm</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>515 mm</td>
</tr>
<tr>
<td>5</td>
<td>Cutting unit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material of bottom cutting blade</td>
<td>Heated steel</td>
</tr>
<tr>
<td></td>
<td>No. of bottom cutting blade</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Length of blade, mm</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>Width of blade, mm</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Thickness of blade, mm</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Flange</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diameter of flange, mm</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>Thickness of flange, mm</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>Off baring system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shovel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height of shovel, mm</td>
<td>425</td>
</tr>
<tr>
<td></td>
<td>Width of shovel, mm</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Thickness of shovel, mm</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>High carbon steel</td>
</tr>
<tr>
<td></td>
<td>Tyne</td>
<td></td>
</tr>
</tbody>
</table>
### 3.4 Experimental procedure

The instruments and equipment’s used for the field test tractors, measuring tape, soil sample auger, metallic core cylinder, digital dynamometer, stop watch, etc. Before conducting the actual field test, necessary settings and proper attachments were made and preliminary tests were conducted. Marking of the test field was done with white
powder as per layout. Tractor drive wheel was marked with colored tapes for easy counting of number of revolutions during slip measurement. The performance parameters like speed of operation, time loss, damage stubble, shaved stubble, field efficiency, moisture content of the soil, depth and Width of coverage, fuel consumption, draft, field capacity, depth of fertilizer placement and wheel slip were determined. The other details of experimental fields are given in Table 3.6.

**Table 3.6: Details of experimental field**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location of experimental field</td>
<td>Village - Netrang, Tal. - Kamrej, Dist.- Surat</td>
</tr>
<tr>
<td>2</td>
<td>Type of soil</td>
<td>Medium black</td>
</tr>
<tr>
<td>3</td>
<td>Moisture content, % (d.b.)</td>
<td>17.61</td>
</tr>
<tr>
<td>4</td>
<td>Total area of experimental field, m²</td>
<td>996.03</td>
</tr>
<tr>
<td>5</td>
<td>No. of test plots</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>Length of each test plot, m</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Width of each test plot, m</td>
<td>1.19</td>
</tr>
<tr>
<td>8</td>
<td>Area of each test plot, m²</td>
<td>23.8</td>
</tr>
<tr>
<td>9</td>
<td>Shape of field/ plot</td>
<td>Rectangular shape</td>
</tr>
<tr>
<td>10</td>
<td>Bulk density, g/cc</td>
<td>1.23</td>
</tr>
</tbody>
</table>

### 3.4.1 Calibration of Fertilizer Applicator

Fertilizer dropping rate was obtained at different hopper capacity and different speed when the machine was stationary. The test was conducted at full, \(\frac{3}{4}\) and \(\frac{1}{2}\) capacity of hopper and 2 to 5 km/h speed. It was done so as to determine the fertilizer application rate per hectare. The detailed results are presented and discussed section 4.1.1. (source: Indian Standard Test Code, IS-6316:1993).

1. The nominal width of coverage of the stubble shaver cum fertilizer was determined. The nominal width is equal to the product of the number of furrow openers and the spacing between two consecutive openers.
2. Area covered in 20 revolution of ground wheel was determined.
3. The seed drill was jacked up so that the drive wheel runs freely. A mark was made on the drive wheel at convenient place on the body of the stubble shaver cum fertilizer to help in counting the revolutions of the drive wheel.

4. The fertilizer was filled in the hopper and sack under each boot for seeds.

5. The drive wheel was rotated manually at different speed like 2 to 3 km/h, 3 to 4 km/h and 4 to 5 km/h.

6. The quantity of fertilizer dropped each from furrow opener for 20 revolutions was collected and weighed.

7. The quantity of fertilizer dropped was calculated on hectare basis. (i.e. kg/ha)

8. This test was repeated 5 times for each full, \(\frac{3}{4}\) and \(\frac{1}{2}\) hopper capacity and different speed of 2 to 3 km/h, 3 to 4 km/h and 4 to 5 km/h.

