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Effective Seed Placement and Weed Management in Dry Direct Seeded Rice (DDSR) using Zero Till Seed Drill cum Herbicide Applicator

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***Abstract*:** Rice is typically grown in Asia by transplanting seedlings into puddled soil (land preparation with wet tillage). With accelerated economic growth and COVID-19 outbreak with subsequent lockdown has led to the shortage of labour. There was concern among the farmers on timely completion of transplanting due to shortage of labour. Dry Direct seeded rice (DDSR) is one such technique, probably the oldest method of crop establishment, is gaining popularity because of its low-input requirement. To overcome the effect of rain on the seeds sown by DDSR technique there is a need for creating a provision for settling the seeds in place. The energy spent in the field for individual sowing and herbicide application practice can be reduced by combining both operations. In view of these, the following study was undertaken to perform simultaneous sowing and herbicide application in DDSR technique using a zero till drill and herbicide applicator. A tractor operated zero-till drill cum herbicide applicator serves as a multi-purpose implement that helps in carrying out two or more operations simultaneously. The sole purpose of the implement was to settle the seed in the furrow by using levellers followed by herbicide application which acts as a pre-emergence herbicide preventing the immediate emergence of weeds. By adopting this practice, about 300 MJ ha^{-1} energy and Rs. 3000 spent for weed control can be saved. The emergence of the seed was not affected by the herbicide application as they are separated using a protective hood.

Keywords: Dry direct seeded rice, Herbicide, Nozzles, Zero till drill, Weeding

Rice is the world's most cultured crop, and more than half of the world's population devours it as a staple food. With the continuous rising in world's population, there is a need to increase rice productivity to meet global rice demand. The chances of increasing the rice-growing area in the near future are beyond our control. So the additional rice production must come from increased productivity. The main difficulty is to make this improvement while using less water, labour and chemicals as well as assuring long-term viability. Rice is typically grown in Asia by transplanting seedlings into puddled soil (land preparation with wet tillage). Puddling benefits rice because it reduces water loss through percolation, controls weeds, makes seedling establishment easier and creates anaerobic conditions to improve nutrient availability. On the other hand, puddling repeatedly has a negative impact on soil physical qualities by disintegrating soil aggregates, limiting permeability in subsurface layers and producing hard pans at shallow depths (Sharma et al 2004). It's a conventional practise that requires not only a lot of water but also a lot of effort. Various issues such as dwindling water tables, labour shortages during peak seasons and declining soil health, demand an alternate establishment strategy to ensure rice yield and natural resource sustainability. With accelerated economic growth and COVID-19 outbreak with subsequent lockdown has led to the shortage of labour. There was concern among the farmers on timely completion of transplanting due to shortage of labour. Direct seeded rice (DSR) is one such technique, probably the oldest method of crop establishment, is gaining popularity because of its low-input requirement. DDSR is direct seeding of rice in which seeds are directly sown in the field rather than using transplanting seedlings from the nursery. It aims to sow short duration and high yield varieties. It is done through DSR machines (Zero till drill, Happy seeder etc.,) which are used for planting seeds directly into combine harvested paddy fields.

Farmers who practiced DDSR technique, complained about rodent attacks. Usually in normal transplanting method, the crops are not vulnerable to rodent attacks. This is because, they cannot survive in flooded fields. Rice is commonly farmed using this DSR approach in Bangladesh and India, but it has been discovered that poor weed management procedures resulted in ineffective and poor weed control in DSR, resulting in yield reductions of 50-91 percent (Gupta et al 2006, Hussain et al 2008). In farmers' field trials in Tevai, Uttaranchal, India, herbicide spraying within two days of sowing resulted in good weed control and higher grain yield in DSR (Singh et al 2005), indicating that adopting appropriate weed management practises at the right time is critical to harvesting good paddy yields of direct seeded rice (Akhtar et al 2010). The farmers complained about DDSR technique getting effected by overnight rains that transport the seeds and reducing the yield. And since it is a new technique, farmers are having misconceptions and fears related to yield.

