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Performance evaluation of fruit grader for spherical fruits

Mohini M Dange

Abstract
Considering the huge amount of human energy involved in grading of fruits and thereby degrading the quality by handling the fruits number of times the PDKV spherical fruit grader is fabricated utilizing four pairs of PVC pipes and the diverging gaps between each pair of pipes. The grader is tested for grading Nagpur oranges, guava, onion and kagzi lime. The parameters *viz.* slope and feed rate were optimized for optimum grading the grading efficiency for all the fruits was observed to be 73-90% and the capacity was observed to be 10-12 tonnes /day. The unit was found techno economically feasible with BEP 44%. The unit is suitable for rural entrepreneurship development.

Keywords: Fruits, grader, efficiency, capacity

Introduction
The total production of fruits in the world is around 370 million MT. India ranks first in the world with an annual output of 32 million MT. While there are almost 180 families of fruits that are grown all over the world, citrus fruit constitute around 20% of worlds total fruit production. India with its current production of around of around 32 million MT accounts for about 8% of the worlds fruit production the diverse agro climatic zones in the country make it possible to grow almost all the varieties of fruits and vegetables in India. Although, India is the largest producer of fruits in the world. (Biswas, et.al, 2002) [3] the production per capita is only about 100 gms per day. However, it is estimated that more than 20-22% and the total production of fruits is lost due to spoilage at various post harvest stages, thus the per capita availability of fruits is further reduced to around 80 g per day which is almost half the requirement for balanced diet. whereas for Maharashtra the total area under fruit cultivation is 795727 ha and total production of fruits in the state is 11441070 tons (Anon 2005) [2]. Post harvest management of fruits is of prime importance in order to sustain higher production, proper distribution with minimum losses and increasing export. In India due to lack of proper post harvest handling system and appropriate processing technology, not only does a huge quantity of fruits go waste but also the country dose not get proper distribution of fresh fruits and good market for processed products for both internal trade and export.

Systematic grading is a prerequisite for efficient marketing systems, as a well design programme on grading and standardization brings about an overall improvement not only in the marketing system but also in raising quality consciousness.

At present grading of Nagpur mandarin, guava, onion and kagzi lime is done manually in orchard, mandies or packing stations and only skilled persons are doing this job. Huge amount of human energy is invested in this operation and the produce is handled for number of times in this operation which results in increase in respiration rate thereby causing weight loss. The growers, wholesalers, preharvest contractors and packing stations are in urgent need of low cost mechanical graders, because the graders provided by various companies are costly.

The project was undertaken with following objectives

Objectives
1. Development of spherical fruit grader
2. Performance Evaluation of grader for different fruits such as Nagpur Mandarin, Kagzi lime, Guava, Onion, etc.

Materials and Methods
The spherical fruit grader (Fig. 1) consisted of a 1830 x 1300 mm frame made up of m.s.

angles 35 x 35 x 5 mm was fabricated. Four pairs of PVC pipes of 75 mm diameter and 1300 mm length were provided keeping spacing of 40 mm at the feed end and 80 mm at the opposite end between two pipes of each pair. These pipes were mounted over 30 mm diameter shaft by fixing four spacers of m.s. plate along the length for fitting these pipes over shafts. These shafts are fitted with the help of pillow block bearing (No. 204) in grooves at both ends of the frame. A chain and sprocket arrangement is provided at the feed end for power transmission from pipe to pipe. The chain is linked alternately on the pipes at each pair so that both the pipes of each pair will rotate in opposite direction outwardly by 80 rpm. One idler in the groove is also provided to give tension while adjusting spacing between the pipes.

