Investigation on the Influence of Machine and Operational Parameters for the Development of a Manually-Drawn Rice Seeder for Direct Sowing

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ABSTRACT

This study was conducted to develop a direct seeder based on the machine and operational parameters involved in direct sowing of rice. In the existing models of the direct rice seeder, the dry/wet seeds are drilled continuously at a higher seed rate than the recommended and without desired seed to seed spacing. It is observed that as the seed drum empties the seed rate obtained increases steadily and steeply at the end i.e. the uniformity in seed rate is not maintained through out its operation. Hence investigation was carried out to study the influence of the machine and operational parameters viz., drum shape, diameter of drum, diameter of seed metering hole, number of seed metering holes and forward speed of operation on seed rate of the rice drum seeder in the laboratory condition. The hyperboloid drum shape was optimized with 200 mm drum diameter, 9 number of seed metering holes having 10 mm diameter of seed metering hole and 1.0 km h^{-1} forward speed of operation. The seeder developed using the hyperboloid drum performed better when compared to the existing seeder.

Keywords: direct sowing, rice seeder, machine parameters, operational parameters

1. INTRODUCTION

The transplanting of rice seedlings being a high labour-intensive and expensive operation needs to be substituted by direct seeding which could reduce labour needs by more than 20 per cent in terms of working hours (Pradhan, 1969; Fujimoto, 1991; Santhi *et al.*, 1998.). Direct seeding is an age-old practice of paddy cultivation in India, particularly in rain fed areas, where farmers totally eliminate seedling preparation in nursery and the required transplanting operation. Rice is either dry seeded on well prepared dry/moist soil or wet seeded on a puddled soil. Drum seeder is becoming popular for wet seeding because of its less initial investment, easy operation, and low repair and maintenance cost. Different models of drum seeders which are manually operated and are highly suitable for fragmented Indian fields were developed by International Rice Research Institute, Philippines and modified by different organizations/institutions. In all these models, the dry/wet seeds are drilled continuously at a higher seed rate than the recommended seed rate and without any seed to seed spacing. It is observed that as the seed drum empties, the seed rate obtained increases steadily and steeply at the end i.e. the uniformity in seed rate is not maintained throughout the operation. Hence, a modified drum seeder which provides uniform seed distribution with respect to time will be more useful in maintaining uniform plant population. This creates a condition similar to that of the transplanted crop to have a noticeable improvement in crop growth environment. Also the problem of thinning the crop sown by presently available models of drum seeders could be eliminated.

Pradhan (1969) demonstrated the successful adoption of direct seeding in lines in puddled rice fields using a seeder. This practice could replace transplanting without much reduction in yield but with reduced cost of operation. Row sown rice showed rapid establishment and greater vegetative growth due to absence of transplanting shock. Sowing of pre-germinated paddy seeds as an alternative to transplanting has gained acceptance over the years. Kandasamy (1987) reported a saving of 298.8 mm of water under direct sown crop, which was 22.1 per cent less than the amount used by transplanted crop. Wang and Sun (1990) noticed that duration was shortened by 7-15 days in direct seeded rice compared to transplanted rice. Shekar and Singh (1991) stated that direct seeding of sprouted seeds under puddled condition resulted in significant improvement in yield attributes like number of effective tillers and grain yield. Borlagdan and Yamauchi (1995) developed a drum seeder at IRRI for sowing pre-germinated seeds on the surface of puddled soil. The seeder was tested with five rice varieties with varying seed rate of 38 to 80 kg ha^{-1}. The shapes of the drums were cylindrical. The number of tillers per unit area and the leaf area index were more in row sown rice than in broadcast and transplanted rice (Bharathi, 1996). Based on the available literature, the investigation was carried out to study the influence of the machine and operational parameters viz., drum shape, diameter of drum, diameter of seed metering hole, number of seed metering holes and forward speed affected the seed rate of rice drum seeders.

2. MATERIALS AND METHODS

2.1 Construction of Test Rig

To measure the seed rate of paddy at various forward speeds with different machine parameters, a test rig was developed. The test rig consists of a mainframe and variable speed drive. The main frame was a cuboid shaped with members at all its edges fabricated with 60 x 38 mm mild steel angle sections. The over all dimension of the unit is 1300 x 670 x 820 mm. At one end of the top frame, a 25 mm diameter shaft was mounted through a set of bush bearings for mounting the seed drum. At the other end, a variable speed drive operated by a 0.5 kW electric motor was mounted.