![Plate 3.11: Calibration of Fertilizer Applicator](image)

3.4.2 Experimental design

The following design was used to carry out the selected research project. The details of the selected independents and dependents parameters with their codes are shown in Table 3.7.

3.4.3 Layout of experimental plot

i. Statistical design: Factorial RBD design

ii. No. of treatment combination: \(3 \times 3 = 9\)

iii. No. of replications: 4

iv. No. of observations: \(9 \times 4 = 36\)
Table 3.7: Details of experimental variable included for the study

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Variables</th>
<th>Parameters</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Independent Parameters</td>
<td>Forward Speed, FS</td>
<td>FS₁ = 2-3 km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FS₂ = 3-4 km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FS₃ = 4-5 km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. of blade/flange, BS</td>
<td>BS₁ = 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BS₂ = 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BS₃ = 8</td>
</tr>
<tr>
<td>2</td>
<td>Dependent Parameters</td>
<td>Stubble shaving efficiency (%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percentage of damage stubble (%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.8: Details of treatments

<table>
<thead>
<tr>
<th>Name of Treatment</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>FS₁BS₁</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>FS₁BS₂</td>
</tr>
<tr>
<td>Treatment 3</td>
<td>FS₁BS₃</td>
</tr>
<tr>
<td>Treatment 4</td>
<td>FS₂BS₁</td>
</tr>
<tr>
<td>Treatment 5</td>
<td>FS₂BS₂</td>
</tr>
<tr>
<td>Treatment 6</td>
<td>FS₂BS₃</td>
</tr>
<tr>
<td>Treatment 7</td>
<td>FS₃BS₁</td>
</tr>
<tr>
<td>Treatment 8</td>
<td>FS₃BS₂</td>
</tr>
<tr>
<td>Treatment 9</td>
<td>FS₃BS₃</td>
</tr>
</tbody>
</table>
3.4.4 Statistical Analysis

The field data were statistically analyzed, using analysis of variance (ANOVA) for the Factorial Randomized Block (FRBD) Design (Panse and Sukhatme, 1967). The software used was Microsoft Excel (2013) using ANOVA procedure. The ANOVA procedure was used to evaluate the significance of each parameter and the interactions between parameters.
Plate 3.13: Tractor operated stubble shaver cum fertilizer applicator for sugarcane during field operation.

3.5 Soil parameters

3.5.1 Moisture content of the soil

Moisture content of the soil was determined by standard oven dry method. Five samples were taken from the different locations of the test plots before experiment and another five samples were taken from each treatment in different moisture boxes. These were kept in oven for 24 hours at the temperature of 105°C. The mass of wet and dry samples was determined and average moisture content on dry basis was calculated in the Appendix III. (Source: Indian Standard Test Code, 2720-2 (1973)).

\[
\text{Moisture Content (d. b.)} \% = \frac{W_w - W_d}{W_d} \times 10 \quad \ldots(3.15)
\]

Where,

\( W_w \) = Weight of the wet soil, g

\( W_d \) = Weight of the dry soil, g

3.5.2 Bulk density of the soil

Metallic core cylinder was used to take sample from the field. Samples were taken in 5.4 cm diameter and 8.8 cm long core sampler. The dry weight of the samples was calculated from the moisture content (w.b.) in the Appendix III. The ratio of the dry weight of the soil to the volume gives the bulk density (Punmia et al., 2009).
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Bulk density of soil (g/cm³) = \( \frac{W - (W \times MC/100)}{V} \)  \( \ldots \) (3.16)

Where,

\( W \) = Weight of moist soil collected, g
\( V \) = Volume of metallic core, cm³
\( MC \) = Moisture content of the soil, %

Plate 3.14: Measuring soil moisture content and bulk density of soil

3.6 Crop Parameters

3.6.1 Height of stubble before shaving

For the measurement of stubble before shaving, square ring of size 1m x 1m was randomly placed in field and its average were taken.