A universal joint was provided at the feed end of each shaft, so that while adjusting the spacing between the pipes of each pair the alignment of the chain and sprocket will not be disturbed. Thus, the spacing between the two pipes of each pair can be varied. This facilitates the grading of spherical fruits of various sizes, by adjusting the spacing as per the grades desired. The m.s. sheet with sufficient cushioning in ‘V’ shape was welded on the feed trough so as to divert the fruits in the diverging gap between two pipes of each pair of pipes available for grading fruits. The frame was mounted on two stands made of m.s. angle 35 mm x 35 mm x 5 mm in such a way that, pipe makes a slope of about 32.5%. The tallest end was chosen as feed end with a rectangular holder of size 1250 x 760 mm made of m.s. sheet (20 gauge) with proper frame support. For outlet of fruits trapezoidal shaped frames of m.s. flats fitted with m.s. sheet partitions was provided as shown in Fig. 1. The placement of the partitions can be adjusted in the groves as per the requirement of particular grade. Steel pipes of 8 mm diameter were provided over the pvc pipes, so as to guide the fruits between two pipes of each pair, to avoid divergence of fruit. One horsepower single phase electric motor was used as a prime mover.

As the grader was versatile in nature for grading all types of spherical fruits, the grader was tested by using Nagpur mandarin, Kagzi lime, guava and onion. For grading Nagpur mandarin fruits, the partitions of outlets were provided where the spacing between two pipes of each pair was 40 mm, 50 mm, 60 mm, 70 mm and 80 mm thereby receiving the fruits of 40 to 50 mm diameter 50 to 60 mm diameter, 60 to 70 mm diameter and 70 to 80 mm diameter. For grading kagzi lime fruits, the spacing between two pipes of each pair was reduced and the partition of outlets were provided where the spacing between two pipes of each pair was 25 mm, 30 mm, 35 mm, 40 mm and 45 mm thereby receiving the fruits of <30 mm diameter, 30 to 35 mm diameter, 35 to 40 mm diameter and 40 to 45 mm diameter.. For grading guava fruits, the partitions of outlets were provided where the spacing between two pipes of each pair was 40 mm, 50 mm, 65 mm, 80mm and 90 mm thereby receiving the fruits of less than 50 mm diameter,50 to 65 mm diameter, 65 to 80 mm diameter and greater than 80mm diameter. For grading onions, the spacing between two pipes of each pair was reduced and the partition of outlets were provided where the spacing between two pipes of each pair was 25 mm, 35 mm, 45 mm, and 55 mm thereby receiving the fruits of <35 mm diameter, 35 to 45 mm diameter and greater than 45 mm diameter.

The grading efficiency is sensitive to feed rate and slope of the pipes (feed end to opposite end). Hence these two factors were considered for optimization for better grading efficiency by using response surface methodology.

The experimental plan selected was for two variables and five levels in response surface methodology (Cochran and Cox, 1975) [4] for optimization of factors for maximum grading efficiency. The two independent variables, feed rate kg/min (x_1) and slope, percent, (x_2) and their levels, coded and uncoded are shown in Table 1 for Nagpur mandarin, kagzi lime, guava and onion. The centre point values were chosen as 30 kg/min feed rate and 32.5 per cent slope for Nagpur mandarin, guava and onion grading and 25 kg/min and 32.5 per cent slope for kagzi lime grading respectively, from previous results at this centre. The two higher and two lower levels were added using equation.

Central level $\pm$ ($\sqrt{2}$ x interval) ……………………………(1)

The second order polynomial equation of the following form can be assured to appropriate the true functions.

$$Y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 \quad \text{……….(2)}$$

Where b_0, b_1, b_2, b_{11}, b_{22} and b_{12} are the constant co-efficients and x_1 and x_2 are the coded independent variales. These coded variables (x_i) in any particular application are linearly related to X_i by the following equation.

$$x_i = \frac{2X_i - (X_{iH} + X_{iL})}{X_{iH} - X_{iL}} \quad \text{………………………(3)}$$

Where,
x_i = Coded variable
X_i = Decoded variable
X_{iH} = High level (+1) of X_i
X_{iL} = Low level (-1) of X_I