The drive to the seed drum rotating shaft is transmitted through counter shafts and pulley system. A control switch was provided on the main frame to operate the electric motor. The speed obtained from the electric motor was reduced from 1420 rpm to the required level of 9 to 11 rpm for seed drum through the variable speed drive mechanism and pulleys mounted on the counter shafts. The test seed drum was mounted on the drum shaft of the test rig. A hopper made of 1.5 mm GI sheet was provided at the bottom of the drum to collect the falling seeds. The seeds were collected in a container for a known number of revolutions of the seed drum and weighed.

2.2 Machine Parameters

The machine parameters that affect the performance of a drum seeder are drum shape (S), drum diameter (D), diameter of seed metering hole (d), number of seed metering holes (n) and forward speed (v) of operation. The influence of these parameters on seed rate was investigated under the laboratory conditions.

Three shapes of drum *viz.*, cylindrical, hyperboloid and cylindrical ellipsoid with four diameters of 150, 175, 200 and 250 mm in each were fabricated (Fig.1). The drums were made of 22 gauge GI sheet material with provision to mount strips of GI sheets having 5, 6, 7, 8 and 9 number of holes with varying hole diameters of 7, 9 and 11 mm. For each size of drum, the desired diameter of seed metering hole with selected number of holes can be obtained by mounting the required strip on the drum. The drums were equipped with 25 mm diameter mild steel bushes on both ends to facilitate mounting on the drive shaft of the test rig.

Figure1. Seed drums for laboratory study

2.3 Optimization of Machine Parameters

The developed test rig was used to evaluate the seed drums with selected levels of variables in order to achieve the desired seed rate of paddy. A drum with seed metering holes of specific diameter and number of holes was mounted on the test rig and seeds were filled into the drum to 2/3rd of its volume and the drum was rotated at selected forward speed. The seeds falling from the drum were collected for 50 revolutions and weighed. Each test was replicated three times. Similar testing procedure was adopted for all the three shapes of the drums and for all combinations of the test parameters.

2.4 Statistical Analysis and Mathematical Modeling

The results were analyzed through Statistical Packages for Social Studies (SPSS). The level of significance between treatments was tested using DMRT. For optimization the mathematical models were established. From the results of the analysis, the best combination of the parameters was chosen to obtain the recommended seed rate of 80 kg ha^{-1}.

2.5 Per Cent Variation in Seed Discharge

From the results of the analysis of the laboratory studies, the prototype drum with optimized parameters was fabricated. The drum having optimized parameters was further tested in the test rig with two levels of filling *viz.*, half and two-third of the drum volume to analyze the effect of filling on per cent variation in seed discharge. The seeds were collected at one-minute interval till the drum was emptied. From the values of weight of seeds collected, the per cent variation in seed discharge was calculated. The percent deviation of mass of the seeds collected from the drum at each minute interval was computed using the following expression.

$$\text{Per cent variation in seed discharge} = \frac{(M_a - M_r)}{M_r} \times 100 \qquad (1)$$

where,

M_a = Mass rate of seeds collected from the drum, g/min
M_r = Mass rate of seeds required to be dropped to achieve the recommended seed rate, g/min

The percent variation in seed discharge obtained at each minute interval must be minimum to get the uniform plant population throughout the field.

2.6 Effect of Baffles on Per Cent Variation in Seed Discharge

For uniform flow of seeds from the drum, the percent variation in seed discharge should be minimum. For achieving the above goal, baffles of varying configuration were provided in between the holes inside the drum with a view to reduce the bridging effect thereby the uniformity of flow is reached. These baffles were fixed in between the holes to disturb the bridging effect and to create agitation of seeds on rotation of the seed drum. The seed drums after incorporation of baffles were mounted on the test rig and the uniformity of seed distribution was measured. The results are recorded to analyze the effect of baffles on percent variation in seed discharge.

2.7 Development of Prototype Drum Seeder

A manually operated prototype model of the drum seeder with optimized levels of variables was fabricated for performance evaluation (Fig.2.). The unit consists of a seed drum, main shaft, ground wheel, floats, furrow openers and handle. The seed drum is of hyperboloid in shape (truncated cone) with 200 mm diameter having 12 mm flat spikes of 25 mm length kept parallel to the axis of rotation. The slopes of the cone facilitate the free flow of seeds towards the metering holes. Nine seed metering holes of 10 mm diameter were provided along the circumference of the drum at both ends at a row-to-row spacing of 200 mm. The main shaft of the drum seeder consists of a 25 mm diameter mild steel pipe of thickness 1.5 mm to accommodate the seed drums. For better traction, 12 numbers of lugs made of 22 gauge galvanized iron sheet were welded to the inner periphery of the wheel. Two floats were provided on either side to restrict the sinkage and to facilitate easy pulling of the unit.

