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Design, development and evaluation of a manually operated onion grader for Rose onion

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■ **ABSTRACT :** A manually operated onion grader was designed, developed and evaluated at I.I.H.R., Bangalore for Rose onion verities commonly cultivated in Bangalore into three grades based on geometric dimensions of the selected variety. The linear dimensions like polar diameter, equatorial diameter and thickness of Rose onions were found in the range of 21.92 - 54.54 mm, 15.83 - 59.13 mm and 16.52 - 50.22 mm, respectively. The angle of repose of Rose onions were found as 54.5°, and co-efficient of static friction for onions on different surfaces like galvanized iron 0.402, for stainless steel 0.414, for aluminum 0.386, for mild steel 0.522 and for plywood 0.366, respectively. Experiments were conducted with three types of slopes, at each slope three different feed gate opening lengths and two swing directions. The statistical analysis showed that the standardized parameters were slope 4°, length wise swing direction and feed gate at full opening. The grader has a grading capacity 1105 kg/h at overall grading efficiency 75 per cent and required grading efficiency 75 per cent. The operation cost of machine was 6 times less than manual operation cost.

■ **KEY WORDS :** Rose onions, Grading, Grading efficiency, Grading capacity, Damage efficiency

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Rose onion (*Allium cepa* L.) is one of the most popular crop, grown by farmers in different parts of India mainly in Karnataka state. The Rose onion variety grown in India are very much in demand in gulf countries, Singapore, Malaysia, Sri Lanka and Bangladesh. The Rose onions are highly pungent, which is why they are so popular in international markets. The bulbs are flattish round and deep scarlet in colour, may vary in size from 2.5 – 3.5 cm. The Rose onion quality specifications for export are that the diameter should be a minimum 28 mm and should consist of a single bulb with tight neck (based on farmer's feedback). This variety earns higher foreign exchange than all other varieties of onion that India export.

Grading is one of the important primary unit operation and involves the inspection, assessment and sorting of various commodities regarding quality, freshness, legal conformity and market value. When freshly harvested, Rose onions may contain different sizes of bulbs, some dirt and foreign materials. Grading is done manually in many onion fields, mandies or packing stations and only skilled persons are doing this job. Huge amount of energy is invested in this operation and the produce is handled for number of times in this operation which results in increasing of wastage and may decrease marketing value.

Mechanical grading gains more importance in large scale marketing to fetch higher prices and also India have good mechanical grading equipment based on various criteria like size, shape, weight, colour etc. Van (1965) developed a spiral tomato-grading machine. Goodman and Hamann (1968) designed, developed and tested a machine to field size sweet potatoes. Singh (1980) developed differential belt speed expanding pitch type potato grader. Gadakh and Gangarde (1981) tested the groundnut grader for effect of speed and angle of inclination of rollers on feeding rate and separation efficiency. Hann and Van (1987) studied grading and sorting of potatoes using a square mesh riddle system with reference to uniformity, accuracy, damage and capacity. Anonymous (1989) developed a hand operated orange size grading machine which was based on tapering roller principle. Nevkar (1990) developed and tested the divergent roller type grader for lemon fruits. Amin (1994) developed a grading machine consisting of a rotating cylinder and perforated concave to grade potato, onion and oranges. Suppavit *et al.* (1995) developed a belt type grader to sort exported onions on basis of size. Shukla and Srivastava (1995) developed a potato-cum-onion grader. Mosa (1998) designed a diverging bar or roller cylinder sizing machine for orange and Egyptian lime. Patil and Patil (2002) designed, developed and tested performance of sapota fruits grader which was based on divergent roller principle. Anonymous (2003) designed and developed a divergent roller type of onion grader where separation of onion is achieved on the basis of size. Narvankar and Jha (2005) developed a rotating screen grader suitable for fruits like lemon, ber, aonla to grade the samples into 4 grades. Mahmoudi *et al*. (2006) designed a separation system, based on combination of acoustic detection and artificial neural networks, for classifying four Iranian’s export pistachio nut varieties. Ukey and Unde (2010) designed and developed a sapota fruit grader based on divergent roller type principle; in order to increase the output of fruit grading and save time and labour cost. Borkar *et al.* (2013) developed an apple and pomegranate grader. Such high grading equipment are not useful to small scale farmers because of high cost of machine, high cost of operation and more maintenance cost. The small scale farmers and wholesalers are in urgent need for low cost graders. To address this, a manually operated grader for Rose onion was designed, developed and evaluated.