All above mentioned fruits were procured from the garden nearby Akola city and transported to testing unit with sufficient cushioning material in order to minimize bruising. The sample size of 20 kg, 15 kg. 15 kg and 12 kg fruits of Nagpur mandarin, guava, onion and kagzi lime resp. were used for each test. Various feed rates were achieved by feeding the same fruit lot during different durations and five levels of slopes were achieved by keeping required thickness of m.s. plates at the bottom of the feed end or opposite end. The major diameters of fruits before grading were measured by vernier caliper. These fruits were divided in different grades, the coding was given and weights were taken before grading (Table 2 to 5)

The Nagpur oranges of *Mrig* bahar were used for testing the grader. The test lot of fruits was consisting of 171 oranges, weighing 20 kg (Table 2). Out of which there were 20 fruits weighing 4.000 kg of major diameters more than 70 mm (A), 55 fruits weighing 8.140 kg of major diameter ranging between 60 to 70 mm (B), 67 fruits weighing 6.280 kg of major diameter ranging between 50 to 60 mm (C) and 29 fruits weighing 1.600 kg of major diameter less than 50 mm (D). The average weight of each fruits of grade A,B,C and D was 0.200, 0.148, 0.094 and 0.055 kg respectively as given in Table 2. Guava fruits of Sardar variety were used for testing the grader. The test lot of fruits was consisting of 93 fruits, weighing 15 kg (Table 3). Out of which there were 11 fruits weighing 3.820 kg of major diameters more than 80 mm (A), 22 fruits weighing 4.760 kg of major diameter ranging between 65 to 80 mm (B), 49 fruits weighing 5.820 kg of major diameter ranging between 50 to 65 mm (C) and 11 fruits weighing 0.600 kg of major diameter less than 50 mm (D). The average weight of each fruits of grade A, B, C and D was 0.347, 0.216, 0.119 and 0.055 kg respectively as given in Table 3.

The test lot of onion (variety-PKV Selection white) was consisting of 378 fruits weighing 15 kg (Table 4). Out of which there were 114 fruits weighing 8.52 kg of major diameter greater than 45 mm (A), 114 fruits, weighing 3.680 kg of major diameter ranging between 35 to 45 mm (B), 150 fruits weighing 2.800 kg of major diameter less than 35 mm (C). The average weight of each fruit of grade A, B and C was 0.075, 0.032 and 0.019 kg respectively as given in Table 4.

The test lot of kagzi lime fruits was consisting of 357 fruits weighing 12 kg (Table 5). Out of which there were 114 fruits weighing 5.44 kg. of major diameter greater than 40 mm (A), 115 fruits, weighing 3.900 kg of major diameter ranging between 35 to 40 mm (B), 94 fruits weighing 2.200 kg of major diameter ranging between 30 to 35 (C) mm and 34 fruits weighing 0.460 kg of major diameter less than 30 mm (D). The average weight of each fruit of grade A, B, C and D was 0.048, 0.034, 0.023 and 0.014 kg respectively as given in Table 5.

After testing the grader by using Nagpur mandarin, guava, onion and kagzi lime as per treatment combinations given in Table 1 replicated thrice, the grading efficiency was calculated by dividing the weight of correctly graded fruits by total weight of fruits taken for grading. After optimizing the input parameters (feed rate and slope) for maximum grading efficiency by using response surface methodology, the grader was tested by using the optimized input parameters. The percent overall effectiveness of separation was also calculated as described in Annexure A by using optimized input parameters

Results and Discussion

The experimental average results of three replications for grading efficiency are depicted in Table 6 for Nagpur mandarin, guava, onion and kagzi lime. The observed data was fitted in second order polynomial model equation. The partial regression coefficients obtained after multiple regression analysis are presented in Table 7. The regression analysis resulted the following second order polynomial equations for grading efficiency.