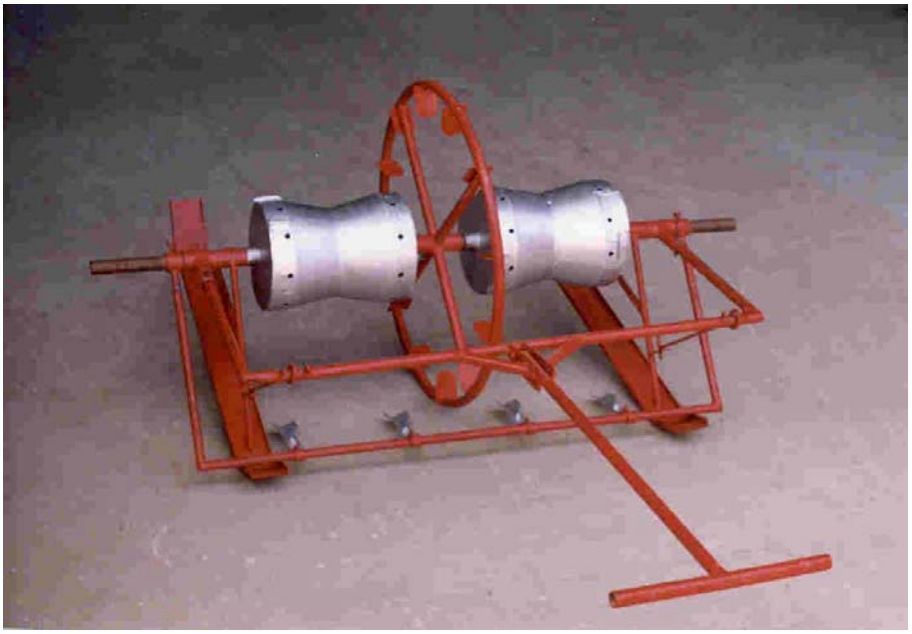

Figure 2. Prototype drum seeder

To make the seeds fall on an opened furrow and to avoid the scattering of seeds furrow openers of IRRI design were provided. The position of the opener was set to have a marked furrow on the soil surface. The depth of furrow can be adjusted by adjusting the position of nut and bolt on the travel hole of the furrow opener. The handle of the drum seeder was made of 18 mm diameter mild steel pipe and hinged to the main shaft by 25 mm mild steel pipe bushes. The height of the handle from the ground level can be adjusted using the holes provided depending on the height of the operator.

3. RESULTS AND DISCUSSION

3.1 Cylindrical Seed Drum

The effect of diameter of seed metering holes on seed rate at selected forward speeds of operation for different drum diameter in cylindrical drum is presented in Fig.3.