Plate 3.15: Measuring height of stubble before shaving

3.6.2 Stubble diameter

The diameter of the stubble is an important factor in designing the size of cutting for shaving unit of machine. The stubble was taken and maximum and minimum were measured by using Vernier Caliper.
3.6.3 Stubble population per m$^2$

For the measurement of stubble population, square ring of size 1m x 1m was randomly placed in field and no. of stubbles were measuring at different locations and its average were taken.

3.7 Operating parameters

The following operating parameters of the developed stubble shaver cum fertilizer applicator were measured with the help of described methods (Mehta and Verma, 1995). The detail results of these parameters are presented and discussed under section 4.3.1.

3.7.1 Width of coverage

The Width of coverage was determined by measuring the horizontal distance cut by blade with the help of measuring tape.
3.7.2 Operating speed

Outside the boundary of the test plot, two poles with red flags at 20 m apart were placed approximately in the middle of test run. The time required to travel the distance of 20 m was recorded and the speed of operation was calculated.

3.7.3 Measurement of Wheel slip

The amount of wheel slip was measured by marking the mark with colored tapes on the tractor drive wheel. The distance (P) covered in 10 revolutions with no load was also measured. After that, the distance travel (Q) in 10 revolutions with load was also measured on the same surface. Pegs were used for marking on the field. The percentage slip calculated with the following formula.

\[
\text{Percentage of wheel slip} = \left\{ \frac{(P-Q)}{P} \right\} \times 100
\]

\[\text{...(3.17)}\]

3.8 Performance parameters

The performance parameters for the stubble shaver cum fertilizer applicator were determined with the following methodology as per the test code for tractor operated equipment (Indian Standard Test Code, IS-6316:1993). The detail results of these parameters are presented and discussed under section 4.3.2.

3.8.1 Fuel consumption

The fuel consumption of the stubble shaver cum fertilizer applicator was measured as per the standard prescribed method. The fuel tank of tractor was filled to its full capacity before and after 20 m test run. The quantity of fuel filled at the end of test divided by the total time of operation gave the fuel consumption.

3.8.2 Draft of implement

A digital dynamometer (0-2000 kg) was attached to the front of the tractor on which stubble shaver cum fertilizer applicator was mounted. Another auxiliary tractor was used to pull the stubble shaver mounted tractor through the dynamometer. The auxiliary tractor pulls stubble shaver mounted tractor with the latter tractor in neutral gear but with the stubble shaver in operating position. Then the pull in the measured distance (20 m) as well as time taken to transverse were recorded. On the same field,
the stubble shaver was lifted and the pull was recorded. The difference between two reading gave the pull requirement of the stubble shaver.

Now, the draft calculated by the following formula.

\[ D = P \cos \theta \] 

\text{Where,}

\[ D = \text{Draft, kg} \]
\[ P = \text{Horizontal pull, kg} \]
\[ \theta = \text{pull angle, degree (Take zero degree for tractor operated stubble shaver cum fertilizer applicator)} \]

\subsection*{3.8.3 Time loss}

The time loss in turning of the tractor as well as cleaning adjustment of stubble shaver cum fertilizer applicator was observed as stated below.

\text{a) Turning time}

The time taken in turning at the end of each row was observed and recorded. Then, the total time loss in turning per unit area was worked out.

\text{b) Refilling of fertilizer}

The time required in refilling of fertilizer device was recorded and reported. The total time loss per unit area was worked out with the consideration of four events of refilling of fertilizer in hectare area

\subsection*{3.8.4 Power requirement (hp)}

The power requirement of the stubble shaver cum fertilizer applicator was calculated with the help of following formula.

\[ \text{Power requirement (hp)} = \frac{\text{draft (kg)} \times \text{speed (m/s)}}{75} \] 

\subsection*{3.8.5 Field Capacity}

The field capacities of the stubble shaver cum fertilizer applicator were calculated with the help of following formulae (Sahay, 2008).
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a) **Theoretical field capacity (ha/h)**:

The theoretical field capacity was calculated by following formula.

\[
\text{Theoretical field capacity } (\text{ha/h}) = \frac{\text{Theoretical width, } m \times \text{Speed, } \frac{\text{km}}{\text{h}}}{10} \quad \text{...(3.20)}
\]

b) **Field performance index (%)**:

The field performance index was calculated by using following formula.

\[
\text{Field performance index } (%) = \frac{\text{Te}}{\text{Te} + \text{Th} + \text{Ta}} \times 100 \quad \text{...(3.21)}
\]

Where,

- \( \text{Te} \) = time required to cover one hectare theoretically
- \( \text{Th} \) = time lost due to interruption which is not proportional to area like time of filling
- \( \text{Ta} \) = time lost due to interruption which is proportional to area like taken for turning

c) **Effective field capacity**:

The effective field capacity was calculated by using following formula.

\[
\text{EFC (ha/h)} = \text{field performance index} \times \text{theoretical field capacity} \quad \text{...(3.22)}
\]

3.8.6 **Depth of fertilizer placement**

The depth of fertilizer placement was measured with the help of scale. For these ten observations were taken and average was calculated.

Plate 3.18: Measuring depth of fertilizer placement
3.8.7 Depth of off barring

Depth of off barring is the actual working depth of tynes of implement. It is measured from ground level to furrow sole. It is measured with the help of depth scale.

![Plate 3.19: Measuring depth of off barring](Image)

3.8.8 Percentage of damage stubble (%):

For the measurement of damage stubble, square ring of size 1m x 1m was individual plots of 1.19 m x 20 m size placed in field and no. of damaged stubbles were measuring at different locations and its average were taken.

\[
\text{Percentage of damage stubble} = \frac{\text{No. of damage stubble after cutting}}{\text{No. of stubble before cutting}} \times 100 \quad \text{...(3.23)}
\]

![Plate 3.20: Sugarcane damaged stubble](Image)
3.8.9 Stubble shaving efficiency (%):

After completion of the stubble shaving operation of the machine from the individual plots of 1.19 m x 20 m size, number of stubbles per m$^2$ was measured with the help of square ring of size 1m x 1m before and after shaving operation at different locations and average was taken. Then stubble shaving efficiency was calculated with the help of following formula.

$$\text{Efficiency} = \frac{\text{No. of unshaved and damage stubble after operation}}{\text{No. of stubble before operation}} \times 100 \quad \ldots(3.24)$$

![Plate 3.21: Sugarcane shaving stubble](image)

3.9 Economics of stubble shaving methods

The economics of the manual stubble shaving, off baring and fertilizer application in terms of time energy and operation was observed and compared with the developed stubble shaver cum fertilizer applicator for sugarcane crop. The detailed results of these parameters are presented and discussed under section 4.4.

3.9.1 Manual stubble shaving method

The working capacity of a human labour varies in the course of a day. Generally, it is higher in the morning and declines in the middle of the day. Again, in the afternoon, it increases for a short period and then falls rapidly. It also depends upon the weather condition and kind of field work. The manual stubble shaving of sugarcane crop is mostly performed in a sitting or bending posture, which rapidly increases fatigue. In this method, the stubble shaving was stubble cut manually, fertilizer application was
manually and manually off barring operation are carried out separately by labour which results in wasting of time and requires increased human energy.

3.9.1 Time

During the experiment, time required per unit area for manual stubble shaving, off barring and fertilizer application of sugarcane crop as per farmer’s practice i.e. sugarcane plant with stubble shaving, off barring and fertilizer application them in row at middle of bed was observed and on the basis of it, the time required per hectare was determined.

3.9.1.2 Energy

The human energy utilized in manual stubble shaving method was evaluated by the following formula (Chaudhary, et al., 2006).

\[ E_m = 1.96 \times N_m \times T_m \]  
\( \ldots (3.25) \)

Where,

\( E_m \) = Manual energy expended, MJ/ha  
\( N_m \) = Number of labour spent on a farm activity  
\( T_m \) = useful time spent by a labour on a farm activity, h/ha

3.9.1.3 Cost of operations

On the basis of actual labour hours, the operational cost of manual harvesting was calculated. In the present study, it was considered as ₹250/- per day of eight hours and thereby the cost of operation per hectare was determined. During the peak season, the labour charge was ₹300 – 350/- per day of eight hours.