■ METHODOLOGY

The present research study was undertaken in the section of Agricultural Engineering, Indian Institute of Horticultural Research, Hessaraghatta, Bangalore.

Determination of physical and mechanical properties of Arka Bindu variety of Rose onions :

To fabricate grading sieves, physical properties of the Rose onions were determined. The properties include linear dimensions (polar diameter, equitorial diameter and thickness), sphericity, geometric mean diameter, bulk density, true density and weight of Rose onions. For buildup hopper and selection of constructing material, mechanical properties like angle of repose and co-efficient of static friction were determined.

One hundred Rose onions were randomly selected from the variety and were measured with precision digital vernier calipers that would measure to the nearest ± 0.01mm, bulk density measured with bulk density apparatus, true density was measured by liquid displacement method (Toluene solution was used) and individual weight of Rose onions measured with electronic balance. The mechanical properties like angle of repose of sample was measured by emptying method and co-efficient of static friction measured by inclined plane method with different surfaces like galvanized iron, mild steel, stainless steel, ply wood and aluminum. These were used to calculate the various aperture sizes of the grading screens as suggested by Mohsenin (1970).

Description of manually operated Rose onion grader :

From the results of physical and mechanical properties of the selected Rose onion variety, a manual operated Rose onion grader was designed and constructed. It consisted of round slotted oscillating sieve, a collecting tray with cushioned material for avoiding damage and with outlets, 40 kg capacity of hopper, chain for oscillation and an angle frame of 40×40×5 mm dimensions (Fig. A). The maximum height was 1500 mm. The oscillating sieve has slot sizes of 25 mm (480 holes) and 30 mm (280 holes), respectively that is oscillated manually with 20 mm diameter of handle. The grader classifies Rose onions into three distinct grades according to size.