For Nagpur mandarin

$$Y = 75.461 + 1.820\, x_1 + 3.120\, x_2 - 2.592\, x_1^2 - 4.192\, x_2^2 - 1.112\, x_1x_2 \quad (R^2 = 0.886) \text{ --- ----------------(4)}$$

For guava

$$Y = 90.42 + 0.514\, x_1 - 2.463\, x_2 - 1.056\, x_1^2 - 1.473\, x_2^2 - 0.5\, x_1x_2 \quad (R^2 = 0.852) \text{ -------------------(5)}$$

For onion

$$Y = 72.254 + 0.05x_1 + 3.271x_2 - 1.030\, x_1^2 - 1.410x_2^2 - 0.9\, x_1x_2 \; (R^2 = 0.853) \quad \text{-----------------(6)}$$

For kagzi lime

$$Y = 76.620 + 3.052x_1 + 3.382x_2 - 1.513\, x_1^2 - 4.682x_2^2 - 3.13\, x_1x_2 \; (R^2 = 0.878) \quad \text{-----------------(7)}$$

The analysis of variance (Table 8) for the effect of factors on response indicated that the regression was significant (at 10% level) and lack of fit was non significant and hence the mathematical model can be considered as quite adequate for the Nagpur mandarin, guava, onion and Kagzi lime grading.

The stationary point where the slope of the curve on the first derivative is zero was located as described. Results in Table 9 show that the stationary points for the responses was lying inside the experimental region defined by $x_1 = \pm 1.414$ and $x_2 = \pm 1.414$. The model were tested whether the function has maximum or minimum prediction values. It was observed that, the function possesses maximum value for all types of fruits taken for grading. The co-ordinates ($x_1 = 0.279$ & $x_2 = 0.335$) correspond to the uncoded values as 31.67 kg/min feed rate ad 35.01 per cent slope of pipes for Nagpur mandarin grading, The co-ordinates ($x_1 = 0.460$ & $x_2 = -0.914$) correspond to the uncoded values as 32.76 kg/min feed rate and 25.65 per cent slope of pipes for guava grading and coordinates ($x_1 = -0.306$ and $x_2 = 1.221$) correspond to the uncoded value as 28.16 kg/min feed rate and 41.66 per cent slope for onion grading and coordinates ($x_1 = 0.973$ and $x_2 = 0.035$) correspond to the uncoded value as 29.86 kg/min feed rate and 32.67 per cent slope for kagzi lime. Using these input factors the grading efficiency was calculated to be 76.24 per cent for Nagpur mandarin, 91.66 per cent for guava, 74.37 per cent for onion and 78.16 per cent for kagzi lime respectively.

The response surface and contour plots were generated on computer screen in order to study the pictorial form of behavior of response variables using the prediction model equation as shown in Fig. 2, 3, 4 and 5 for grading efficiency for Nagpur mandarin, guava, onion and kagzi lime respectively.

Table 10 presents the statistical analysis of joint test on the two parameters involving one particular factor. For example, test x_1 tests the hypothesis that parameters of model equation *viz.* x_1, $x_1^2$and x_1x_2 are all zero. Similar is the case for x_2. Table 10 revealed that, x_2 (slope) is highly significant at 10% level than x_1 (feed rate). This shows that, the effect of slope is much effective than the feed rate for the response.

