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RESEARCH ARTICLE

Development and performance evaluation of narrow row spaced weeder

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Abstract

The weeds are undesirable, unwanted plants. Weeding is an important operation in crop production and labour-intensive agricultural operation. Weeding is generally done 15 - 20 days after sowing. Weeding is carried out at the initial stages of crop growth especially for controlling the weeds. After weeding operation, soil earthing-up provides favourable condition for crop growth. Weeding in narrow row spacing is difficult operation with less space between the two rows. In addition to that the soil compaction is the limiting factor due to the rotary motion of rotating blade in dry land weeder hence to avoid this, reciprocating motion type weeder was developed and performance was evaluated in narrow row spaced crop of 200 - 300 mm. The weeder consists of prime mover, ground wheel, power transmission unit, scotch yoke or spading mechanism, spading blade and earthing-up unit. Ground wheels were provided for the stability of the equipment. Scotch yoke mechanism consists of two turning pairs and two sliding pairs which were used for converting rotary motion into a reciprocating motion. The mechanism comprising of four links *viz.,* fixed link or frame, rotating cam disc, connecting arm and spading arm. The inversion is obtained by fixing any one of the links namely as frame. Spading blade was mounted at the end of connecting arm. Earthing-up operation was done with ridger type blade which was provided at rear side of spacing mechanism. The maximum rotating speed of cam disc and forward speed of unit was measured as 125 rpm and 1.5 km h^{-1} respectively. The power required was calculated as 0.39 kW and bite length of cutting blade is 190 mm. The results for field evaluation of developed prototype weeder revealed that the weeding efficiency, plant damage, actual field capacity and performance index are 78.35 %, 5.1 %, 0.03 ha h^{-1} and 571.95 respectively. The cost of the developed prototype weeder was ₹35000. The cost of operation of the machine was ₹3871.66 ha^{-1} compared to ₹6152 ha^{-1} for hand weeding.

Keywords: field capacity; narrow row; reciprocating motion; weeding efficiency

Introduction

Weeds are undesirable, unwanted plants, which compete with the crop for nutrients, moisture, space and solar radiation. Weeding is an important practice to be carried out during the initial stages of crop growth especially for controlling the weeds competing with the crop, stirring the soil for aerating the crop root zones and for burying the weeds into the soil. The qualitative and quantitative crop production depends upon the effectiveness and timeliness of weeding; as weeds are biggest crop enemy which causes 45 % of annual yield loss as compared to the disease as 20 %, insects as 30 % and pest as 5 % (1). Delay and negligence in weeding operation affect the crop yield and the loss in crop yield due to weeds vary from 40 to 60 % and in many cases cause complete crop failure (2). The common methods of weed control are manual, mechanical, chemical and integrated weed management out of which mechanical weeding is most effective in dry land farming. In India, most of the farmers are small and marginal, hence there is a demand of small implements that could be used as multi-functional equipment. Earthing-up involves cutting/ stirring, lifting, pulverizing and turning the soil from the central portion of the space between rows towards the base of the plants to cover the plant base or certain plant organs grown from below or at the soil surface. This leads to an increase groundnut surface area in contact with the soil and stimulates 'pegging' from the previously exposed portion of the stem. Hence earthing up is an important operation and it must be done during the weeding process, which could reduce labour, time and increase the crop yield (3).

Manual weeding requires huge labour force and accounts for about 25 per cent of the total labour requirement which is usually 900 to 120-man h ha^{-1} (4). Hand hoe or khurpi is another effective method adopted widely to control weeds in inter-row spaces of a line-sown crop. This method provides excellent physical condition to the crop growth by way of soil aeration through stirring of the soil. Thus, manual weeding can give a clean weeding; but it is a slow process.

Mechanical weed control techniques manage weed populations through physical methods that remove, kill or make the growing conditions unfavourable. The mechanical operation between the rows takes five to ten times less than manual weeding, even if a complementary weeding on the rows is necessary at the beginning of the crop. Apart from the investment cost, mechanical weeding does not imply any financial expenditure since the work is usually done by family members. Mechanical weeding devices can be more efficient and less labour-intensive than the hand weeding and they can be used to cover larger areas in a short period of time (5). Mechanical weeding loosens the soil around seedlings, improve the physical properties of soil and reduce environmental pollution compared to chemical weed control method. Mechanical weed control is an effective approach to replace chemical and manual weed control. On considering the above said facts, this study was undertaken to develop the power operated weeder for narrow row spaced crops and evaluated in groundnut field.