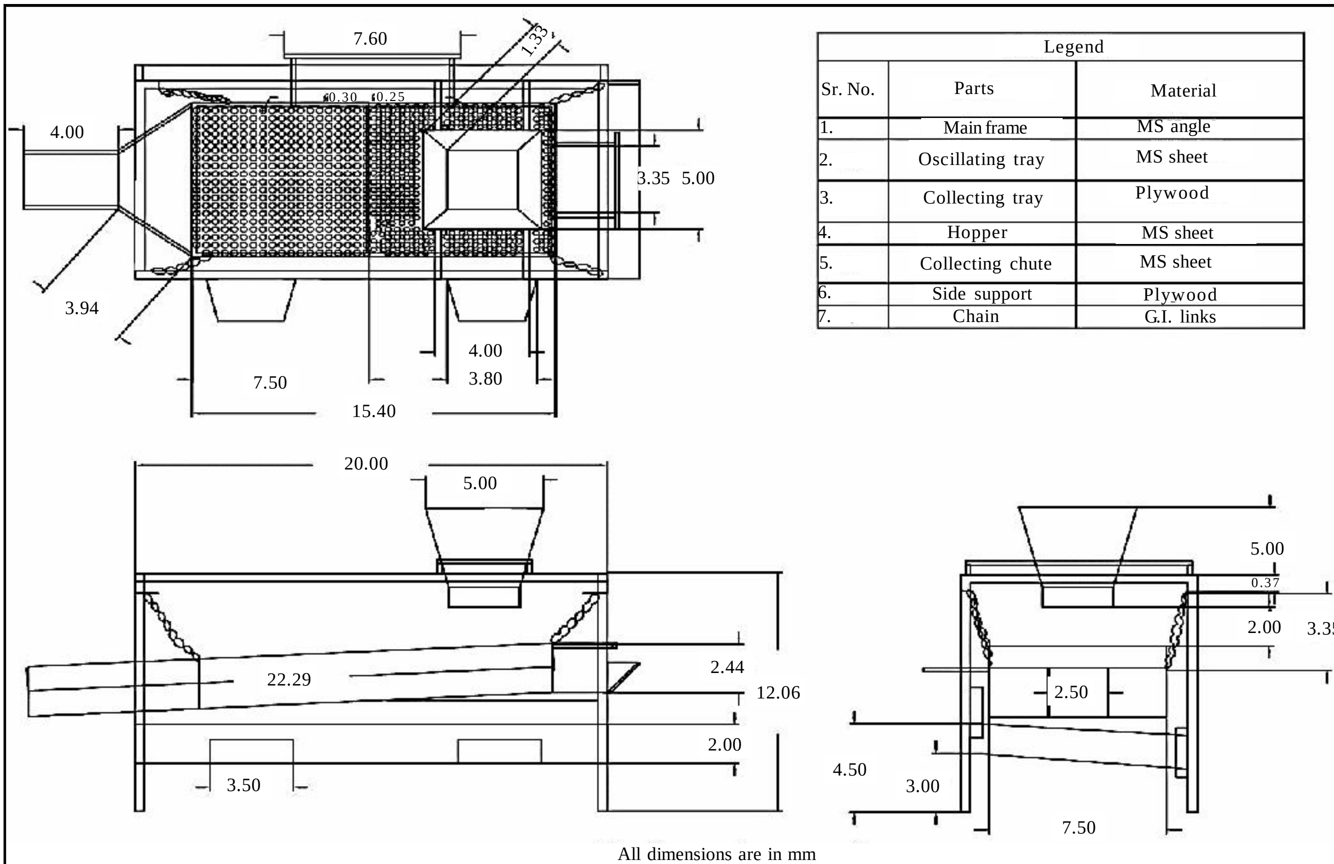

Fig. A : Manually operated Rose onion grader

Principle of operation of the manually operated Rose onion grader :

Rose onions were fed through the hopper. By oscillating the tray the onions travel through the perforated sieve that was greater than its major diameter and drops into the collecting tray. The Rose onions with major diameter larger than the sieve diameter were collected at respective outlets. The Rose onions are collected in a collecting tray with respective outlets determine its grade. The three grades were Grade –I (> 30 mm), Grade –II (25-30 mm) and Grade- III (< 25 mm).

Performance test and evaluation of manually operated Rose onion grader :

The developed grader was tested as per standard procedures for combination of various treatments. A known weight of sample was fed into the grader of different slopes, feed gate opening length and direction of swing at each done at three replications according to testing procedures. The oscillating tray (sieve) could separate the Rose onions as three grades *viz.*, grade I (over size, >30 mm), grade II (medium size, 25 – 30 mm) and grade III (undersize, < 25 mm). The Rose onions from each outlet were collected and weighed. Based on feeder trials the operating parameters of the Rose onion grader were optimized as swing direction, slope of oscillating tray and feed gate opening length. The performance of manually operate Rose onion grader was evaluated in terms of overall grading efficiency, grading efficiency of required size, grading capacity and damage efficiency. These were determined by using the following formula as suggested by Cochran and Cox (1975).

$$\text{Grading efficiency (\%)} = \frac{W_t - W_u - W_o}{W_t} x100$$

where,

W_t = Total weight of Rose onions, kg

W_u = Weight of under size of Rose onions, kg

W_o = Weight of over size of Rose onions, kg.

$$\text{Grading capacity kg/h} = \frac{\text{Weight of Rose onions collected at outlets (kg)}}{\text{Time taken for grading (h)}}$$

$$\text{Damage efficiency (\%)} = \frac{E}{A} \times 100$$

where,

E = Quality of damaged Rose onions collected at outlets per unit time

A = Total Rose onions output per unit time by weight, kg

Formulas for calculating errors in physical and mechanical properties of Rose onions:

$$\text{Standard deviation} = \sqrt{\frac{(x_1 - x_2)^2}{n}}$$

$$\text{Standard error of mean} = \frac{\text{Standard deviation}}{\sqrt{\text{No. of samples}}}$$

95 per cent confidences level = Standard error of mean×1.96 (where, 1.96 = Constant value)

$$\text{Co-efficient of variation} = \frac{\text{Standard deviation}}{\text{Average value of samples}}$$

Statistical analysis :

The results of the machine performance for different treatments of Rose onion grading were analyzed, using Fisher's Factorial Completely Randomized Block Design with three replications by using agers software.