Hence to overcome the effect of rain on the seeds sown there is a need for creating a provision for settling the seeds in place. Also the energy spent in the field for individual sowing and herbicide application practice can be reduced by combining both operations. In view of these, the following study was undertaken. The objective of the study was to perform simultaneous sowing and herbicide application in DDSR technique using a zero till drill and herbicide applicator.

MATERIAL AND METHODS

The experiments are conducted at the Department of Farm Machinery and Power Engineering, Dr. NTR College of Agricultural Engineering, ANGRAU, Bapatla. A herbicide spraying technology/sprayer was designed and attached behind the existing tractor operated zero till seed drill for simultaneous sowing and herbicide application. The major components of the machine are a simple leveller, hood to separate seed from herbicide, triplex plunger pump and a spray boom fitted with nozzles.

Existing zero-till seed-cum-fertilizer drill: Zero-till-drill consists of frame, seed box, fertilizer box, seed metering mechanism, fertilizer metering mechanism, seed tubes, furrow opener, seed/fertiliser adjusting mechanism and transport cum power transmitting wheel. The frame is built of mild steel box section of dimensions 185 x 60 cm. There are 9 to 13 inverted T-type furrow openers on it. When affixed to a tine, these T-type furrow openers open a tiny slit 3-5 cm wide. The tynes are clamped in place to achieve infinite row spacing, as required by various crops. Furrow openers are positioned 17.5 cm apart in a zero-till seed-cum-fertilizer drill. The fundamental difference between a zero-till drill and a standard drill is that instead of reversible shovels, it features inverted T-type furrow openers placed on the tynes. The main benefit of inverted t-type furrow openers is that they do not generate clods, uses less draught, and penetrate the soil more easily.

Design of leveller: Inverted T-type furrow opener provided on the tynes creates a small opening less than 3 cm depth to drop the seed. Now the purpose is to design a leveller capable enough to close this opening without creating much disturbance on the soil. An annealed mild steel material of 5 mm thickness will be used to develop supporting flanges and end collector's plates. Supporting flanges will be spaced at 20 cm apart as shown in fig. 2 so that it matches the tyne spacings. End collector plates help in rolling the soil in the direction of travel covering the opened furrows.

Immediately after closing the furrow pre emergence herbicide will be applied to prevent weeds. There is a chance of herbicide coming in contact with seeds due to drift. So in order to prevent this, a protective hood will be installed on the supporting flanges as shown in Figure 2. A light weight 1 mm thick GI sheet will be used for developing protective hood.

Static structural analysis of leveller: Leveller is 1.6 m long and has to withstand soil resistance and undulations in the

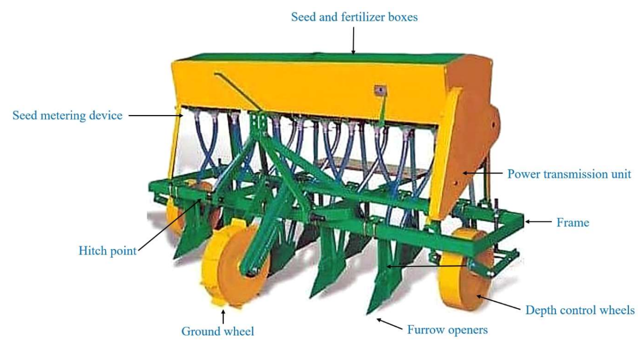

Fig. 1. Zero-till seed-cum-fertilizer drill

Table 1. Specifications of the existing zero-till seed-cum-fertilizer drill

Particulars	Zero-till drill
Working width, cm	180-200
Row spacing, cm	18-20 (Adjustable)
Furrow opener	Inverted "T" and narrow shoe
No of furrow openers	9/11
Drive wheel	Lug-front mounted
Weight, KN	2100
Unit Price, (Rs)	75,000