Materials and methods

Weeding in narrow row spacing is difficult operation with less space between the two rows (6). Hence, power operated single row weeding cum earthing-up equipment was developed and evaluated in narrow row spaced crops. Crop, weed and soil parameters were studied to develop a prototype weeder for narrow row spaced crops and is described below. The groundnut field is shown on Fig. 1.

Crop parameters

Various crop- and weed-related parameters were studied and the data was recorded. The important crop parameters that influenced the weeding operation were row to row spacing and shoot length of the crop. Row spacing is the main parameter that helps in allowing the equipment for operation. Hence, groundnut crops were selected for the study.

Weed parameters

Depth of weeding and power requirement for uprooting the weeds was decided by length of the root. Eight types of weeds were uprooted without damaging the roots by hand pulling.

Soil parameters

Soil parameters influencing the performance of weeders-such as soil moisture, cone index, bulk density, and pulling force-were measured in the field for the development of a weeder suitable for narrow row spacing. Soil moisture is determined by using a tension-meter at five different locations in the field. The average soil moisture content (db) was recorded during the study period. Bulk density is a measure of compactness of the soil. It is measured by using a core sampler at five different locations (7). The bulk density was calculated as

$$B = (W_s - W_c) / V_c \qquad \text{(Eqn. 1)}$$

Where, B = Bulk density of soil (g/mm^3), W_s= Weight of the container filled with soil (g), W_c= Weight of the empty container (g) and V_c=Volume of the container (g)

The average bulk density of the soil was observed that 1.38 g cm^{-3}.

Cone index is a measure of penetration resistance of the soil. The cone index was measured using manually operated CPM-84 digital cone penetrometer. The resistance offered by the soil for the penetration of cone were sensed by load cell and transmitted to the load indicator and recorded. The recorded data was transferred to the computer. It is measured in five different places in the field as shown in Fig. 2.

Pulling force depends on the soil moisture, cone index and root length of the weeds. It represents the resistance offered by the root zone of the weeds for uprooting. The force required to pull the weeds is determined using spring balance (Fig. 3). The experiment was carried out in field with various weeds and the observations were recorded.

Development of narrow row spaced weeder

Narrow row spaced weeder consists of prime mover, ground wheel, power transmission unit, scotch yoke or spading mechanism, spading blade and earthing-up unit (Fig. 4). Ground wheels were added to keep the equipment stable. The Scotch yoke mechanism, which includes two rotating pair and two sliding pair, was used to change rotary motion into back-and-forth (reciprocating) motion. This mechanism has four

Fig. 1. Groundnut field.

Fig. 2. Measurement of cone index.

Fig. 3. Pulling force measurement.

main parts namely as fixed link or frame, rotating cam disc, connecting arm, and spading arm. By fixing one of these parts (usually the frame), the mechanism works correctly. The spading blade was attached to the end of the connecting arm to perform soil work. For the earthing-up process (gathering soil around plants), a ridger-type blade was attached at the back of the mechanism. The maximum cam disc speed was measured at 125 rpm and the forward speed of the machine was 1.5 km h^{-1}. The power required to run the system was 0.39 kW and the blade cuts the soil with a bite length of 190 mm.

Performance evaluation of developed narrow row spaced weeder

The developed prototype was evaluated in a groundnut field at Oilseed department, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The performance of narrow row spaced weeder was assessed in terms of weeding efficiency, plant damage, field capacity and performance index (8).

The weeding efficiency was calculated using the weed count method. To determine weeding efficiency, the plot of 1000 x 1000 mm was taken and the number of weeds before as well as after the weeding operation was noted. It was calculated using the following formula;

$$e = \frac{(N_1 - N_2)}{N_2} X\ 100 \qquad \text{(Eqn. 2)}$$

Where, e = Weeding efficiency (%), N_1= Number of weeds before weeding and N_2= Number of weeds after weeding

To determine plant damage, the number of main crop present in 5 m row length before and after weeding was noted. The percentage of plant damage was calculated according to the formula,

$$d = P/Q \times 100 \qquad \text{(Eqn. 3)}$$

Where, d = Plant damage (%), P = Number of damaged main crop after weeding and Q = Number of main crop before weeding