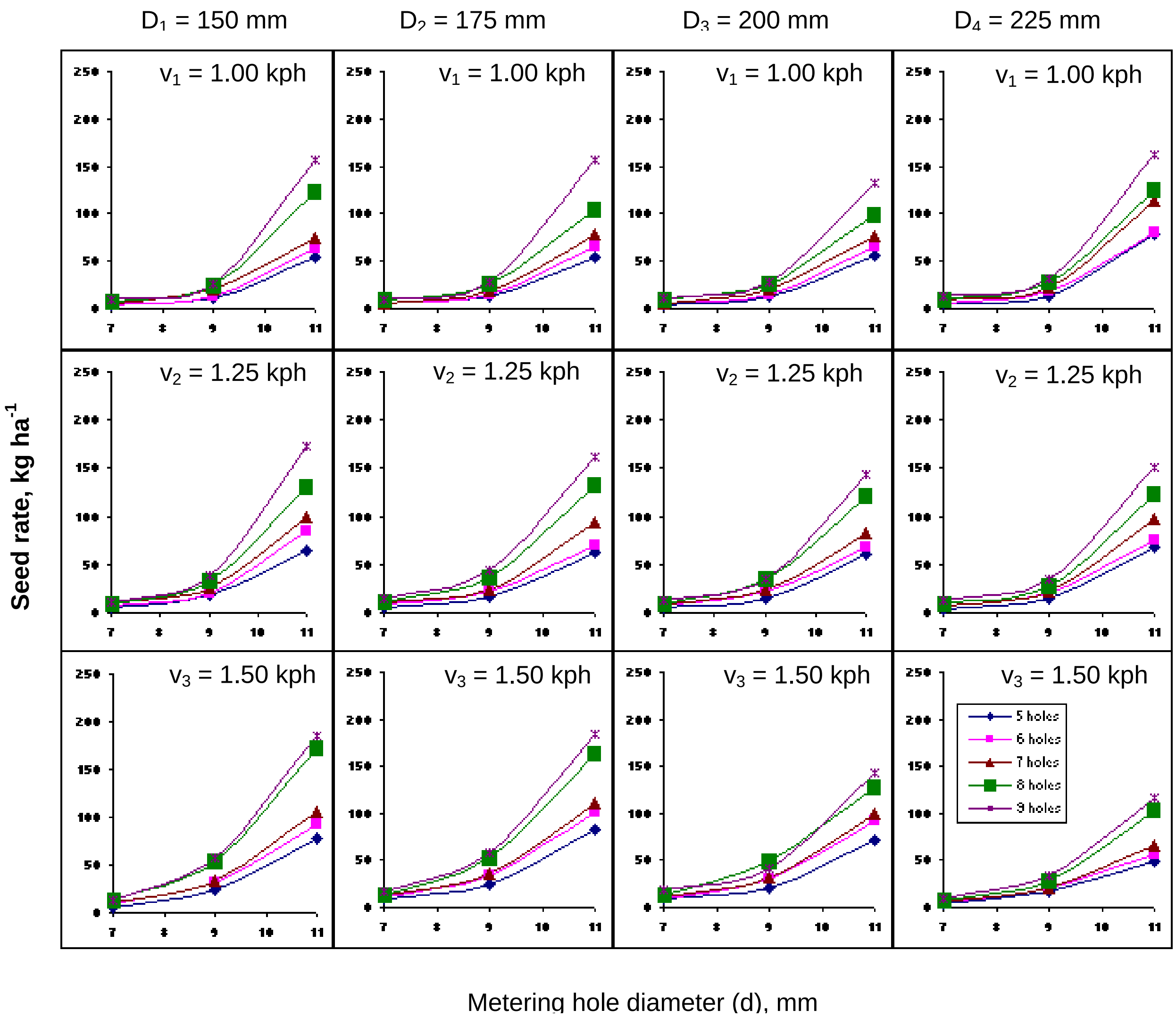

Figure 3. Effect of metering hole diameter on seed rate at selected forward speed of operation for cylindrical drum

From the figure, it is observed that the increase in diameter of seed metering holes from 7 to 9 mm resulted in a uniform and gradual increase in seed rate for all the selected number of seed metering holes and are not significantly different. Further increase in diameter from 9 to 11 mm yielded in a very significant increase of seed rate. The increase of forward speed of operation from 1.0 - 1.5 km h^{-1} had little or insignificant effect on seed rate for all combinations of diameter of seed metering holes and number of seed metering holes.

In all cases, the desired seed rate of 80 kg ha^{-1} was obtained for the combination of diameter of seed metering holes range of 10 - 11 mm and only at 7, 8 and 9 number of seed metering holes. This holds true for drum diameter of 150, 175 and 250 mm. But in the drum diameter of 200 mm, the desired seed rate range was obtained only with 8 and 9 number of seed metering holes. The increase in drum diameter from 175 - 200 mm had resulted in lowering the seed rate for all combinations of diameter of seed metering holes and number of seed metering holes. However, further increase in drum diameter to 250 mm resulted in increase in seed rate except at 1.5 km h^{-1}.

3.2 Hyperboloid Seed Drum

The effect of diameter of seed metering holes on seed rate at selected forward speeds of operation for different drum diameters in hyperboloid drum is presented in Fig.4 and it is noticed that the trend of seed rate exhibited is similar to that of cylindrical drum for all combinations of diameter of seed metering holes and number of seed metering holes at different forward speeds of operation and drum diameters except for 200 mm diameter seed drum.

The seed rate obtained from the seed metering hole diameters of 7 to 9 mm with all the selected number of seed metering holes was less than the desired seed rate of 80 kg/ha. When the seed metering hole diameters are increased from 9 mm to 11 mm the seed rate obtained increased significantly.