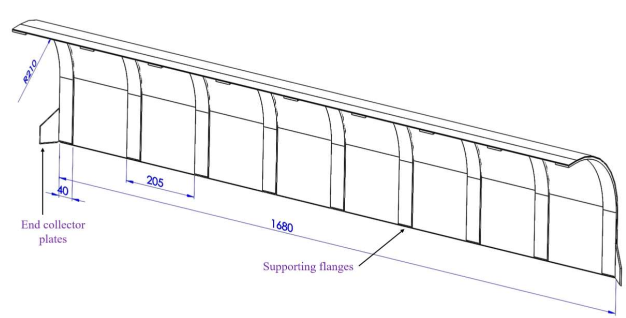

Fig. 2. Isometric view of leveller

field. So a static structural analysis has been carried out in solid-works simulation software with assumed load of 1000 N (including weight of frame, soil resistance and undulations). Mild steel AISI 1018 was applied to the body. A soil resistance of 1000 N has been applied on the face of leveller to determine the strength of the design. The stress, displacement and factor of safety plots of leveller were shown in Figure 3 to 5. Upon application of 1000 N, a maximum stress of 8.07×10^{7} N m^{-2} was experienced by the body which is in safe limit since yield stress of selected material was much higher i.e., 4.7×10^{8} N m^{-2}. In case of static displacement, upon 1000 N load a very less displacement has been noted. At the point where flange is welded with frame, a negligible displacement of 1×10^{-30} mm was noted. At the face of leveller a displacement i.e., backward thrust of 5.3 mm was noted but no failure in the design was observed. Factor of safety was about 5.8 i.e., it can withstand 5.8 times more load than the applied load.

Design of herbicide applicator: In direct-seeded rice systems, herbicides are one of the most essential instruments for weed control. Because of the scarcity of labour at important weeding times and high labour costs, herbicide use in these systems is projected to rise in the near future. Improper and ineffective herbicide application can result in nontargeted plant damage, a large waste of chemicals that pollutes the environment, and harmful impacts on human health. Herbicides can be applied with a knapsack, foot sprayer or pedal pump, as well as tractor-mounted and aerial sprayers; however, in Asia, knapsack sprayers are the most common (Chauhan 2012). Flat fan, hollow cone nozzle and solid cone nozzles are among the spray nozzles utilized. In multiple-nozzle booms, flat fan nozzles are employed because the spray pattern is tapered from the centre to the edges. By overlapping nearby nozzles, such patterns aid in the creation of consistent coverage. Hence, a plunger type pump compatible with tractor p.t.o. as shown in Figure 4 was selected to integrate with tractor operated zero till drill. Power to the sprayer will be tapped from ground wheel using a simple four bar mechanism.

Plunger pump: The pump had to supply four nozzles at 2.25 L min^{-1} discharge each at high pressure. The HTP (Horizontal