The plot of 1000 x 1000 mm was marked and weeding was done with developed equipment. To determine the effective field capacity, the

$$C = (S \times W) / 10 \qquad \text{(Eqn. 4)}$$

average rate of area covered by the weeder and the time taken was recorded. It was calculated by the following formula:

Where, C = Actual field capacity (ha h^{-1}), W = Width of the area covered (m) and S = Speed of Operation (km h^{-1})

$$PI = \frac{[cx(100 - q) \times e]}{p} \qquad \text{(Eqn. 5)}$$

The performance index of the prototype weeder was calculated using the following equation

Where, PI = Performance index, c = Actual field capacity of the weeder (ha h^{-1}), q = Plant damage (%), e= Weeding index (%) and P = Power required to operate the weeder (kW)

The fuel consumption has direct effect on the economics of the weeder. It was measured by top fill method (9). The fuel tank was filled to full capacity before the testing at level condition. After completion of test operation, the amount of fuel required to top fill again is the fuel consumption for the test duration. The fuel consumption is expressed in terms of lh^{-1}

Fig. 4. Narrow row spaced weeder.

Results and Discussions

Measurement of crop, weed and soil parameters

The crop, weed and soil parameters are most influencing factors in development of narrow row spaced weeder. The average row to row spacing for the groundnut in the range of 220 to 250 and plant to plant spacing is 100 to 120 mm. The shoot length of the groundnut crop was measured and it was recorded as 300 to 550 mm. The average root zone depth of weed varies between 70 to 100 mm. The soil parameters such

as soil moisture content of 18.56 % (db), bulk density of 1.38 g cm^{-3}, cone index of 23.83 kg cm^{-2} and pulling force of 5.82 kgf, were identified during the study period.

Performance evaluation of developed narrow row spaced weeder

Fig. 5. Performance evaluation of narrow row spaced weeder.

The developed power operated weeder for narrow spaced crop was evaluated with optimized levels of variables in narrow row spaced field (Fig. 5). The prototype was tested in 5000 mm length of strip with 300 x 200 mm plant geometry of groundnut field.

The weeding efficiency of developed weeder was determined and presented in Table 1. The weeding efficiency was observed as 78.35 per cent during field evaluation. The plant damage was recorded as 5.10 per cent during field evaluation and furnished in Table 2. The actual field capacity of prototype was calculated as 0.03 ha h^{-1}. The performance index of developed weeding cum earthing-up equipment was 571.95 (Table 3). Fuel consumption of the weeder was calculated by "topping method". It was observed that the fuel consumption of narrow row spaced weeder varied between 0.527 L h^{-1} to 0.612 L h^{-1} and the average fuel consumption was 0.5 L h^{-1}.

Table 1. Weeding efficiency of weeding cum earthing-up equipment

Sl. No.	Parameter	Value
1.	Crop	Groundnut
2.	Row to row spacing (mm)	220 - 250mm
3.	Before weeding (nos.)	157
4.	After weeding (nos.)	34
5.	Weeding efficiency (per cent)	78.35

Findings

The soil is one of the most influencing parameters to design cutting blade in development of a power operated weeding cum earthing-up equipment. Based on the optimized level of variables the narrow row spaced weeder was developed and evaluated in groundnut field. The weeding efficiency, plant damage, actual field capacity and performance index were found as 78.35 %, 5.1 %, 0.03 ha h^{-1} and 571.95 respectively from the study. The cost of the developed prototype weeder cum earthing up equipment was Rs. 35000. The actual field capacity of the weeder is 0.03 ha h^{-1} and the cost of operation of the machine was Rs. 3871.66 ha^{-1} compared to Rs. 6152 ha^{-1} for hand weeding.

Table 2. Plant damage

Sl. No.	Parameter	Value
1	No. of plants in a row	333
2	No. of damaged plant in a row	17
3	Plant damage (per cent)	5.10

Table 3. Performance index for developed weeder

Sl. No.	Parameter	Value
1	Actual field capacity (ha h^{-1})	0.03
2	Plant damage (per cent)	5.1
3	Weeding efficiency (per cent)	78.35
4	Power (kW)	0.39
5	Performance Index (per cent)	571.95

Authors' contributions

All authors have contributed equally to the conception, design and drafting of this review article.

Compliance with ethical standards

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical issues: None

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