The mathematical model was evaluated for its adequacy by testing the grader by using Nagpur mandarin for three samples (sample size 30 kg) with factors constant at above level (32 kg/min feed rate and 35% slope). The grading efficiency of grader was found to be 75.62 per cent with $\pm$ 0.82 standard deviation. The corresponding average overall effectiveness of separation was 24.42 per cent with $\pm$ 0.24 standard deviation. The mathematical model was evaluated for its adequacy by testing the grader by using guava for three samples (sample size 20 kg) with factors constant at above level (32.76 kg/min feed rate and 25.65% slope). The grading efficiency of grader was found to be 90.53 per cent with $\pm$ 0.87 standard deviation. The corresponding average overall effectiveness of separation was 75.00 per cent with $\pm$ 0.11 standard deviation. Similarly the mathematical model was evaluated for its adequacy by testing the grader by using onion for three samples (Sample size 20 kg) with factors constant at above level (28.16 kg/min feed rate and 41.66% slope). The grading efficiency was found to be 73.80 per cent with $\pm$ 0.63 standard deviation. The corresponding average overall effectiveness of separation was 47.00 per cent with $\pm$ 0.39 standard deviation. Similarly the mathematical model was evaluated for its adequacy by testing the grader by using kagzi lime for three samples (Sample size 50 kg) with factors constant at above level (30 kg/min feed rate and 33% slope). The grading efficiency was found to be 76.83 per cent with $\pm$ 0.71 standard deviation. The corresponding average overall effectiveness of separation was 24.65 per cent with $\pm$ 0.31 standard deviation. This lower overall effectiveness of separation can be attributed to the difference between the major and minor diameter of fruit (fruit being not perfectly spherical) ranging from zero to 9 mm and the orientation of fruit (either major diameter/ minor diameter perpendicular to slope) while conveying within the diverging gap between two pipes of each pair, which caused the mixing of various grades of fruits. Moreover, the overall effectiveness of separation is the multiplication of effectiveness of separation of each grade /outlet.

With the optimized feed rate the capacity of grader for grading Nagpur mandarin comes out to be 15.20 tonnes per day of eight hours and with 80 per cent efficiency, the capacity of the grader is 12.16 tonnes of per day of eight hours for Nagpur mandarin. With the optimized feed rate the capacity of grader for grading guava comes out to be 15.76 tonnes per day of eight hours and with 80 per cent efficiency, the capacity of the grader is 12.61 tonnes of per day of eight hours for guava. With the optimized feed rate, the capacity of the grader for grading onion comes out to be 13.52 tonnes per day of eight hours and with 80 per cent efficiency, the capacity of the grader is10.82 tonnes per day of eight hours. Similarly with the optimized feed rate the capacity of the grader for grading kagzi limes comes out to be 14.33 tonnes per day of eight hours and with 80 per cent efficiency, the capacity of the grader is 11.46 tonnes per day of eight hours.

The PDKV Fruit grader is techno economically feasible unit with BEP 44% (Table 11) Pay back period for equipments 1.75 yrs. and the Annual net profit of Rs. 56560/- can be earned by using this equipment. The employment generated is 300 man days /year. (Annexure B.)

Table 1: Experimental design for two variables five levels in response surface analysis

Expt. No.	Levels of input variable				
	x_1	Feed rate, kg/min Nag. man., guava.& onion	Kagzi lime	x_2	Slope, percent
1	-1	24	20	-1	25
2	1	36	30	-1	25
3	-1	24	20	1	40
4	1	36	30	1	40
5	-1.414	21.36	17.93	0	32.5
6	1.414	38.64	32.07	0	32.5
7	0	30	25	-1.414	21.7
8	0	30	25	1.414	43.3
9	0	30	25	0	32.5
10	0	30	25	0	32.5
11	0	30	25	0	32.5
12	0	30	25	0	32.5
13	0	30	25	0	32.5

Table 2: Details of Nagpur mandarins taken for testing

Code	A	B	C	D	Total
Diameter, mm	>70	60-70	50-60	<50	
No. of fruits	20	55	67	29	171
Weight, kg	4.000	8.140	6.280	1.600	20.00
Average weight, kg	0.200	0.148	0.094	0.055	

Table 3: Details of guava fruits taken for testing

Code	A	B	C	D	Total
Diameter, mm	>80	65-80	50-65	<50	
No. of fruits	11	22	49	11	93
Weight, kg	3.820	4.76	5.82	0.60	15.00
Average weight, kg	0.347	0.216	0.119	0.055	

Table 4: Details of onions taken for testing

Code	A	B	C	Total
Diameter, mm	>45	35-45	<35	
No. of fruits	114	114	150	378
Weight, kg	8.52	3.68	2.80	15.00
Average weight, kg	0.075	0.032	0.019	