Cost economics :

The cost economics of developed manually operated Rose onion grader was determined taking into account the fixed and variable costs (labour, raw materials etc.) as per the procedures described by IS: 9164-1979.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Results of physical and mechanical properties of Rose onions :

The data on linear dimensions, geometric mean diameter, sphericity, bulk density, true density, angle of repose, co-efficient of static friction and individual onions weight are shown in Table 1 for Rose onions. The range, mean, standard deviation and standard error mean values of Rose onions with respective properties are as shown in Table 1. Examining linear dimensions data (major diameter); it was observed when all the data for all the samples were pooled together, that their range falls between 16.7 mm and 46.78 mm. Based on marketing dimensions the size range required is 25 – 30 mm and the range chosen is 16 – 46 mm. The three grades chosen were >30 mm, 25-30 mm and <25 mm. The range of values suggests that two sieves would be constructed for the grader. Considering the impact on the operator due to more weight of Rose onions, one sieve was designed with two grade sizes, having the following dimension for the grader; half portion has 25 mm and remaining has 30mm diameter holes. On observing sphericity values, the shape of the Rose onions were found almost round suggesting that round shape holes are suitable for oscillating tray.

Results of grading of Rose onions :

Analysis of the results obtained for grading the

Table 1: Physical and mechanical properties of Arka Bindu variety of rose onions

Sr. No.	Properties	Properties of rose onions			
		Range	Mean	Standard deviation	Standard error mean
1.	Moisture content (%) (Wb)	27.1-36.6	30.86	2.62	1.72
2.	Equitorial diameter (mm)	15.8-59.1	30.57	6.97	1.36
3.	Polar diameter (mm)	21.9-54.5	34.30	6.46	1.36
4.	Thickness (mm)	16.5-50.0	28.25	5.93	0.59
5.	Geometric mean diameter (mm)	18.1-43.7	29.56	4.81	0.48
6.	Sphercity (mm)	0.71-0.98	0.866	0.09	0.04
7.	Individual onion weight (g)	2.87-47.56	29.56	4.81	0.48
8.	Bulk density (kg/m^3)	358-422	398.6	26.75	11.96
9.	True density (kg/m^3)	195-3262	1099.4	640.25	286.25
10.	Angle of repose (^{o})	54.5-57.3	54.4	2.64	0.83
11.	Co-efficient of static friction for mild steel	0.466-0.624	0.5226	0.012	0.008

variety of Rose onions are given in Table 2. The overall grading efficiency (%), required size grading efficiency (%) and grading capacity (kg/h) were computed. It is seen that maximum average overall grading efficiency and average required size grading efficiency obtained (83.24% and 81.97%) at feed gate at 1/3 opening, slope 2° and width wise swing direction as shown in Fig.1 and 2 plotted between treatments and overall grading efficiency (%), required size grading efficiency on X and Y axis, respectively. The maximum average grading