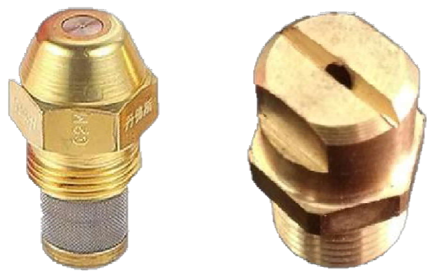

Fig. 4. Solid cone and flat fan nozzles

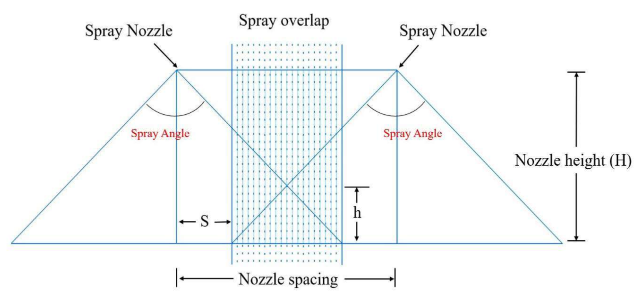

Fig. 5. Effect of nozzle height on spray pattern

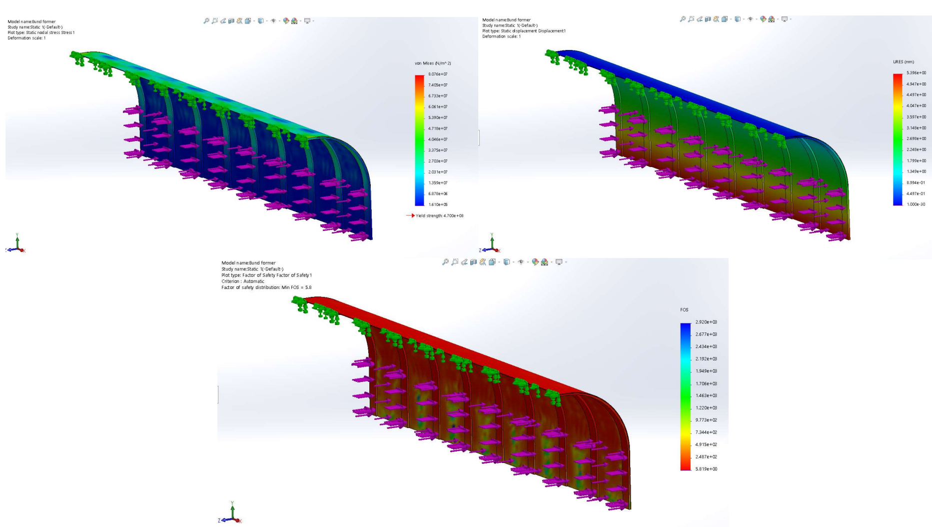

Fig. 3. Stress distribution, displacement curve and factor of safety curve of the designed leveller

Triplex Pump) was chosen, which has a free discharge capacity of 40-45 litres per minute. The pump's installation and driving arrangement from the tractor's PTO (Power Take Off) was at the rear. For operation, the shut off trigger valve of the lance is closed and the engine/ electric motor is started to actuate the pump. The pump draws the spray liquid from the tank, imparts pressure energy and sends it to the delivery line/lines (Mohan et al 2021).

Patternator: Effectiveness of a sprayer nozzle depends on the ability to provide good deposition on target area. Calibration of sprayer nozzles was usually carried out on a spray patternator. It is the most simple method of evaluating the spray distribution by a nozzle. A simple channel roof cover can also be used as a patternator. Grooves are maintained at equal spacing and mounted on an inclined stand. Directly below the grooves a provision was created to hold the corresponding spray collecting jars. To mount the spray nozzle at certain height, a height regulator or adjustable frame provided alongside the patternator. Markings were made on the mounting frame to adjust the height of nozzle from the surface.

Solid cone nozzle: Solid cone nozzle consists of an additional internal jet which strikes the rotating liquid within the orifice. Due to this impact the breaking of liquid droplets takes place causing fine distribution of spray particles inside the cone.

Flat fan nozzle: In a flat fan nozzle the liquid droplets are sprayed in the shape of a thin sheet. It is widely used for spraying pesticides over and between the rows. A flat fan nozzle attached with spray lance was operated at low pressure to maintain the spray pattern. Size of the liquid droplets will be larger than that in case of other nozzles.

Design considerations: Nozzle mounting height can be decided directly by measuring the swath length and spray angle. Tan of spray angle is equal to the division of nozzle mounting height and half of swath length. 2

$$\text{Tan}\,\frac{\theta}{2}=\frac{S}{h}$$

$$\frac{H}{h}=\frac{\text{Overlap}+S}{S}$$

Where,

θ = Spray angle, H = Nozzle mounting height, S = Half of swath length, h = Height of overlap

Uniformity and density of spray deposition varies from centre to side. Density of the spray will be thick in the middle and further becomes thin over the edges. So overlap of the spray is recommended in a multi nozzle or boom type sprayer for uniform distribution.

The spacing between the nozzles was calculated by given formula:

$$S_d = 2h\,\text{Tan}(\frac{\theta s}{2})(1-\frac{S}{100})$$

Where,

S_d = Spacing between nozzles, mm, h = boom height, mm, θ_s= Nozzle spray angle

s = Overlap, %

An overlap of 40% for fan nozzles, 25% for cone nozzles and 100% for flood jet has been recommended (Varshney et al 2004))

The length of the boom was calculated by using the following formula.

$$L = n \times S_d$$

Where,

L = Length of the boom, S_d = Spacing between the nozzles, mm, n = Number of nozzles

From above formula's and design considerations, the following have been calculate. Let the possible nozzle spacing be 45 cm with a spray angle of 60° and an overlap of 40 %. The required height of mounting will be,

$$\text{Tan}\,\frac{\theta}{2}=\frac{S}{h}\quad \text{(Since, overlap = 18 cm, } \theta = 60^0\text{, s= 13.5 cm)}$$

Height of overlap, h = 23 cm

$$\frac{H}{h}=\frac{\text{Overlap}+S}{S}$$

Height of mounting, H = 50 cm

Discharge rate: Discharge rate is the amount of herbicide discharged from the nozzles. It is calculated as $l\,h^{-1}$.