Table 5: Details of kagzi lime fruits taken for testing

Code	A	B	C	D	Total
Diameter, mm	>40	35-40	30-35	<30	
No. of fruits	114	115	94	34	357
Weight, kg	5.440	3.900	2.200	0.460	12.000
Average weight, kg	0.048	0.034	0.023	0.014	

Table 6: Observed and predicted response for grading efficiency (percent) under various treatment conditions

Expt. No.	Grading efficiency							
	Nagpur mandarin		Guava		Onion		kagzi lime	
	Obser. Y	Predi. Y	Obser. Y	Predi. Y	Obser. Y	Predi. Y	Obser. Y	Predi. Y
1	63.12	66.49	87.4	89.34	63.1	65.59	61.22	60.68
2	66.06	67.78	90.27	91.37	67.47	67.49	75.12	73.04
3	74.33	73.50	85.67	85.42	72.7	73.94	76.12	73.70
4	72.83	72.29	86.54	85.44	73.47	72.24	77.50	73.55
5	65.23	73.79	88.6	87.58	72.5	70.12	68.12	69.27
6	74.50	73.85	88.86	89.04	69.15	70.27	74.58	79.91
7	64.20	62.15	92.93	90.96	66.33	64.81	61.20	62.11
8	69.13	70.28	82.86	83.99	73.8	74.06	68.11	71.68
9	75.36	75.46	90.35	90.42	72.1	72.25	76.72	76.62
10	75.28	75.46	90.32	90.42	72.2	72.25	76.54	76.62
11	75.39	75.46	90.5	90.42	72.15	72.25	76.24	76.62
12	75.58	75.46	90.55	90.42	72.15	72.25	76.82	76.62
13	75.68	75.46	90.38	90.42	72.32	72.25	76.78	76.62

Table 7: Values of partial regression co-efficient of second order polynomial equations for grading efficiency

Response	Partial regression coefficient					
	b_0	b_1	b_2	b_{11}	b_{22}	b_{12}
Nagpur mandarin	75.461	1.820	3.120	-2.592	-4.192	-1.112
Guava	90.42	0.514	-2.463	-1.056	-1.473	-0.5
Onion	72.254	0.050	3.271	-1.030	-1.410	-0.9
Kagzi lime	76.620	3.052	3.382	-1.513	-4.862	-3.13

Table 8: Analysis of variance for the effect of input variables on grading efficiency (Y)

Source	Nagpur mandarin		Guava		Onion		Kagzi lime	
	df	SS	df	SS	df	SS	df	SS
Model (Reg.)	5	261.099*	5	71.998*	5	107.718*	5	374.999*
Residual	4	33.605	4	12.520	4	18.637	4	52.295
Lack of fit	3	33.495	3	12.48	3	18.535	3	52.068
Pure error	1	0.110	1	0.0398	1	0.102	1	0.228
F ratio (LDF)	-	101.991	-	104.52	-	60.387	-	76.298
R^2	-	0.886	-	0.852	-	0.853	-	0.878

*Significant at 10% level

Table 9: Predicted levels of factors yielding optimum response

Factors	Grading efficiency (Y)							
	Nagpur mandarin		Guava		Onion		kagzi lime	
	Coded	Uncoded	Coded	Uncoded	Coded	Uncoded	Coded	Uncoded
Feed rate, kg/min	0.279	31.67	0.460	32.76	-0.306	28.16	0.973	29.86
Slope, percent	0.335	35.01	-0.914	25.65	1.221	41.66	0.035	32.67
Response, per cent	76.24		91.66		74.37		78.16	

Table 10: Analysis of variance for the overall effect of individual factor

Factor	df	S.S.	Mean square	F ratio
Nagpur mandarin				
x_1	3	69.253	23.084	2.041
x_2	3	181.632*	60.544	5.352
Guava				
x_1	3	10.14	3.38	0.80
x_2	3	59.28*	19.76	4.70
Onion				
x_1	3	9.065	3.021	0.481
x_2	3	87.496*	29.165	4.644
Kagzi lime				
x_1	3	113.737	37.912	2.156
x_2	3	258.999*	86.333	4.909