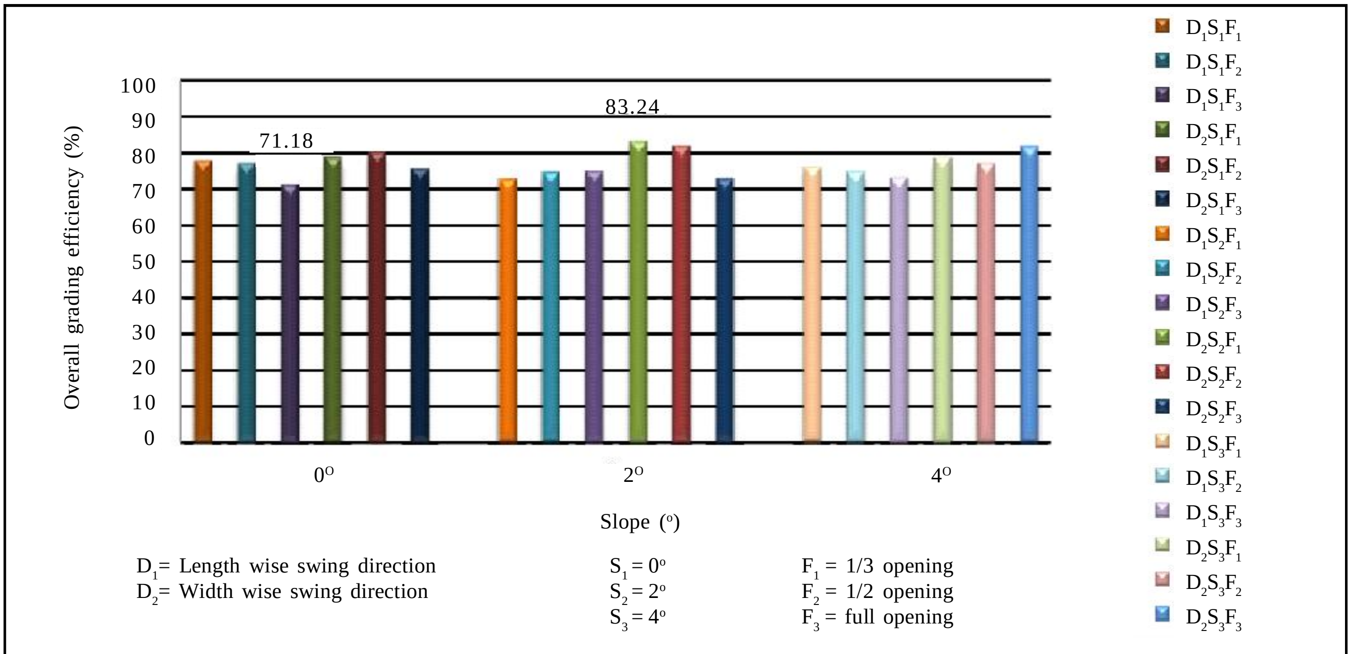

Fig. 1 : Effect of direction of swing, slope and feed gate opening length on overall grading efficiency

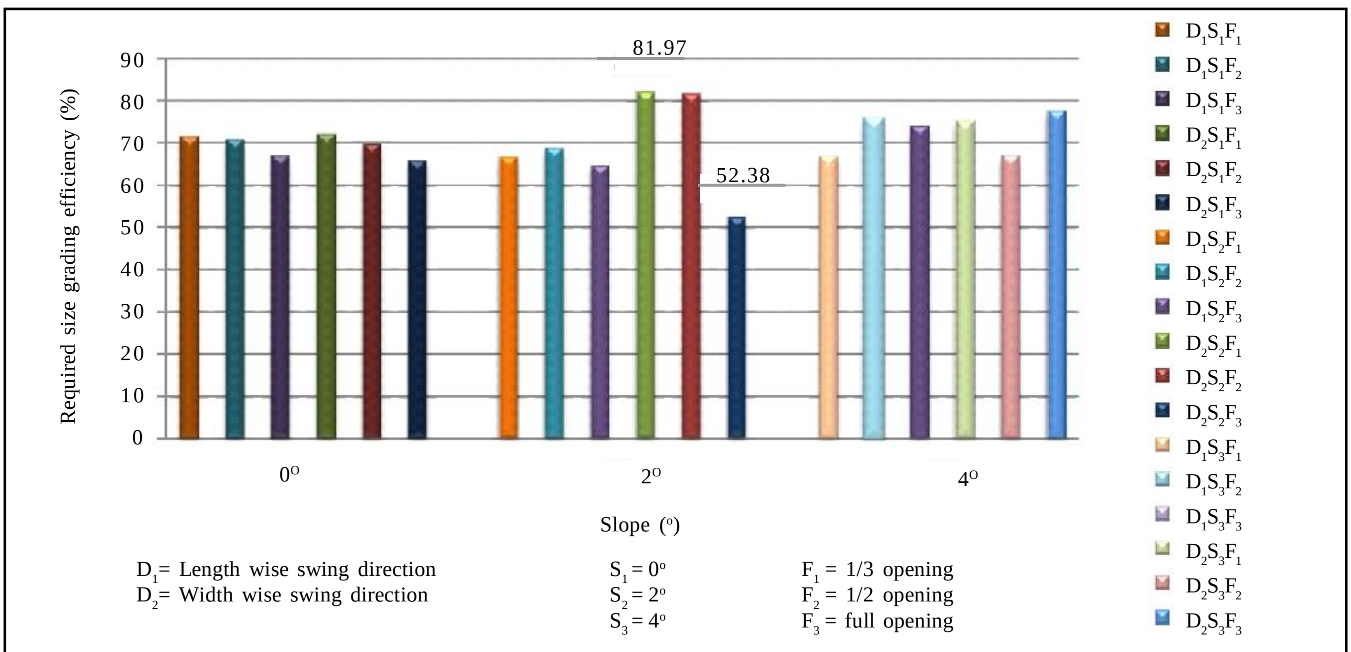

Fig. 2 : Effect of direction of swing, slope and feed gate opening length on required size grading efficiency

Table 2: Effect of direction of swing direction, slope and feed gate opening length on average overall grading efficiency, average required size grading efficiency and average grading capacity