Discharge/Flow rate is determined by

$$Q=\frac{1}{600}\times M\times A\times V$$

Where, Q = Flow rate/discharge, m^3/s, M = Application rate, $l\,ha^{-1}$, A = Area of cross section of pipe, m^2

V = Velocity of sprayer, kmph

From above formula's and design considerations, the following have been calculated **(Section 2.3)**

Application rate (M) = 300 $l\,ha^{-1}$

(Since, active ingredients in concentrated herbicide solution are high, dilution with prescribed amount of water is needed. 3 g for every 1000 ml of water is usually preferred. Herbicide application rate was limited to 1000 g a.i per ha (Singh et al 2016) (Singh et al 2015))

Area of cross section of pipe (A) = 1.8 m^2

Velocity of sprayer (V) = 2.5 kmph

$$\text{Flow rate/discharge from nozzle} = \frac{1}{600}\times M\times A\times V = 2.25\ l\ min^{-1}$$

Total discharge rate from boom = flow rate of nozzle × No. of nozzles = 2.25 × 4 = 9 $l\ min^{-1}$

The available tank capacity is 75 litres (2 No's), the time required to apply 150 litres of chemical will be

$$= \frac{150 \times 10 - 3}{9 \times 10 - 3} = 16.6\,\text{min}$$

Thus, total area covered in 16.6 min will be=

$$16.6\text{ min} \times \frac{2.5 \times 1000}{60} \times 18$$

= 1250 m^2 or 0.125 ha

Hence 8 fillings will be needed to cover over a hectare of land.

Suggestions

- Use clean water and a plastic container to make spray solution as herbicides bind with suspended soil particles and metal surfaces (e.g., iron bucket).
- Use a multiple-nozzle boom fitted with flat-fan nozzles for full coverage

Tractor operated zero-till drill cum herbicide applicator: A tractor operated zero-till drill cum herbicide applicator serves as a multi-purpose implement that helps in carrying out two or more operations simultaneously. The sole purpose of the implement was to settle the seed in the furrow by using levellers followed by herbicide application which prevents the emergence of weeds. The leveller and spray nozzles are spaced apart to prevent contact with seed. Spray nozzles frame was placed at a distance of 52 cm from the frame which holds two 75 litre sprayer tanks as shown in Figure 7. From the design calculations, spray boom with 4 nozzles at a spacing of 45 cm will be fixed at 45-50 cm height from ground as shown in Figure 6.

Field capacity: It is the actual area covered by the machine based on its total time consumed and actual working width under field condition. It is expressed in terms of area covered per unit time of operation. It is calculated by

$$\text{Field capacity (ha h}^{-1}\text{)} = \frac{\text{Actual area covered}}{\text{Total time consumed}}$$

(Mohan and Jayan 2021)

Field efficiency: Field efficiency is the actual average rate of coverage by the machine, based upon the total operation set time. It is a function of the rated width of the machine, speed of operation and the amount of time lost during the operations. Effective field capacity is usually expressed as hectare per hour (Kepner et al 2005).

$$\text{Field efficiency (\%)} = \frac{\text{Actual field capacity}}{\text{Theoritical field capacity}}$$

(Mohan and Jayan 2021)

Application rate: It is the ratio of volume of herbicide sprayed in the test plot and the area of test plot.

$$\text{Application rate, 1 ha}^{-1} = \frac{\text{Volume of herbicide sprayed}}{\text{Area of test plot}}$$

RESULTS AND DISCUSSION

Laboratory evaluation of triaxial plunger pump was carried out with two different nozzles at three operating pressures and three mounting heights. Variation in discharge with change in operating pressure and nozzle height, change in swath width with pressure were analysed by using a patternator (Farooq et al 2001).