Significant at 10% level

Table 11: Cost economics of PDKV fruit grader

1	BEP, %	44
2	Pay back period for equipment, yr	1.75
3	Pay back period for project,yr	1.92
4	Return on investment	43.02
5	Employment generation mandays/ year	300
6	Annual Net profit, Rs	56560

Conclusion

- The PDKV fruit grader is developed
- For maximum response, of grading efficiency, the input factors, feed rate and slope of grader were optimized to 31.67 kg/min and 35.01 per cent respectively for Nagpur mandarin, 32.76 kg/min and 25.65 per cent respectively for guava and 28.16 kg/min and 41.66 per cent for onion and 29.86 kg/min and 32.67 per cent for kagzi lime.
- Using optimized input factors, the grading efficiency and capacity was found to be 75.62 per cent and 12.16 tonnes per day (at 80% efficiency) of eight hours for Nagpur mandarin.
- Using optimized input factors, the grading efficiency and capacity was found to be 90.53 per cent and 12.61 tonnes per day (at 80% efficiency) of eight hours for guava.
- For onion, the grading efficiency and capacity was found to be 73.80 per cent and 10.82 tonnes per day (at 80% efficiency) of eight hours by using optimized input parameters.
- For kagzi lime, the grading efficiency and capacity was found to be 76.83 per cent and 11.46 tonnes per day (at 80% efficiency) of eight hours by using optimized input parameters.
- The unit is technically feasible and economically viable.

References

1. Anonymous. Agriculture situations in India. Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, New Delhi; c1996.
2. Anonymous. Statistics. Government of Maharashtra, Department of Agriculture; c2005. Available from: www.agri.mah.gov.nic.in.
3. Biswas S, Chandrashekhar T, Rajan YS, Singh DN, Amudeswari A. Long-term technology vision: An Indian experience; c2002. Available from: www.tifac.org.in/news/view3.
4. Cochran WG, Cox GM. Response surface design and analysis. 1st ed. New Delhi: Marcel Dekker Quality Press; c1957.

Appendix - A

Effectiveness of Separation

Let a feedlot of X oranges contain four sizes of oranges, *viz.* X1, X2, X3 and X4. of Grade I, Grade II, Grade III and Grade IV respectively.

Now,

X'1 = No. of oranges of X1 collected in grade I

X"1 = No. of oranges of X1 collected in other outlet

X'2 = No. of oranges of X2 collected in grade II

X"2 = No. of oranges of X2 collected in other outlet

X'3 = No. of oranges of X3 collected in grade III

X"3 = No. of oranges of X3 collected in other outlet

X'4 = No. of oranges of X4 collected in grade IV

X"4 = No. of oranges of X4 collected in other outlet

Then for material balance,

X = X1 + X2 + X3 + X4

= X'1 + X''1 + X'2 + X''2 + X'3 + X''3 + X'4 + X''4

$$\text{Effectiveness } X_1 = \frac{X'_1}{X'_1 + X''_1} \quad ....(1)$$

Effectiveness for X2,

$$\text{Effectiveness } X_2 = \frac{X'_2}{X'_2 + X''_2} \quad ....(2)$$

Effectiveness for X3,

$$\text{Effectiveness } X_3 = \frac{X'_3}{X'_3 + X''_3} \quad ....(3)$$

Effectiveness for X4,

$$\text{Effectiveness } X_4 = \frac{X'_4}{X'_4 + X''_4} \qquad \text{........(4)}$$

Overall Effectiveness of separation according to size,
= Eff. X1 x Eff. X2 x Eff. X3 x Eff. X4 ....(5)