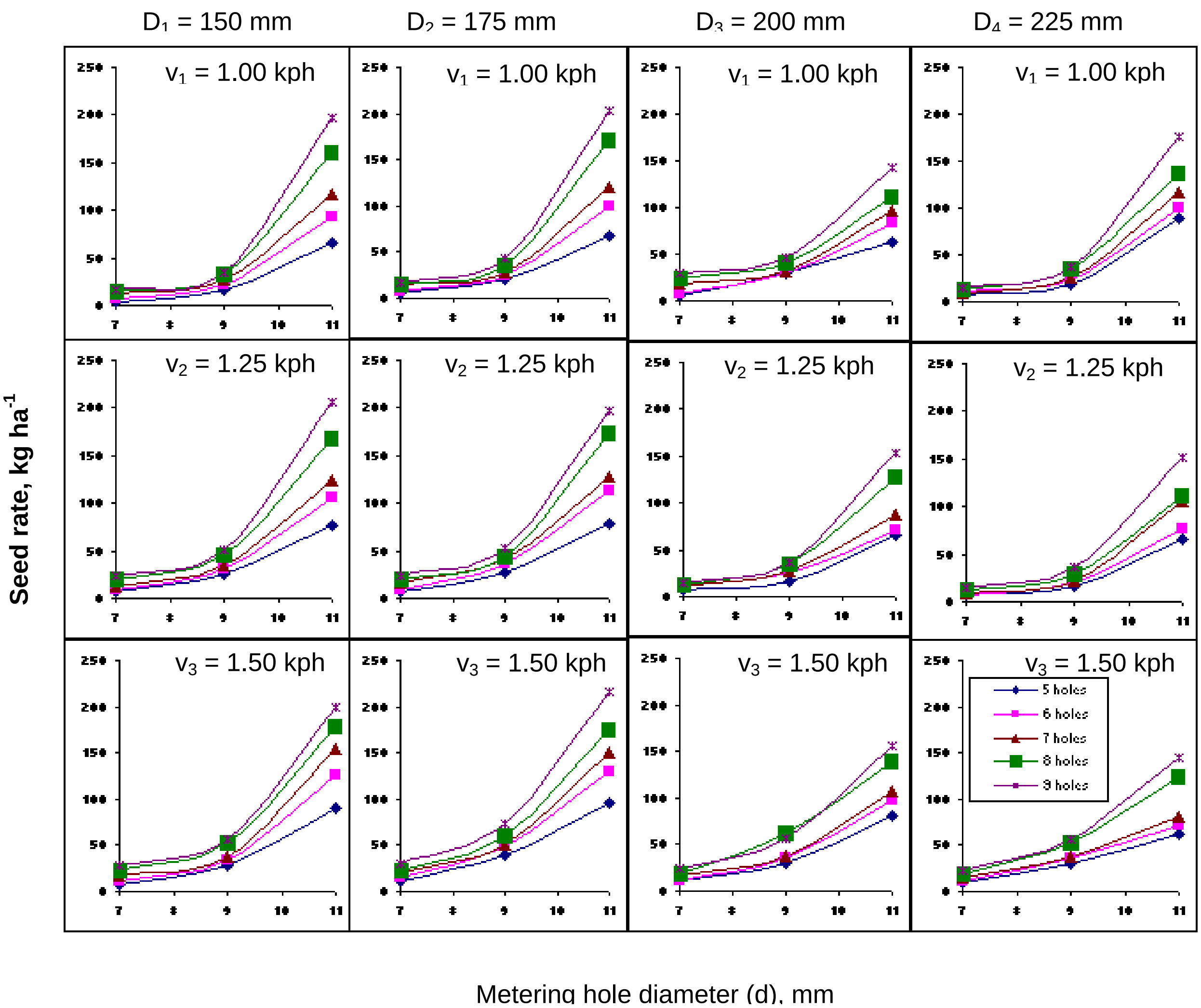

Figure 4. Effect of metering hole diameter on seed rate at selected forward speed of operation for hyperboloid seed drum

The seed rate obtained from the drums of diameters of 150, 175 and 250 mm were more compared to the drum diameter of 200 mm. The variation in seed rate with increase in diameter of seed metering holes is less with 200 mm seed drum diameter.

The effect of forward speed of operation on seed rate for all combinations of drum diameter, diameter of seed metering holes and number of seed metering holes had little or insignificant effect.

3.3 Cylindrical Ellipsoid Seed Drum

The effect of diameter of seed metering holes on seed rate at selected forward speeds of operation for different drum diameters in cylindrical ellipsoid drum is presented in Fig. 5. It is found that the behaviour of seed rate in cylindrical ellipsoid drum is following the same trend as that of cylindrical and hyperboloid drums for all combinations of diameter of seed metering holes and number of seed metering holes at different forward speeds of operation and drum diameters.