Treatments	Feed gate opening	Average overall grading efficiency (%)	Average required size (grade II) grading efficiency (%)	Average grading capacity (kg/h)
$D_1S_1F_1$	1/3	77.83	71.45	308.84
$D_1S_1F_2$	2/3	77.08	70.83	272.86
$D_1S_1F_3$	Full	71.18	67.00	504.62
$D_2S_1F_1$	1/3	78.77	72.11	336.96
$D_2S_1F_2$	2/3	80.33	69.67	232.2
$D_2S_1F_3$	Full	75.71	65.80	255.29
$D_1S_2F_1$	1/3	72.65	66.64	507.61
$D_1S_2F_2$	2/3	74.60	68.71	617.38
$D_1S_2F_3$	Full	74.86	64.50	44.90
$D_2S_2F_1$	1/3	83.24	81.97	233.36
$D_2S_2F_2$	2/3	81.90	81.57	260.70
$D_2S_2F_3$	Full	72.95	52.38	275.52
$D_1S_3F_1$	1/3	76.00	66.84	516.90
$D_1S_3F_2$	2/3	74.67	75.68	606.60
$D_1S_3F_3$	Full	73.24	73.88	1104.76
$D_2S_3F_1$	1/3	78.83	75.12	271.76
$D_2S_3F_2$	2/3	77.13	66.94	215.97
$SD_2S_3F_3$	Full	81.65	77.64	303.38

capacity obtained (1104.76 kg/h) at feed gate at full opening, slope 4° and length wise swing direction shown in Fig.3, plotted between treatments and grading capacity. The result shows no damage efficiency.

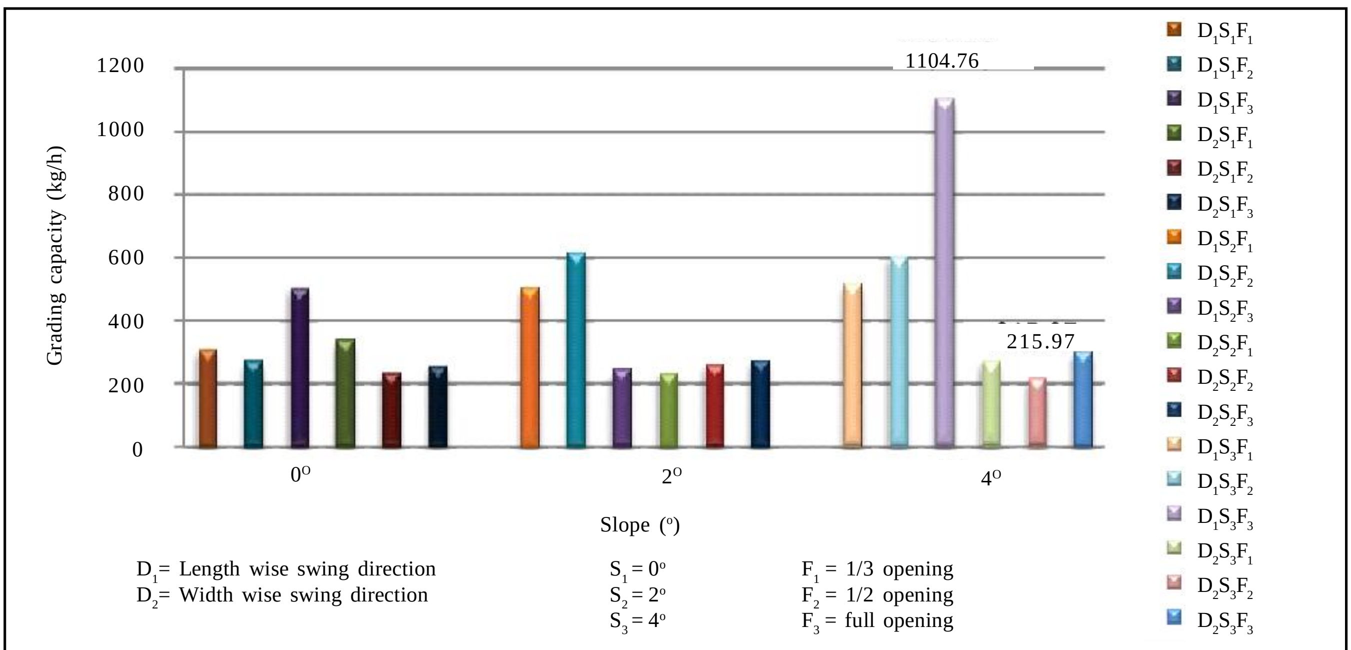

Fig. 3 : Effect of direction of swing, slope and feed gate opening length on grading capacity