Fig. 1: PDKV Fruit Grader developed at Akola Center

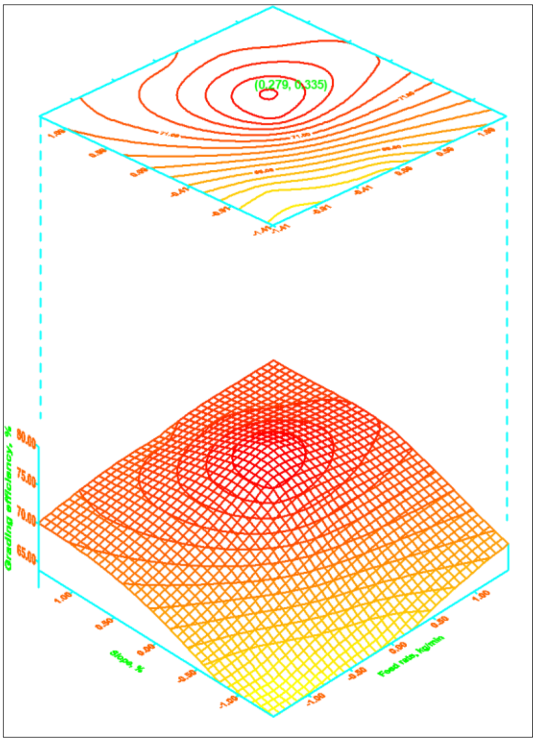

Fig 2: Contour plot and response surface showing effect of feed rate and slope on grading efficiency of Nagpur mandarin

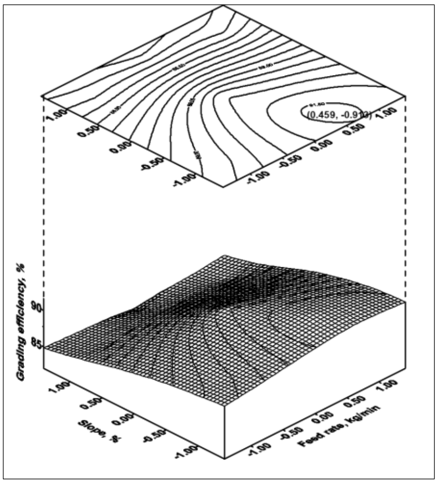

Fig 3: Contour plot and response surface showing effect of feed rate and slope on grading efficiency of guava

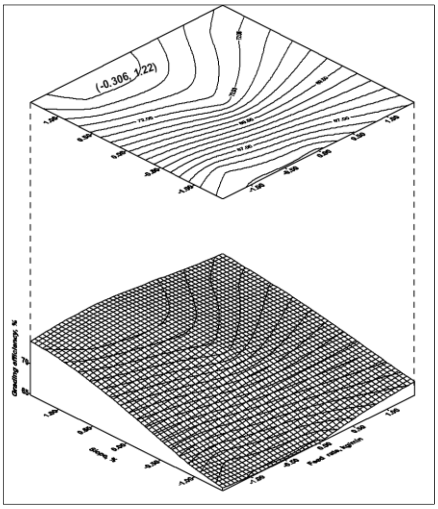

Fig.4: Contour plot and response surface showing effect of feed rate and slope on grading efficiency of onion

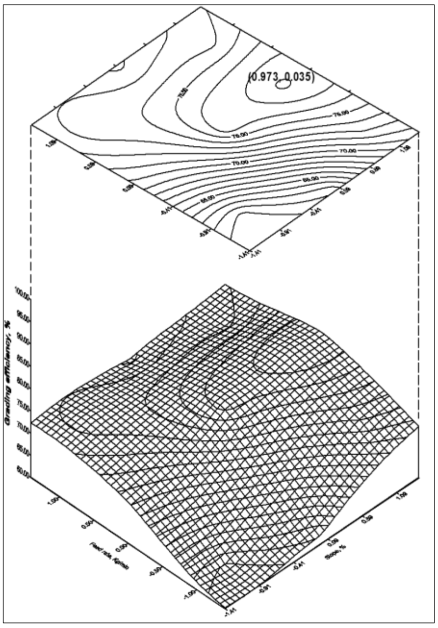

Fig 4: Contour plot and response surface showing effect of feed rate and slope on grading efficiency of kagzi lime