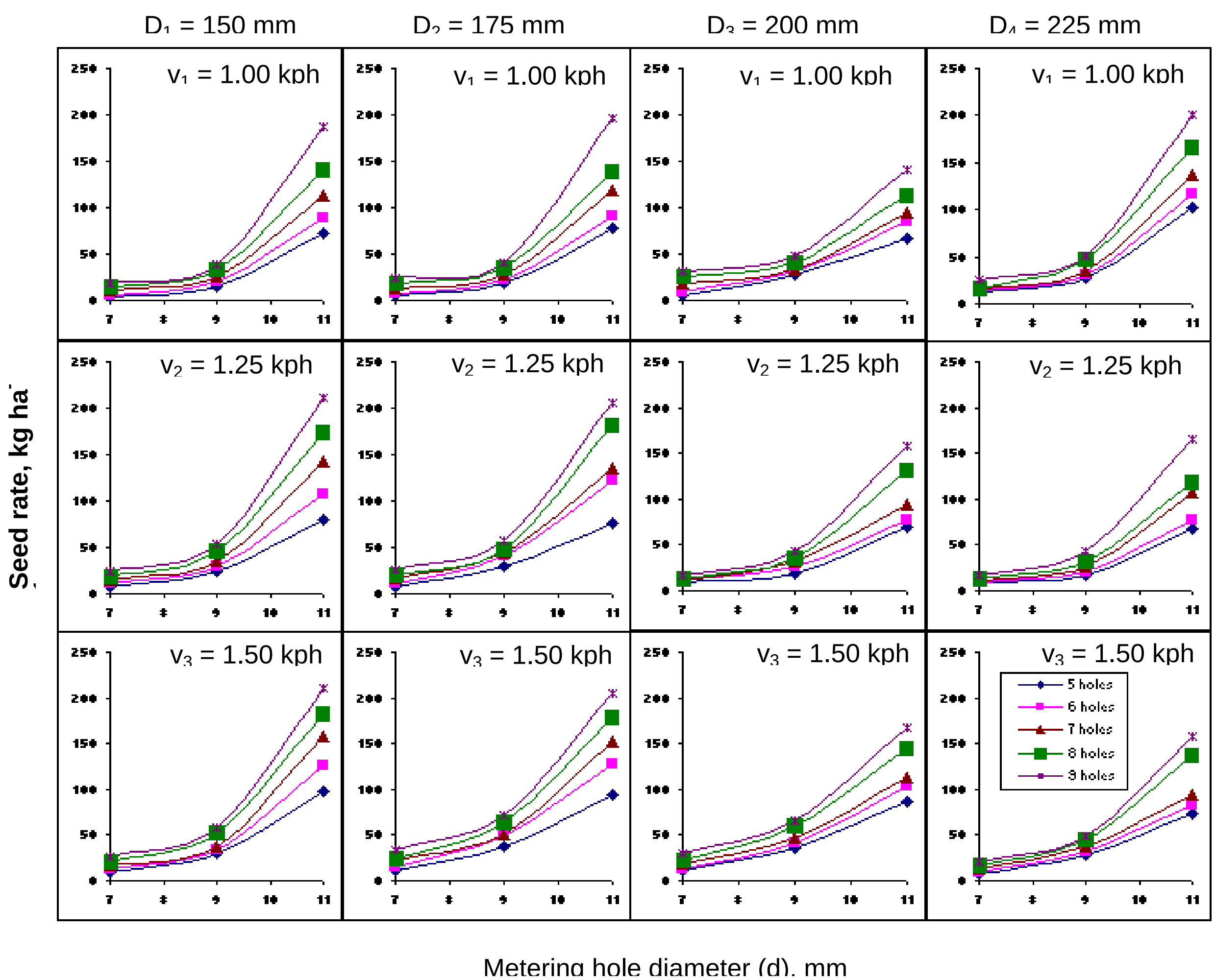

Figure 5. Effect of metering hole diameter on seed rate at selected forward speed of operation for cylindrical ellipsoid drum

In cylindrical ellipsoid drum also the seed discharge was more in 150, 175 and 250 mm diameter drums compared to 200 mm diameter drum for all combinations of seed metering holes and forward speed of operation except for 1.50 kph. The effect of forward speed of operation on seed rate was same like other two shapes.Thus it can be inferred that a higher seed rate is possible with the seed metering hole diameter of 10 to 11 mm and 8 and 9 numbers of seed metering holes for selected drums for all forward speeds of operation and drum diameters. As the effect of forward speed of operation on seed rate is insignificant, the optimization was done based on the practical difficulty of walking in puddled field and pulling the drum seeder. The forward speed of operation was fixed at a level of 1.0 km h^{-1} which is in close agreement with the results of the studies conducted by other researchers (Anon, 1992 and Anon, 2000).