Statistical analysis :

The ANOVA results suggest that the model is acceptable from a statistical perspective with a significant F statistic (P= 0.01) indicating that the model can be used to predict the grading efficiency and grading capacity. Three factors *viz.*, direction swing

Table 3 : ANOVA table of effect of direction of swing, slope and feed gate opening length on overall grading efficiency of Rose onion grader

Swing direction	D_1 74.6793	D_2 78.9448	
Slope of tray	S_1 76.8198	S_2 76.6989	S_3 76.9194
Feed gate opening length	F_1 77.8872	F_2 77.6118	F_3 77.9306
Source	F-value	S.E.±	C.D. (P = 0.01)
D	**	1.65448	4.49974
S	NS	2.02632	………
F	NS	2.02632	……....
DS	NS	2.86565	………
SF	NS	3.50969	………
DF	NS	2.86565	………
DSF	NS	4.96345	………

** indicate significance of value at P=0.01 NS = Non-significant

Table 4: ANOVA table of effect of direction of swing, slope and feed gate opening length on required size grading efficiency of Rose onion grader

Swing direction	D_1 69.5207	D_2 74.5448	
Slope of tray	S_1 70.1072	S_2 73.3022	S_3 76.6889
Feed gate opening length	F_1 72.3544	F_2 73.2328	F_3 71.5111
Source	F-value	S.E. ±	C.D. (P = 0.01)
D	**	1.72353	4.68754
S	NS	2.11089	………
F	NS	2.11089	……....
DS	**	2.98525	8.11906
SF	NS	3.65617	………
DF	NS	2.98525	………
DSF	NS	5.17060	………

** indicate significance of value at P=0.01 NS = Non-significant

Table 5: ANOVA table of effect of direction of swing, slope and feed gate opening length on grading capacity of Rose onion grader

Swing direction	D_1 542.6230	D_2 265.0111	
Slope of tray	S_1 318.4617	S_2 389.9056	S_3 503.0839
Feed gate opening length	F_1 362.4206	F_2 367.6206	F_3 481.4100
Source	F-Value	S.E. ±	C.D. (P = 0.01)
D	**	28.03236	76.24037
S	**	34.33249	93.37500
F	**	34.33249	93.37500
DS	**	48.55348	132.05219
SF	**	59.46563	161.73024
DF	**	48.55348	132.05219
DSF	**	84.09709	228.72110

** indicate significance of value at P=0.01 NS = Non-significant

(D), slope (S), feed gate opening length (F) are involved in ANOVA table. The ANOVA result of overall grading efficiency required grading efficiency and grading capacity are shown in Table 3, 4 and 5. As per the analysis, direction of swing effects the overall grading efficiency, direction of swing and slope of tray are together effects the required size grading efficiency and all three factors (direction of swing, slope of tray and feed gate opening length) effects the grading capacity. The SED (Standard error deviation) and CD (Critical difference) values are given in Table 3, 4 and 5.

Cost economics :

Cost economics of manually operated Rose onion grader was worked out based on variable and fixed cost of the machine. Total fixed cost (Depreciation, interest and housing charges) was 27.41(Rs./h) and total variable cost (repair and maintenance cost and labour cost) was 25.77 (Rs./h). The total cost of machine and operation cost per kg were 15,570/- and 0.036/-, respectively.

Conclusion :

A manually operated Rose onion grader has been designed, developed and evaluated. For maximum response, the overall grading efficiency, required size grading efficiency and grading capacity were optimized to 75 per cent, 75 per cent and 1105 kg/h. Damage efficiency was nil. The optimized parameters were length wise swing direction, slope of tray at 4° and feed gate opening length at full opening. According to AGER'S SOFTWARE, direction of swing effect on overall grading efficiency, direction of swing and slope of tray had effect on required size grading efficiency and all three factors (direction of swing, slope of tray and feed gate opening length) had effect on grading capacity. Total operational cost was Rs. 53.18/h. the operation cost per kg was Rs. 0.036. The operation cost of machine was 6 times less than manual operation cost. Grading is crucial because of its potential to regain and increase export earnings.

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