Variation in discharge rate w.r.to operating pressure and mounting height in a solid cone nozzle: Solid cone nozzle emits thick sprays throughout the diameter with equal density of spray particles. Variation in discharge along the grooves was comparatively less than the other nozzles. Figure 8 shows the parabolic increase and decrease in discharge rate from 4^{th} to 12^{th} groove at 50 cm mounting height. The discharge rate of solid cone nozzle ranged from 5-130, 5-135 and 5-150 ml min^{-1} with change in operating pressure from 2-3 kg cm^{-2} where the nozzle was fixed at a height of 30, 40 and 50 cm respectively.

Variation in discharge rate w.r.to operating pressure and mounting height in a flat fan nozzle: A flat fan nozzle achieves more spread of spray over the grooves compared to solid cone and hollow cone nozzles. Figure 9 clearly shows the uniform spray distribution throughout the grooves with change in operating pressure. The flat fan nozzle discharge rate varied from 15-150, 5-140 and 5-155 ml min^{-1} with change in operating pressure from 2-3 kg cm^{-2} where the nozzle is fixed at a height of 30, 40 and 50 cm respectively.

Variation in swath width w.r.to operating pressure and mounting height: Swath width is a major operational parameter which is effected by operational pressure, mounting height and type of nozzle during laboratory and

Table 2. Levels of variables

Description of variable	Levels	No. of levels
Type of nozzle	Solid cone Flat fan	3
Operating pressure	2 kg cm^{-2} 2.5 kg cm^{-2} 3 kg cm^{-2}	3
Mounting height	30 cm 40 cm 50 cm	3