3.4 Effect of Drum Diameter

The desired seed rate could be obtained in all the drum shapes at 10 to 11 mm diameter of seed metering holes with 8 and 9 numbers of holes for all the four levels of drum diameter. All the three drum shapes having 8 and 9 number of holes at 200 mm drum diameter resulted in insignificant variation of seed rate whereas at other diameters the variation in the seed rate is significant in all drum shapes. The insignificant variation in seed rate at 200 mm diameter in all the drum shapes might be attributed to the combined effect of seed drum curvature and rotational speed which influence the flow path trajectory of paddy in addition to the gravitational force. Also, the seed flow from the preceding holes might have affected the seed rate.

The increased drum diameter beyond 200 mm might have had an effect on the increased gravitational force and flow path trajectory of paddy seeds, which might be the reason for the increased seed rate. The increase in seed rate beyond 200 mm might also be due to the fact that more empty space is available which leads to free flow of seeds. This may also be due to the increased agitation leading to less bridging effect between the paddy seeds near the holes.

3.5 Statistical Analysis and Mathematical Modeling

To optimize the shape of the drum, statistical analysis of the data was performed to assess the significance of the variables namely number of seed metering holes (X_1), diameter of seed metering holes (X_2), forward speed of operation (X_3), and the diameter of seed drum (X_4) on the shape of the drum for seed discharge. The best model obtained for each shape was differentiated with respect to each variable partially and equated to zero. The simultaneous equations obtained on the above first order condition were solved and the results are presented in Table 1.

Table 1. Solutions of variables for the statistical models

Sl.No.	Drum shape	Solutions arrived			
		X_1 (Number of seed metering holes)	X_2 (Diameter of seed metering holes, mm)	X_3 (Forward speed of operation, m s^{-1})	X_4 (Diameter of drum, mm)
1	Cylindrical	-0.61	9.14	0.41	-100.66
2	Hyperboloid	9.11	6.82	0.295	183.59
3	Cylindrical ellipsoid	-0.766	9.93	0.288	198.00

Based on the R^2 value and the solutions obtained from the partial derivative of simultaneous equations, it is observed that the hyperboloid drum gave the realistic values. To obtain the desired seed rate (Y) of 80 kg ha^{-1}, in the analyzed model for hyperboloid drum Y was fixed at 80 kg ha^{-1} and corresponding oscillations were made within the realistic limits to obtain the values for X_1, X_2, X_3 and X_4. Considering the practical difficulty in the field operation the forward speed of operation (X_3) was fixed at 1.0 kph.

Taking into account the effect of drum curvature and gravitational forces and the trajectory of movement of paddy seeds due to rotation, the seed drum diameter (X_4) value was fixed as 200 mm which was close to the computed value of 183.59 mm.

The number of seed metering holes (X_1) was selected as 9 and the solved value was 9.11. By fixing the values of X_1, X_3 and X_4 as discussed above, to obtain the desired seed rate level of 80 kg ha^{-1}, the diameter of seed metering hole (X_2) was oscillated and accordingly the computed value was arrived at 9.9 mm. Hence the value of X_2 was fixed at 10 mm which is higher than the length of different paddy varieties studied (6.9 to 9.8 mm).

3.6 Percent Variation in Seed Discharge

The prototype drum with the optimized parameters was tested for per cent variation in seed discharge with respect to time. The comparison on per cent variation in seed discharge between the prototype drum seeder and the existing seeder (Tamil Nadu Agricultural University model) is presented in Fig. 6. From the results it is seen that the deviation of seed discharge from the desired seed rate of 80 kg/ha is more and very high in the existing seeder. But in case of the newly developed seeder the percentage deviation is in the negative side at the initial stages and the deviation decreases upto 14 minutes of operation and then it increases upto 30 minutes. This trend of seed distribution creates a uniform seed distribution throughout the field compared to the existing model.

It is observed that the time consumed for emptying the drum in the existing TNAU drum seeder was 17 minutes with higher seed rate, whereas in the prototype drum seeder it took 33 minute to empty the drum with reduced seed rate variation.