3.9.2. Mechanical stubble shaving method

The developed sugarcane stubble shaver was able to perform multiple operations such as stubble shaving, off barring and placement of basal dose of fertilizers all to gather while retaining the trash at the soil surface. Stubble shaver shaves the stubbles while off barring unit trims the root zone along the side wise of stubble and it forms a trench to place the fertilizer at uniform depth.
3.9.2.1 Time

During the field trial, the time required for mechanical stubble shaving per unit area of the crop was observed and on the basis of it, the time required per hectare was determined.

3.9.2.2 Energy

The mechanical energy utilized in mechanical stubble shaving of sugarcane crop was evaluated by the following formulae (Umar, 2003).

\[ E_f = 56.31 \times D \]  

...(3.26)

Where,

\( E_f \) = Fuel (diesel) energy expended, MJ/ha

\( D \) = Amount of fuel (diesel) consumed, l/ha

3.10 Cost of operation

The operation cost of the developed stubble shaver cum fertilizer applicator was worked out by the straight-line method as given in Appendix VII. Cost analysis was made for estimating the cost of different operations. In case of mechanical equipment, the fixed and variable costs were taken into consideration to estimate the cost of operations. Accurate cost estimates play an important role in every machinery management decision, namely, when to trade, which size to buy, how much to buy, etc.

A. Fixed Cost

Fixed costs of a machine include depreciation, costs of interest, taxes, insurance and shelter. Depreciation is usually the largest component of machine total costs. It measures the amount, by which the value of a machine decreases in time, whether it is used or not (Hunt, 2001).

There are several methods of calculating depreciation. The most common methods are straight line method, declining balance depreciation and decremental depreciation (Witney, 1988).
a. Depreciation

It means a loss in the value of a machine owning to time and use. Often, it is the largest of all costs. Machine depreciate, or have a loss of value, for several reasons, viz. age of machine, wear and tear of machine and obsolescence.

**Straight Line Method**: In the straight-line depreciation method, an equal reduction of value is used is used for each year the machine is owned. This method can always be used to estimate costs on a specific period of time, period of time, provided the proper salvage value is used for the age of the machine. Use of tractor and another implement was considered as 1000 and 200 h respectively. The annual depreciation value can be calculated from the following expression.

\[ D = \frac{P - S}{L \times H} \]  
\[ \text{...(3.27)} \]

Where,

\( D \) = average annual depreciation, Rs./h

\( P \) = purchase price, Rs.

\( S \) = salvage value, taken as the purchase price

\( L \) = life of machine, years

\( H \) = annual use of machine, h

b. Interest on Investment

In the agricultural machinery management interest is the secondary largest item of expanses. The interest is calculated on the average value of the machine.

\[ I = \frac{(P+S)}{2} \times \frac{i}{100} \]
\[ \text{...(3.28)} \]

Where,

\( I \) = interest on investment, Rs.

\( P \) = purchase price, Rs.

\( S \) = salvage value, taken as the purchase price
\[ I = \text{rate of interest} \]

\[ c. \quad \text{Taxes, housing, and insurance} = 2\% \text{ of initial investment} \quad \ldots (3.29) \]

B. Variable Cost

The variable costs of a machine as it names suggests vary with its use and they are expressed as costs per area worked or hour of operation. They are divided into maintenance and repair costs and costs of fuel and oil. The fuel consumption is based on the fuel requirements per hectare or per hour (Witney, 1988).

Fixed and variable costs give the overall costs of operation of a machine. Labour charges must be added depending on labour requirements of particular operation. The average labour costs include National insurance contribution, employer’s liability, overtime and benefits.

These costs depend on how much it is used. Variable costs include,

1. Repair and Maintenance cost = 5\% of purchase price
2. Fuel Cost = Rs. 65 / liter
3. Lubricants = 25\% of fuel cost

The straight-line method assumes equal reduction in the value of machine every year. Use of tractor and another implement was considered as 1000 and 200 h respectively.