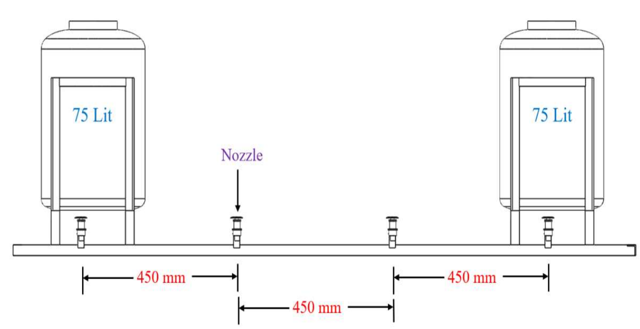

Fig. 6. Supporting frame and nozzle's arrangement

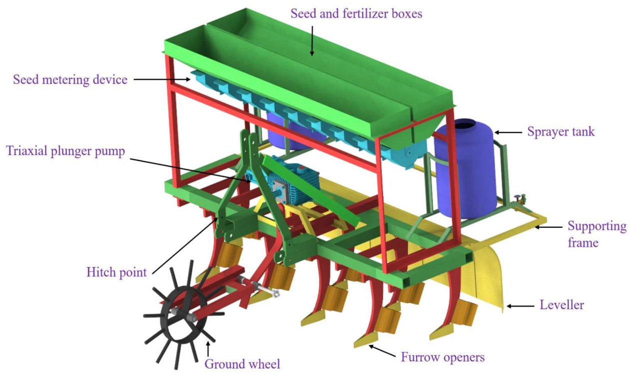

Fig. 7. Isometric view of zero till drill with herbicide applicator

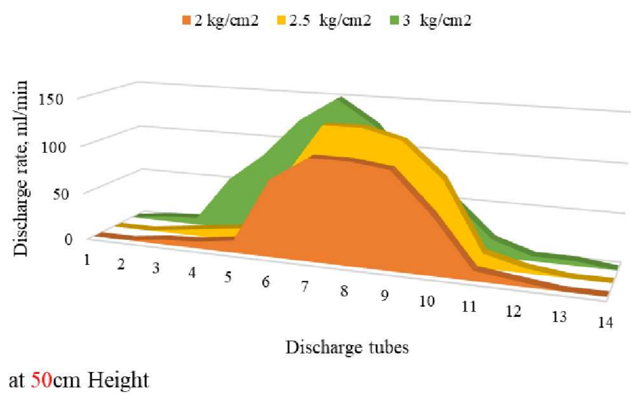

Fig. 8. Variation in discharge rate at 50 cm height

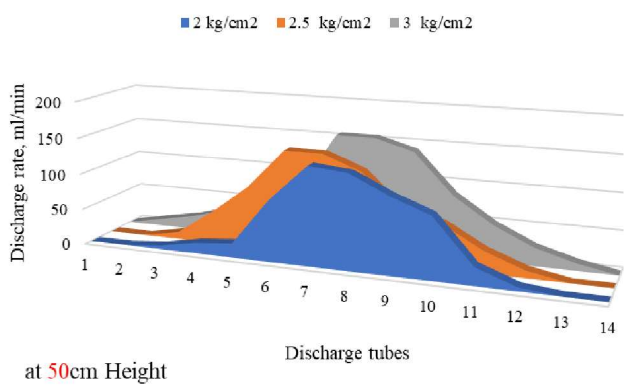

Fig. 9. Variation in discharge rate at 50 cm height

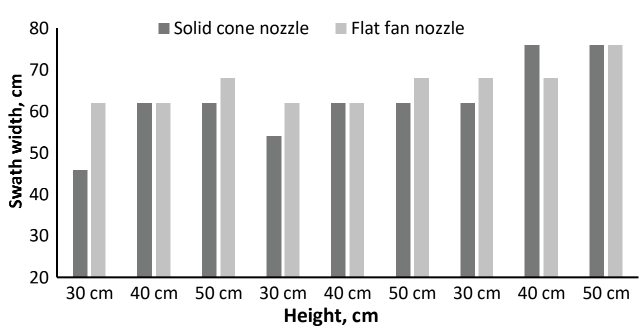

Fig. 10. Variation in swath width with mounting height and operating pressure

field evaluation of a sprayer. A flat fan nozzle covers more swath width compared to solid cone nozzles as shown in Figure 10. At 50 cm mounting height and 3 kg cm^{-2} pressure, equal swath width was achieved for both the nozzles.

Solid cone nozzle swath width ranged in between 46-76 cm at a height of 30-50 cm with operating pressure of 2-3 kg cm^{-2} respectively. Flat fan nozzle swath width varies from 62-76 cm at a height of 30-50 cm with a pressure of 2-3 kg cm^{-2} respectively. Width of the swath was increased with increasing the height of the nozzle. The actual field capacity of the machine was found to be 0.18 ha h^{-1} at a forward speed of 1.5 kmph, 0.20 ha h^{-1} at 1.7 kmph and 0.23 ha h^{-1} at 2.0 kmph. Maximum field capacity was noted at a forward speed of 2.0 kmph but the application rate of herbicide was relatively less. Leveller attachment immediately behind the furrow openers helped in settling the seeds followed by herbicide application.

CONCLUSION

Rice is the world's most cultured crop, and more than half of the world's population devours it as a staple food. Puddling is a conventional practise that requires not only a lot of water but also a lot of effort. It benefits rice because it reduces water loss through percolation, but puddling repeatedly has a negative impact on soil physical qualities like limiting permeability in subsurface layers and producing hard pans at shallow depths. DDSR is direct seeding of rice in which seeds are directly sown in the field rather than using transplanting seedlings from the nursery. Due to sudden rains, seeds sown with DDSR technique are transported. Also due to direct drilling of seeds without any prior tillage, emergence rate of weeds is high. Hence a tractor operated zero-till drill cum herbicide applicator must be adopted since it serves as a multi-purpose implement that helps in carrying out two or more operations simultaneously. The sole purpose of the implement was to settle the seed in the furrow by using levellers followed by herbicide application which prevents the emergence of weeds. Maximum field capacity of the machine was noted at a forward speed of 2.0 kmph i.e., 0.23 ha h^{-1}. By adopting this practice, about 300 MJ ha^{-1} energy and Rs. 3000 spent for weed control can be saved. Herbicide application did not affect the emergence rate of seed and it will economically benefit the farmers in overcoming the drudgery.

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