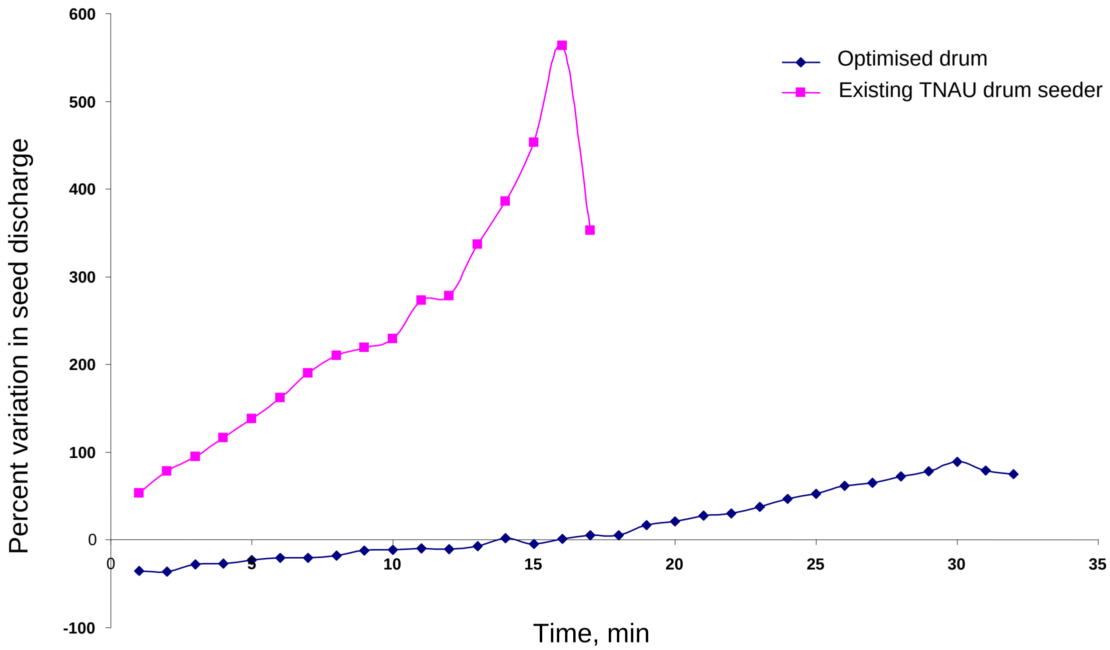

Figure 6. Percent variation in seed discharge with respect to time

4. CONCLUSIONS

Based on the laboratory studies conducted the specification for the prototype drum seeder were arrived as detailed below.

The seed drum was hyperboloid in shape with 200 mm drum diameter having 9 numbers of seed metering holes of diameter 10 mm. The operating speed of the seeder which resulted in recommended seed rate was 1.0 km h^{-1}.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Anonymus. 1992. Fabrication and evaluation of low land paddy seeder. Annual report of AICRP on FIM, TNAU, Coimbatore.

Anonymus. 2000. Feasibility testing of paddy row seeder for direct sowing and comparing with other available seeders. Annual report of AICRP on FIM, ANGR Agricultural University, Hyderabad.

Bharathi, T. 1996. Management options for seeding and weeding in wet-seeded rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, India.

Borlagdan.P.C., and M. Yamauchi . 1995. Seeder developed for direct sowing of rice under the puddled soil surface. *IRRN*. 20(1) 29 –30.

Fujimoto, A. 1991.Technology and economics of rice direct-seeding in Tokai district: A comparative analysis of Shizuoka and Aichi Prefectures. *Journal of Agricultural Science*, 35: 4, 197-205; 6 ref

Kandasamy, O.S. 1987. Water, weed and nitrogen management for direct seeded, irrigated lowland rice. Ph.D. Thesis. Tamil Nadu Agricultural University, India.

Pradhan, S.N. 1969. Mechanization of rice cultivation. *Oryza,* 6: 67-71.

Santhi, P., K. Ponnuswamy and N.K. Chetty. 1998. Effect of seeding methods and efficient nitrogen management practices on the growth of lowland rice. *Journal of Ecobiology*. 10(2): 123-132.

Shekar, J. and C.M.Singh, 1991. Influence of methods and dates of stand establishment on growth and yield of rice. *Oryza*, 28:45-48.

Wang, H.Y. and T.S. Sun. 1990. The characteristics of machine direct sown rice following wheat and the corresponding techniques. Acta Agricultural Universities Jiangxiensis 12: 34-39.